ORIGINAL ARTICLE

Clinical Evaluation of Marginal and Internal Gaps of Zirconia-based 3-unit CAD/CAM Fixed Partial Dentures

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Clinical significance

Due to superior esthetics and biocompatibility, all-ceramic FPDs have become increasingly popular in clinical practice. This study clinically evaluated the marginal and internal gaps of all-ceramic FPDs fabricated using the CAD/CAM system.

Abstract

Purpose: We conducted an in vivo evaluation of the marginal and internal gaps of 3-unit all-ceramic fixed partial dentures (FPDs) with zirconia frameworks by using black and white silicone materials. These FPDs were fabricated using a computer-aided design/computer aided machining (CAD/CAM) system (Circon Smart Ceramic).

Methods: Forty-two abutments of 21 Circon FPDs were examined before the final cementation. Silicone materials obtained from each FPD were sectioned buccolingually and mesiodistally, and the thickness of the silicone layer was measured under a microscope.

Results: The mean marginal gaps of the mesial and distal abutments were 83.3 and 90.6 μm , respectively. No difference was observed between the corresponding measurement points on the mesial and distal abutments with regard to the gap size.

Conclusion: The mean marginal gap between the abutments and the retainers of the 3-unit zirconia FPDs fabricated using the Circon system was 86.9 μm , which is a clinically acceptable value.

Keywords: gap, all-ceramic fixed partial denture, CAD/CAM, fit

Introduction

Recently, all-ceramic restorations have been increasingly accepted by clinicians because of their clinical success, strength, natural appearance, and biocompatibility. The indications for all-ceramic crowns and bridges have been determined for anterior and posterior restorations.¹⁻⁷ The long-term success of all-ceramic restorations depends mainly on their marginal gaps and the mechanical strength of the core material. By using computer-aided design/computer aided machining (CAD/CAM) systems, high-strength all-ceramic frameworks have been developed, not only for single crowns but also for multi-unit fixed partial dentures (FPDs). Industrial ceramic processing can produce all-ceramic frameworks that have greater structural uniformity, higher density, lower porosity, and lesser residual stresses than conventional hand-made frameworks. Although many researchers have reported on the marginal gaps of all-ceramic crowns,⁸⁻¹⁷ whereas a survey of the literature shows that few articles were found that address the marginal gaps of 3-unit FPDs.^{15,18-21} Tinschert et al¹⁹ reported that the in vitro marginal fit of zirconia-based FPDs manufactured using the Precident DCS system ranged from 42.9 to 46.3 μm . Stapert et al²¹ found that the mean marginal gap of Empress 2 FPDs, which were not fabricated using CAD/CAM, was 56.8 μm (range, 53.9-59.8 μm) before cementation. In an in vivo study by Wolfart et al,¹⁵ the clinical marginal fit of Empress 2 FPDs was evaluated and found to be 96 μm before cementation, which was similar to the results of other in vivo studies involving single crowns.^{5,16,17} Kohta²⁰ evaluated the marginal and internal gaps of Circon FPDs in an in vitro study

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Fig. 1 Location of the FPDs and abutments (n = 21).

and showed that this gap was $29.3 \mu\text{m}$. All the reports concluded that considering the longevity of the restorations, the determined sizes of the marginal gaps were acceptable.²² However, clinicians must consider the large in vivo variations in marginal gaps.¹⁵

This study evaluated the hypothesis that zirconia-based all-ceramic 3-unit FPDs fabricated using the Cercon system have clinically acceptable marginal gaps.

Materials and methods

Between August 2005 and August 2006, 21 FPDs that replaced 1 missing tooth—either the 2nd premolar or the 1st molar—were fitted in 20 patients at the Tsurumi University Dental Hospital. The study was reviewed and approved by the ethics committee of Tsurumi University (No. 12) prior to its commencement. Each delivered FPDs replaced an intermediary missing tooth and involved 1 pontic and 2 abutments. The Cercon FPDs were fitted in 4 male and 16 female patients. These patients were treated by 2 dentists, and all the Cercon FPDs used in this study were

fabricated in a commercial laboratory (KS Dental Laboratory, Yokohama, Japan). All teeth were prepared such that they had a rounded shoulder margin by using special preparation burs (All-ceramic Preparation Kit, Shofu, Kyoto, Japan). We performed an occlusal reduction of at least 1.5 mm, and then created a circular 1.0–1.2-mm-wide rounded shoulder preparation. The sharp angles were rounded, and subsequently, impressions were obtained using a vinyl polysiloxane impression material (EXAFINE, GC Corp., Tokyo, Japan). Working models were then fabricated using a Type IV stone (GC Fujirock EP, GC Corp., Tokyo, Japan). Before the FPD frameworks were waxed up, each die was coated with a single layer (approximately $30\text{-}\mu\text{m}$ thick) of die spacer (SD Spacer, Sun Dental Co., Tokyo, Japan) to within 1 mm of the finish line. The FPD frameworks were fabricated according to the manufacturer's instructions. Finally, all the FPDs were fired with the same veneering porcelain (Creation ZI, KLEMA Dentalprodukte, Meiningen, Austria) on each framework.

Before cementing the FPDs, the contact points were adjusted at the chairside, and the marginal and internal fits were recorded intraorally by using black and white silicone materials, as described by Obana et al.²³ and Ohshima et al.²⁴ High-flow silicone impression materials (white silicone, FIT CHECKER and black silicone, BITE CHECKER, GC Corp., Tokyo, Japan) were used to measure the gap between the crown and abutment. Previous studies^{23,24} have reported that the film thickness of the silicone material with a base:catalyst ratio identical to that of our study was very similar to the film thickness of zinc phosphate cement mixed at a standard consistency. No internal grinding of the frameworks was performed before obtaining the measurements because the grinding procedure may affect the strength of the framework material. The black silicone material was then mixed (base:catalyst = 6:1) and poured into the FPDs. Next, the FPD was seated on the abutment teeth for 2 min with finger pressure. Five minutes after mixing the silicone material, the FPDs were carefully removed from the abutment teeth. The white silicone material was also mixed (base:catalyst = 4:1) and poured over the black silicone layer in each FPD. After these layers were set, the FPD was separated from the 2 silicone material layers. The FPDs examined in this study are shown in Figure 1. The second maxillary premolar was the

Table 1 Multiple comparisons of the marginal and internal gaps.

	Measurement points	Mesial abutment				Distal abutment			
		Margin	Rounded shoulder	Axial wall	Occlusal area	Margin	Rounded shoulder	Axial wall	Occlusal area
Mesial abutment	Margin	0.000*							
	Rounded shoulder	0.000*	0.000*						
	Axial wall	0.079	0.000*						
Distal abutment	Occlusal area	0.000*	0.772	0.000*					
	Margin	0.998	0.000*	0.326	0.000*				
	Rounded shoulder	0.000*	0.077	0.009*	0.000*	0.000*			
	Axial wall	0.155	0.000*	0.999	0.000*	0.546	0.000*		
	Occlusal area	0.000*	1.000	0.000*	0.327	0.000*	0.021*	0.000*	

* $P < 0.05$ **Fig. 2** Diagram showing the measurement points.

most frequently restored, followed by the first mandibular molar.

The silicone block materials obtained from each FPD were sectioned first, bucco-lingually and then, mesio-distally with a razor blade. Care was exercised to obtain equal sections. The sections were placed under a measuring microscope (Profile Projector V-16D, Nikon, Tokyo, Japan), and measurements (at 10×) of the black silicone layer of each crown were obtained at the points shown in Figure 2. Sixteen different points were evaluated on the buccolingual and mesiodistal sections of each abutment. A total of 42 abutments of 21 FPDs were measured. All the measurements were performed by the same operator. The reference points for measuring the marginal gap were selected as described by Holmes et al.²⁵

All measured data, which were obtained from the mesiodistal and buccolingual sections, were averaged as the data of 4 locations: margin, rounded shoulder, axial wall, and occlusal area.

Fig. 3 Mean gaps of the mesial and distal abutments at the 4 measurement points.

Furthermore, the data were initially analyzed using a two-way ANOVA (abutment position and measurement points) to identify significant differences between the mean mesial and distal abutment gaps at the 4 locations. All analyses were conducted at a 95% confidence level.

Results

Two-way ANOVA revealed interactions between the factors. Then, the combinations of all levels as a factor were made, and one-way ANOVA with Games-Howell's post hoc tests was conducted.

The results showing the mean marginal and internal gaps of the mesial and distal abutments at the 4 measurement points are presented in

Figure 3. The mean marginal gaps of the mesial and distal abutments were 83.3 and 90.6 μm , respectively, and these were the smallest gaps; the rounded shoulder and occlusal area tended to have larger gaps.

There were no differences between the identical measurement points, which compared the gaps of the mesial and distal abutments (Table 1). The maximum gaps of the abutments at the margin, rounded shoulder, axial wall, and occlusal area were 303, 602, 404, and 546 μm , respectively, and the minimum gaps were 0, 0, 0, and 11 μm , respectively.

Discussion

The fit of CAD/CAM-generated restorations has been of great concern to dentists and dental technicians. However, little clinical data are available on all-ceramic FPDs.¹⁵ To obtain a minimal marginal gap, the surface of the exposed cement should be decreased, and this would in turn reduce the dissolution of cement in the oral environment. The marginal gap is expected to affect the rate of cement dissolution. Jacobs and Windeler²⁶ showed that when the zinc phosphate cement was used, a 150- μm gap size increased the rate of dissolution; this would further lead to more plaque accumulation, gingival sulcular fluid flow, bone loss, microleakage, recurrent caries, and periodontal disease.

In this study, the Cercon system was used to fabricate the zirconia frameworks of the FPDs; first, the wax-up of the framework was scanned, and then the presintered block fabricated from yttria-stabilized tetragonal zirconia (Y-TZP) was milled and sintered. During sintering, approximately 30% of the presintered block shrinks; therefore, there are chances of gaps developing between the coping and the abutment tooth, particularly in the case of FPDs. In general, when comparing the marginal gaps of the FPD abutments with single crowns, the more complex geometric form of FPDs must be considered.

Furthermore, there are many different processing methods such as firing, heat pressing, and CAD/CAM, and the accuracy of fit will vary depending on the method employed. Generally, it is very difficult to compare the results of different all-ceramic systems. Moreover, the chances of making errors that affect the precision of fit are greater in an *in vivo* study than in an *in vitro*

study. For example, the abutment heights and taper values are always different between the 2 types of studies. In our study, measurements were obtained for only the premolar and molar abutment teeth. Nakamura et al²⁷ reported that when using the Decsy CAD/CAM system, neither the internal gap nor the marginal gap was affected by the occlusal convergence angle of the abutment. Lin et al²⁸ concluded that with the Procera scanner, the feather-edge finish-line forms, deep retentive grooves, and deep occlusal morphology were not well reproduced by the probe when the dies were scanned. In this study, the Cercon wax-up was scanned using the laser technique; therefore, the tooth preparation technique had only a slight effect on the gap size.

In this study, the Cercon system scanned the wax pattern of the core framework and milled the blank; there will be little possibility to make differences among the mesial, distal, buccal, and lingual measuring points. Therefore, we compared the mean marginal and internal gaps between the mesial and distal abutments.

In this study, a large variation in the gaps was observed: the mean marginal gaps of the mesial and distal abutments were 83.3 and 90.6 μm , respectively. The maximum marginal gap was 303 μm , which might cause some problems clinically after functioning.²⁹ However, this value can not be completely attributed to the milling machine, but can also be due to some errors in fabricating the working cast, trimming the die, etc. Further research is required to determine whether such a marginal gap is clinically acceptable.

Clinicians should be aware that a comparison of the marginal gaps found in other reports shows that the marginal gap could increase after the crowns are luted with cement.¹⁵ Some reports showed marginal gaps without cement. The marginal gaps of *in vitro* data tended to be small, compared to *in vivo* data. Stappert et al²¹ evaluated the marginal gaps of Empress 2 FPDs before and after cementation, and found gaps of 56.8 and 70.8 μm , respectively. These results also revealed greater marginal gaps after cementation. The 70.8 μm gap they reported was similar to the findings in our study. However, if the fabrication methods are different, it is very difficult to compare the marginal gaps among different studies. In this study, silicone materials were used to measure the marginal gaps, a method introduced by Ohshima et al.²⁴ The silicone layer thickness was similar to the film thickness of zinc phos-

phate cement mixed at a standard consistency. Therefore, we believe that the gaps obtained in this study would be simulated clinically.

There were no differences between the identical measurement points, which compared the gaps of the mesial and distal abutments. This implies that the marginal and internal gaps of the Cercon FPDs would be the same for all abutments. Furthermore, the mean gaps at the margin of the FPDs were the smallest among the other measuring points; thus, our results were the same as those for the Procera system¹⁶ and the GN-I system.¹⁷ The results obtained in our study are the typical outcomes of using computer-generated milling systems with burs to fabricate copings or frameworks.

Considering that a marginal gap of 120 μm is clinically acceptable, as reported by McLean and von Fraunhofer,²² then the marginal gap of the Cercon FPDs obtained in this study is also clinically acceptable. However, clinicians must consider that certain areas in the abutment margins may have large gaps between abutments and retainers.

Conclusion

The results of this in vivo study of 3-unit all-ceramic FPDs fabricated using the Cercon Smart Ceramic system showed that there were no significant differences between the identical measurement points of the mesial and distal abutments. Moreover, the marginal gap of these Cercon FPDs was considered clinically acceptable.

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