Evaluation of the marginal fit of finish line designs of novel CAD/CAM restoration materials

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ABSTRACT

Aim: The purpose of this study is to compare the marginal fit of crowns manufactured using different CAD/CAM materials on 2 different types of finish line design.

Material and Method: Tooth preparations were made by creating 2 different finish lines (rounded shoulder, chamfer) on an acrylic mandibular second premolar model. Impressions were taken on each preparation using polyvinylsiloxane impression material, and blocks with three different compositions including lithium disilicate (LDS), zirconia-reinforced lithium silicate (ZLS), and monolithic zirconia (MZ) (UP.CAD, Celtra Duo, and VITA YZ HT) were produced using a CAD/CAM (computer-aided-design and computer-aided-manufacturing) milling device (VHF R5) (n=10). The marginal gap values of the crown restorations were measured by the same operator using a stereomicroscope (LEICA DVM6). Histogram plots and the Kolmogorov-Smirnov test were used to test the normality of the distributions of the variables. The non-normally distributed (nonparametric) variables were compared using the Mann-Whitney U test for two groups and the Kruskal-Wallis test for more than two groups.

Results: The marginal gap values were compared between finish line designs separately for each material. Accordingly, the marginal gap values of the rounded shoulder finish line were smaller than those of the chamfer finish line in all materials. The marginal gap values were also compared among the materials separately for each finish line type. Accordingly, the marginal gap values of the VITA YZ HT (MZ) material were smaller than those of the Celtra Duo (ZLS) and UP.CAD (LDS) materials for both finish line designs. There was no significant difference between Celtra Duo and UP.CAD.

Conclusion: The finish line design is a factor that affects marginal fit. Monolithic zirconia is more appropriate for clinical use as it shows a better marginal fit compared to LDS and ZLS.

Keywords: Finish line, glass ceramic, CAD/CAM, marginal fit, monolithic zirconia

INTRODUCTION

Metal-free all-ceramic restorations have become more prevalently used in recent years due to their high aesthetic properties and excellent biocompatibility. The most frequently preferred all-ceramic restorations are glass ceramic, zirconia-reinforced glass ceramic, and monolithic zirconia restorations (1,2). With the help of monolithic zirconia restorations, which have been developed to eliminate the chipping problem that is seen in cases of stress in porcelains with zirconia substructures, less preparation is needed, and thinner restorations can be produced (3).

The longevity of the survival of these restorations is dependent on many factors such as aesthetics, fracture strength, and marginal fit. The achievement of an ideal marginal fit is directly associated with the finish line design to be preferred in the preparation of the tooth and the material properties of the crown that will be placed on the top (4,5).

The prognosis of the restoration is dependent on the tight fit of the fixed denture on the finish line of the prepared tooth and the minimal gap between the material and the tooth. The microleakage that will occur in cases of inadequate marginal fit will lead to a failure in the treatment by causing caries directly or leading to caries and gingivitis by causing the accumulation of plaque and food in the tooth-crown interface (6-8).
Marginal fit can be defined as the vertical distance from the inner surface of the restoration margin to the outermost edge of the finish line of the preparation. McLean et al. (9) defined clinically acceptable marginal gaps to be in the range of 40 to 120 µm.

The finish line designs that are preferred for all-ceramic restorations are shoulder and chamfer (10-12). While the abutment margin in teeth prepared with chamfer finish line ends at a wide angle at the edge of the gingiva, there is a sharp 90° angle in those prepared with shoulder finish line. Rounded shoulder are a modification of shoulder finish line, and the marginal width in these finish lines is partially narrowed due to the rounding of the interior angle (13).

This study aimed to investigate the marginal fits of crown restorations produced out of different materials (lithium disilicate ceramic, zirconia-reinforced lithium silicate ceramic, and monolithic zirconia) to teeth prepared with different forms of finish lines (rounded shoulder and chamfer) under in-vitro conditions. The null hypothesis was determined as that the material type and finish line design do not affect the marginal fit.

**MATERIAL AND METHOD**

All procedures were carried out in accordance with the ethical rules and the principles. Ethics committee approval is not required as the study was not conducted on humans or animals. Sixty acrylic-based plastic mandibular second premolars (AG-3, Frasaco, Tettnang, Germany) were mounded in cold acrylic (Meliodent; Heraeus Kulzer, Hanau, Germany) up to the enamel-cement interface so that their long axes would be perpendicular to the ground plane by using plastic molds. Tooth preparations were performed by the same operator using diamond burs under water cooling to create equal numbers of preparations with rounded shoulder or chamfer finish lines (Figure 1).

To achieve the standardization of milling amounts, using guide pin burs, 2 mm occlusal reduction was made, while an average of 1.2 mm was reduced from each of the other surfaces. Margin width of 1 mm were created around 30 of the teeth using a rounded shoulder bur with an interior angle of 90° and around the remaining 30 teeth using a conical chamfer bur with a rounded tip at a taper angle of 6°. The acrylic teeth were polished using a rotary rubber polishing tool to eliminate surface roughness. A master die was produced using polyvinylsiloxane impression material. After this, crown restorations were milled of UP.CAD (UpCera, China), Celtra Duo (Dentsply Sirona, USA), and VITA YZ HT (Vita Zahnfabrik, Germany) blocks using a CAD/CAM milling device (VHF R5, Germany). (Figure 2).

Standardization was established by measuring the thicknesses of the restorations using a digital caliper. The crowns that were produced were placed onto the prepared teeth, and the vertical distance from the inner surface of the restoration margin to the outermost edge of the finish line of the preparation was examined using a stereomicroscope (Leica microsystems, model DVM6, Germany) at X47 magnification (Figure 3). The measurements were carried out by the same operator from 4 points (buccal, palatal, mesial, and distal) (Figure 4).

**Statistical Analysis**

The statistical analyses were performed using the SPSS v.25.0 program. The normal distribution of the variables was tested based on histogram plots and the Kolmogorov-Smirnov test. Descriptive statistics were calculated and are presented as mean, standard deviation, median, and min-max values. The non-normally distributed (nonparametric) variables were compared using the Mann-Whitney U test for two groups and the Kruskal-Wallis test for more than two groups. In all analyses, p<0.05 was considered statistically significant.
RESULTS

The mean marginal gap values, standard deviations, median and min-max values for each group are presented in Table 1. It displays that the marginal gap values of the MZ material were smaller significantly than those of the ZLS and LDS materials while there was no significant difference between the ZLS and LDS. Additionally, the marginal gap values of the rounder shoulder finish line were smaller than those of the chamfer finish line. Figure 5 and 6 show that comparisons of marginal fit among the materials and finish line designs.

Table 1. Comparison marginal gap values between the materials and finish line design.

<table>
<thead>
<tr>
<th>Material</th>
<th>Mean±SD</th>
<th>Median (Min-Max)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZLS</td>
<td>111.65±22.97</td>
<td>114 (75-148)</td>
<td>&lt;0.001¹</td>
</tr>
<tr>
<td>LDS</td>
<td>110.1±20.69</td>
<td>110 (83-134)</td>
<td></td>
</tr>
<tr>
<td>MZ</td>
<td>72.55±21.38</td>
<td>71 (44-112)</td>
<td></td>
</tr>
<tr>
<td>Finish line</td>
<td></td>
<td></td>
<td>&lt;0.001²</td>
</tr>
<tr>
<td>RS</td>
<td>78.67±19.31</td>
<td>86 (44-110)</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>117.53±21.16</td>
<td>128 (72-148)</td>
<td></td>
</tr>
</tbody>
</table>

¹Kruskal-Wallis Test ²Mann-Whitney U Test

Table 2 displays that the comparisons of marginal gap values between the finish line types separately for each material. According to Table 2, the marginal gap values of the rounded shoulder were smaller than those of the chamfer in all materials. The marginal gap values were also compared among the materials separately for each finish line. Accordingly, the marginal gap values of the MZ material were smaller than those of the ZLS and LDS materials for both finish line designs. However, there was no significant difference between ZLS and LDS for finish line types. Figure 7 shows distribution of the marginal gap values of the materials according to the finish line designs while Figure 8 shows the distribution of marginal gap values of finish line according to materials.
teeth prepared with different finish line designs. In this study, the effects of different finish line designs and different materials on marginal fit were investigated, and consequently, the null hypothesis was rejected.

While preparing teeth, abutments can be prepared with finish line designs such as the shoulder, rounder shoulder, and chamfer designs. While there are studies in the relevant literature that have concluded that different finish lines have an effect on marginal fit (15,29), there are also those that have stated the opposite (30,31). These differences can be attributed to the differences in methods of analyzing marginal fit, the production technique of restorations or the restoration material itself. In this study, independently of the materials, the marginal gap values of the crowns with rounded shoulder finish lines were smaller than those of the crowns with chamfer finish lines. The results of present study were in agreement with Euan et al. (4)’s study.

The accuracy and dimensional stability of impressions taken from prepared teeth are important. For a fixed denture to be placed onto the existing tooth to have the ideal properties, an identical model of the preparation in the intraoral environment should be created in the laboratory environment. Impressions can be taken using digital methods (intraoral scanners) and conventional methods. Nevertheless, in the literature, there is no consensus on the superiority of both impression techniques to one another. More studies are needed to accurately evaluate the reliability, accuracy, repeatability, and scanning durations of intraoral scanners (32).

Previous studies have examined the marginal fit properties of restorations in cemented (33) or uncemented (19,23,29) forms. Because problems in cementation techniques such as disproportionate finger pressure or the overfilling of the crown with cement lead to loss of marginal fit, in this study, the marginal gap measurements were made before cementing (34).

In general, there is no definite evidence on the best methodology to assess the marginal fit accuracy of CAD/CAM crowns. In previous studies, marginal gap values have been measured using various devices including optical microscopes (15,22) scanning electron microscopes (SEM) (18,33) and stereomicroscopes (29,34). No statistically significant difference has been reported between these methods (35,36). A marginal fit measurement that is made using SEM may require cementation or the cutting of cemented crowns, which may lead to irreversible damage to the master die and limit the number and positions of measurements (37). Although marginal fit measurements can be made without cementing by micro-CT, it would be challenging to maintain a uniform pressure on the crown during measurements. For these reasons, a stereomicroscope was preferred in this study.

**DISCUSSION**

The long-term survival of restorations is closely related to their marginal fit. There are several factors that affect the marginal fit such as finish line design (4,14,15), abutment design (16,17), impression techniques (18,19,20), CAD/CAM systems (4,21,22), sintering time (23), type of material (5,25,26), cement space (26) and cementation (27,28). The literature review that was conducted for this study did not show any study on the marginal fit values of monolithic zirconia, lithium disilicate, and zirconia-reinforced lithium silicate ceramic crowns on teeth prepared with different finish line designs. In this study, the effects of different finish line designs and different materials on marginal fit were investigated, and consequently, the null hypothesis was rejected.
The marginal gap values obtained in different studies differ from each other. There is also an agreement among different researchers that marginal gap values smaller than 120 µm are clinically acceptable (9, 38). In studies in the relevant literature, the marginal gap values of zirconia crowns have been reported in the range of 36.56 to 70.94 µm (39,40) while the values of lithium disilicate crown restorations have been reported between 61.86 and 103.75 µm (40,41). Previous studies have shown smaller marginal gaps in zirconia material than in lithium disilicate material (35). On the other hand, Mohaghegh et al. (42) reported that monolithic zirconia crowns had better marginal fit values than zirconia crowns.

In the study where they investigated the post-cementing marginal fit values of conventional zirconia (Katana zirconia) and lithium disilicate (IPS e.max CAD) crowns by micro-CT, Riccitiello et al. (43) reported marginal gap values of 63 µm in zirconia crowns and 65 µm in lithium disilicate crowns. In our study, in the chamfer finish line measurements, the marginal gap values were found as 90.6±12.17 µm for monolithic zirconia (VITA YZ HT) and 129.9±3.51 µm for lithium disilicate (UP. CAD). The differences in the marginal gap values reported in previous studies and those in present study may be explained by the use of a stereomicroscope as the measurement instrument in our study and the fact that measurements was made before cementing.

In current study, while there was no statistically significant difference between the marginal gap values of the lithium disilicate (LDS) and zirconia-reinforced lithium silicate (ZLS) crowns, the marginal fit values of the monolithic zirconia crowns were found significantly superior to those of the LDS and ZLS crowns. Batson et al. (44) compared the marginal fit values of monolithic zirconia, lithium disilicate, and metal-ceramic restorations and concluded that the best fit was in the monolithic zirconia restorations.

In the study in which they compared the marginal fit values of lithium disilicate and hybrid ceramic CAD/CAM crowns, Azarbal et al. (45) found the mean marginal gap values of the lithium disilicate crowns as 132.25 µm. In present study, the marginal gap value of the lithium disilicate crowns was measured as 90.3 µm. This difference may have been caused by the abutment designs, finish line designs, and differences in milling systems.

A limitation of this study was the fact that the marginal fit of restorations was investigated only in second premolar teeth. Another limitation may be the fact that no thermal aging treatment was applied in our study. In future studies, thermal aging treatments can be performed to investigate whether the marginal fit of crown restorations is influenced by intraoral conditions such as saliva and humidity.

CONCLUSION

1. Clinically acceptable marginal gap values were obtained in all material groups prepared using rounded shoulder abutments.
2. Monolithic zirconia showed better marginal fit values compared to the LDS and ZLS materials in both finish line designs.
3. There was no significant difference between the LDS and ZLS materials in terms of marginal fit.

ETHICAL DECLARATIONS

Ethics Committee Approval: Ethics committee approval is not required as the study was not conducted on humans or animals.

Referee Evaluation Process: Externally peer-reviewed.

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REFERENCES


