Marginal and Internal Fit of All-ceramic Crowns Fabricated with Two Different CAD/CAM Systems

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This study evaluated the accuracy of marginal and internal fit between the all-ceramic crowns manufactured by a conventional double-layer computer-aided design/computer-aided manufacturing (CAD/CAM) system and a single-layer system. Ten standardized crowns were fabricated from each of these two systems: conventional double-layer CAD/CAM system (Procera) and a single-layer system (Cerec 3D). The copings and completed crowns were seated on the abutments by a special device that facilitated uniform loading, and the marginal discrepancies were measured. Internal gaps were also measured using a low-viscosity silicone material. Marginal discrepancies of Procera copings were significantly smaller than those of Procera crowns and Cerec 3D crowns (p<0.05), but Procera crowns and Cerec 3D did not differ significantly from each other (p>0.05). On internal gaps, Cerec 3D crowns showed significantly larger internal gaps than Procera copings and crowns (p<0.05). Within the limitations of this study, the single-layer system demonstrated acceptable marginal and internal fit.

Key words: Marginal and internal fit, All-ceramic crown, CAD/CAM system

INTRODUCTION

All-ceramic crowns are the material of choice for esthetic restorations because of their excellent translucency⁴. However, these crowns can be distorted during the fabrication procedure and thus result in misfit⁵. In particular, the porcelain firing cycle can cause a negative effect on the marginal fit of all-ceramic crowns⁶, and hence the success of the restorations⁷,⁸.

All-ceramic crowns can be fabricated using two types of computer-aided design/computer-aided manufacturing (CAD/CAM) systems⁹: a double-layer type which has a high-strength core, and a single-layer type without core (the entire crown is fabricated by a CAD/CAM system). The addition of porcelain to the copings of double-layer type may cause a negative effect on the fit of the crowns⁹,¹⁰. In the case of single-layer type of CAD/CAM crowns milled from ceramic blocks, they are not subjected to the porcelain firing cycle. Given the guaranteed accuracy of the CAD/CAM system, the single-layer system seems to be a good means to fabricate crowns with good adaptation.

With Cerec 3D system (Sirona, Bensheim, Germany), crowns are fabricated by milling ceramic blocks as the single-layer type system. It has been reported that Cerec 3D system yields reliable marginal and internal fit⁵,¹⁰. The system employs charge-coupled device (CCD) camera to take a three-dimensional image of the abutment tooth, and the ceramic material is milled based on these optical data. For crowns of double-layer type system, the Procera system (Nobel Biocare, Göteborg, Sweden) can be used. After the image of the abutment tooth was acquired by an indirect digitizing scanner (Procera Scanner Model 50, Jemtab Systems, Akers, Sweden), the coping is machined, and then porcelain is veneered over the coping with the hand layering technique.

The purpose of this study was to evaluate the accuracy of marginal and internal fit by comparing the all-ceramic crowns manufactured by a conventional double-layer type CAD/CAM system (Procera) versus those of single-layer type system (Cerec 3D).

MATERIALS AND METHODS

Tooth preparation

A lower left second premolar acrylic tooth model (AG-3, Frasaco, Germany) was prepared for a single crown by using 2566 milling bur (Edenta AG, Switzerland) and a milling machine (PFG 100, Cendres and Metaux, Switzerland). The preparation had a 1.0-mm-wide rounded shoulder around the entire circumference. Height of the preparation was 3.0 mm with a convergence angle of 12 degrees (Fig. 1).
Fabrication of the dies
The original preparation was duplicated using a silicone-based impression material (Aquasil Ultra XLV and LV, Dentsply Caulk, Milford, DE, USA). An autopolymerizing acrylic resin (GC Pattern Resin, GC Corp., Tokyo, Japan) was poured into the impression to form a pattern that was used to create the metal die. The acrylic pattern was invested and cast with a metal alloy (Rebillium III, Jeneric Pentron Inc., Wallingford, CT, USA). After fixing the metal die to the dentoform, 10 silicone-based impressions were made of the abutment and adjacent teeth with plastic dual-arch trays for the fabrication of the Procera crowns. After the impressions were taken, 10 master dies of stone plaster (Fujirock, GC Corp., Tokyo, Japan) were made.

Fabrication of the crowns
Ten standardized all-ceramic crowns were fabricated on a metal die from each of the two systems: conventional double-layer type CAD/CAM system (Procera) and a single-layer type system (Cerec 3D). Copings of the Procera crowns served as the control.

For the Cerec 3D crowns, optical impressions were taken using a CCD camera. Ten experimental crowns were then milled from ceramic blocks (Vitablocs Mark II, Vita Zahnfabrik, Germany) based on the captured optical data. Luting space setting on the computer was 30 \( \mu m \). There were no corrections or adjustments for the fit of the crowns.

For the Procera crowns, a scanner (Procera Scanner Model 50, Jemtab Systems, Akers, Sweden) was used to scan the 10 dies to the end of processing alumina copings with a thickness of 0.6 mm. The data were sent by modem to the manufacturer (Procera Sandvik AB, Nobel Biocare AB, Sweden), with which the \( Al_2O_3 \) copings were fabricated. All copings were clinically evaluated and veneered using a silicate-based veneering ceramic (NobelRondo Alumina, Nobel Biocare AB, Sweden).

Marginal discrepancy evaluation
The copings and completed crowns were seated on the metal die without cementation by a special device. The device was developed to position the coping and the metal model precisely, enabling the force to be applied parallel to the long axis of the tooth and to maintain the force applied so as to prevent the coping from rebounding. Although a torque of 20 to 30 Ncm is frequently employed in gap evaluations, a study suggested that most ceramic copings fractured above 10 Ncm\[12\]. Therefore, in this study, a value of 10 Ncm was employed as a maximum torque to avoid the breakage of ceramics during marginal discrepancy evaluation. This was because no cement material was used between the ceramic and die material. The torque was placed on the upper screw with a torque controller (TorqControl, Anthogyr, Sallanches, France).

Distance between each crown’s margin and the metal die was recorded at 50 points randomly using a measuring microscope (MM-40, Nikon, Tokyo, Japan) at a magnification of \( \times 100 \) (Fig. 2).
Internal gap evaluation

Internal gap was calculated using a silicone paste (Fusion Wash type, GC, Tokyo, Japan). Each crown was filled with the silicone, and then seated on the metal die. A load of 20 Ncm simulating finger pressure was applied on the occlusal surface of the crown using a universal testing machine (Instron Model 4202, Instron Co., MA, USA). In the case of internal gap evaluation, a different torque (20 Ncm) was used. This was because the silicone impression material used between the die and crown was unlike the case of marginal discrepancy evaluation. Consequently, a higher pressure was needed and it was applied with little possibility of ceramic damage.

Before polymerization, excess paste around the crown was wiped away. After polymerization, the silicone paste remaining between the crown and abutment was weighed using an electronic scale (AP210S, Ohaus Corp., Pine Brook, NJ, USA). Surface area of the abutment was measured using a non-contact type contour measuring device (Vivid 910, Konica Minolta, Tokyo, Japan). Thickness of the silicone film was calculated by the following formula:

\[
\text{Thickness} = \frac{\text{weight}}{\text{(surface area \times density)}}
\]

Based on the surface area of the abutment and the weight and density of the silicone material, the result obtained was defined as the internal gap\(^\text{10}\). It is critical that the internal gap widths be represented by several restricted measuring points. Therefore, it seemed reasonable that the average thickness of the whole silicone film, calculated by the formula above, would represent the internal gap. The three-dimensional surface area measured using a non-contact type contour measuring device is presented in Fig. 3.

Statistical analysis

Means of the different groups were compared using one-way analysis of variance with Tukey’s multiple comparison test at a significance level of 0.05. All statistical analyses were performed using SPSS 12.0 for Windows (SPSS Inc., USA).

RESULTS

Table 1 shows the means and standard deviations of marginal discrepancies and internal gaps in each group. The marginal discrepancy width of Procera copings (72.2 ± 7.0 μm) showed significantly smaller gaps than Procera crowns (89.6 ± 9.5 μm) and Cerec 3D crowns (94.4 ± 11.6 μm) (p<0.05). However, there were no significant differences between Procera crowns and Cerec 3D crowns.

Cerec 3D crowns (109.5 ± 4.7 μm) showed significantly larger internal gaps than Procera copings (71.4 ± 5.3 μm) and Procera crowns (68.3 ± 6.9 μm) (p<0.05). There were no significant differences in internal gap width between Procera
copings and Procera crowns (Table 1).

**DISCUSSION**

When all-ceramic crowns are fabricated conventionally, the ceramic is cast from ceramic ingots\(^{13}\) or shaped from firing porcelain powder\(^{14}\). Therefore, distortion that occurs during the manufacturing process will adversely affect crown fitting\(^{1,3,15}\). This is a conspicuous disadvantage of the double-layer type of CAD/CAM crowns. Conversely, the single-layer type of CAD/CAM crowns do not require conventional laboratory works\(^{16}\). Therefore, with no change in size or form, crown fit is improved.

In this study, we focused on the differences in marginal and internal fit between conventional double-layer type of CAD/CAM crowns and those of single-layer type system. Unlike other studies that focused only on comparing the cores of double-layer systems or only on the crowns, this study compared both the core and the crown. In this manner, practical comparisons that are highly desired were now available, whereby the core and crown fabricated with a double-layer system were compared, alongside with comparison between core fabricated with double-layer system and crown fabricated with single-layer system, and between crowns fabricated within these two systems.

The metal die was used as an abutment in this study. Several investigators have used metal\(^{17,18}\) or acrylic resin\(^{19,20}\) dies to measure marginal fit. With a metal die, the advantages are namely standardized preparation and lack of wear during the manufacturing process and measurement.

The margin design of the metal die included a 1.0-mm-wide rounded shoulder around the entire circumference. This design is recommended for the preparation of all-ceramic crowns\(^{17}\). The convergence angle was aimed to be 12 degrees because it has been reported that the actual total occlusal convergence angle for the average abutment in clinical preparations is within the range of 19 degrees\(^{21}\) to 21 degrees\(^{22}\), and that the Cerec system uses a standard total occlusal convergence angle of 12 degrees\(^{23}\).

There are many different locations between a tooth and a restoration where measurements can be made. In this study, misfit measurement was calculated as the absolute marginal discrepancy, which would always be the largest error measured at the margin and would reflect the total misfit at that point\(^{24}\). In the present study, distance between the crown margin and the metal die was recorded at 50 points randomly. Fifty measurements are required for clinically relevant information about gap size regardless of whether the measurement sites are selected in a systematic or random manner\(^{25,26}\).

The marginal discrepancy width of Procera crowns (89.6±9.5 \(\mu m\)) after porcelain firing showed significantly larger gaps than Procera copings (72.2±7.0 \(\mu m\)) (p<0.05). As mentioned above, this was due to the negative effect of double-layer type CAD/CAM system, where porcelain was added to the coping\(^{29}\). On the other hand, there were no significant differences in marginal discrepancy between Procera crowns (89.6±9.5 \(\mu m\)) and Cerec 3D crowns (94.4±11.6 \(\mu m\)) (p>0.05). On marginal discrepancy, these findings suggested that the single-layer type CAD/CAM system, Cerec 3D in this study, was clinically acceptable together with the Procera system.

It has been reported that the internal gap of conventional all-ceramic crowns was within the range of 123 to 154 \(\mu m\)\(^{27}\). In this study, internal gaps smaller than that of conventional all-ceramic crowns were produced, especially with the Procera system. Although the Cerec 3D crowns (109.5±4.7 \(\mu m\)) showed significantly (p<0.05) larger internal gaps than the Procera system (copings: 71.4±5.3 \(\mu m\); crowns: 68.3±6.9 \(\mu m\)), they were well within the clinically acceptable range reported. For the single-layer system fabricated directly from the milling block, relatively large internal gaps existed because of bur size and the accuracy of milling and scanning. Therefore, further investigations on improving and enhancing milling accuracy and scan digitizing are necessary.

**CONCLUSIONS**

In this study, we evaluated the accuracy of marginal and internal fit between the all-ceramic crowns manufactured by a conventional double-layer type CAD/CAM system and a single-layer type system. Within the limitations of this study, the following
conclusions were drawn:
1. There were no significant differences (p<0.05) in marginal discrepancy between the double-layer type CAD/CAM system (Procura) and single-layer type CAD/CAM system (Cerec 3D).
2. The marginal discrepancy width of Procura crowns after porcelain firing showed significantly (p<0.05) larger gaps than Procura copings.
3. There were significant differences in internal gap between the Procura system and Cerec 3D system.
4. The two CAD/CAM systems tested produced crowns that were within a clinically acceptable range reported.

REFERENCES