



Original article

Clinical marginal and internal gaps of zirconia all-ceramic crowns

Yuji Kokubo DDS, PhD^{a,b}, Mitsuyoshi Tsumita DDS, PhD^{a,*}, Takamitsu Kano DDS^a,
Satoe Sakurai DDS^b, Shunji Fukushima DDS, PhD^a

^a Department of Fixed Prosthodontics, Tsurumi University, School of Dental Medicine, 2-1-3 Tsurumi Tsurumi-ku, Yokohama City, Japan

^b Division of Oral and Maxillofacial Implantology, Tsurumi University, School of Dental Medicine, 2-1-3 Tsurumi Tsurumi-ku, Yokohama City, Japan

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Abstract

Purpose: Marginal and internal gaps of NobelProcera crown zirconia were clinically evaluated using silicone materials.

Materials and methods: Ninety-one crowns were examined before final cementation, and white and black silicone materials were used to record the marginal and internal fit. The silicone materials were sectioned bucco-lingually and mesio-distally, and the thickness of the silicone layers was measured using a microscope. Sixteen reference points were measured on each specimen, and mean marginal and internal gaps were obtained. Mean marginal gaps among anterior, premolar, and molar tooth groups, in addition to mean gaps at the reference points within the groups, were compared using two-way ANOVA and Games–Howell analysis.

Results: The marginal mean values were the smallest among all tooth groups, and the largest were at the rounded shoulders. There were no significant differences in the mean marginal gaps among the three tooth groups, while there were significant differences in the mean marginal and internal gaps of each tooth group.

Conclusions: The mean marginal gap of the NobelProcera crown zirconia was 44.2 μm , which is within clinically accepted standards.

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1. Introduction

Owing to their esthetics, biocompatibility, and high strength, the introduction of zirconia-based restorations has become popular [1]. Computer-aided design and manufacturing (CAD/CAM) technology has allowed the fabrication of ideal zirconia coping/framework for not only single but also multi-unit restorations.

The important factors for zirconia selecting all-ceramic crowns are marginal gap, mechanical strength, and long-term clinical results. Several researchers have reported marginal gaps both *in vitro* and *in vivo* [2–5]. The large gap may cause cement solubility and result in plaque accumulation, marginal leakage, second caries, and eventually crown failure [6,7]. The clinically acceptable marginal gap, within 120 μm , was reported by McLean and von Fraunhofer [8].

The Procera system (Nobel Biocare, Zurich, Switzerland) was introduced in 1991. Since then, a number of evaluations have

provided a significant amount of data on mechanical strength, marginal gaps, adhesive cement bonding properties, and clinical evaluation. The clinical use of zirconia copings began in 2006. In general, the fit of zirconia copings varies according to the finish line design [9,10], preparation angles [11,12]. After milling, the coping must be densely sintered. Sintering results in shrinkage rates of about 20% for alumina and about 30% for zirconia. As a result, an enlarged model is used and enlarged coping is fabricated using the Procera system.

Concerning marginal gap, Kokubo et al. [2] measured the clinical marginal gap of Procera AllCeram crowns (alumina) and obtained a result of 34.4 μm . Additionally, Boening et al. [3] reported that the marginal gaps of Procera AllCeram crowns *in vivo* were between 80 and 95 μm in anterior teeth and between 90 and 145 μm in posterior teeth. May et al. [4] found that in Procera AllCeram crowns the mean marginal and occlusal gaps were 63 and 74 μm , respectively. Weaver et al. [5] reported that the marginal gap of Procera AllCeram crown was 82 μm met above-mentioned criterion for an acceptable marginal discrepancy.

To the best of the authors' knowledge, there is no clinical data on the marginal and internal gaps of zirconia all-ceramic crowns.

* Corresponding author. Tel.: +81 45 581 1001; fax: +81 45 573 9599.

E-mail address: tsumita-mitsuyoshi@tsurumi-u.ac.jp (M. Tsumita).

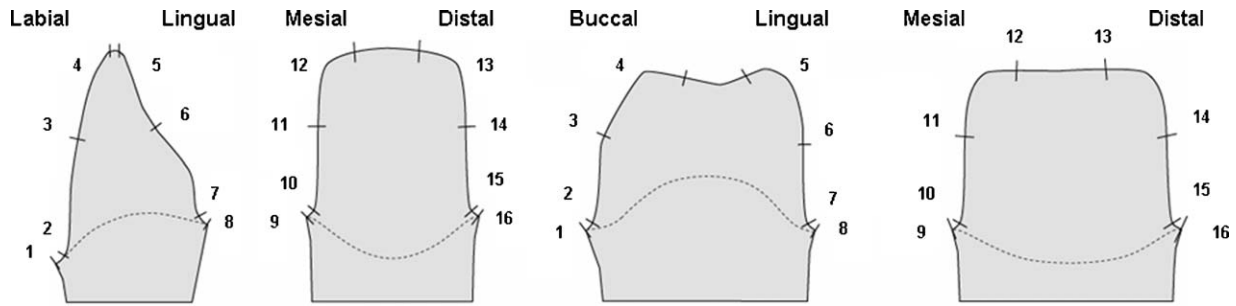


Fig. 1. Diagram showing the measuring points for anterior and molar tooth.

Our hypothesis is that NobelProcera crown zirconia (Nobel Biocare, Zurich, Switzerland) will show marginal gaps within clinically accepted parameters, and their fit will be influenced by three tooth groups (anterior, premolar, and molar).

2. Materials and methods

Ninety-one NobelProcera crown zirconia were placed in 51 Tsurumi University Dental Hospital patients desiring esthetic restorations. The procedures were conducted from December 27, 2006 to March 30, 2009.

All crowns were performed by three dentists and fabricated in a commercial laboratory (KS Dental Laboratory, Yokohama Japan). According to the manufacturer's recommendations, in order that they had a rounded shoulder margin all teeth were prepared using special burs (All-ceramic Preparation Kit, Shofu Inc., Kyoto, Japan). This process resulted in occlusal reduction of at least 1.5 mm and shoulder width of 0.8 mm. The sharp angles were rounded and impressions were obtained using a vinyl polysiloxane impression material (EXAFINE, GC Corp., Tokyo, Japan) and individual autopolymerizing resin trays.

The working models were then fabricated using Type IV stone (GC Fujirock EP, GC Corp., Tokyo, Japan). All the dies were scanned by using Procera Forte (Nobel Biocare), and checked the margin, then selected zirconia coping, which thickness was 0.7 mm evenly.

Initially, the coping data had been sent to the production center in Sweden.

However, since the establishment of Makuhari-Plant in September 2007, these data were being sent to Nobel Procera Makuhari-Plant (Makuhari, Japan) for production of copings.

To finalize production of the all-ceramic crowns, a dental technician fired each coping with veneering porcelain (Vintage ZR, Shofu Inc., Kyoto, Japan).

Before cementing the crowns, the contact points were adjusted at chairside, and, as in previous studies, the marginal and internal fits were recorded intraorally using silicone materials [2,13,14]. The black silicone material (Bite checker, GC Corp., Tokyo, Japan) was mixed and poured inside the crowns, and the crown was seated on the abutment tooth for 2 min with finger pressure. Five minutes after the silicone material was mixed, the crown was removed from the abutment tooth carefully. White silicone material (Fit checker, GC Corp., Tokyo, Japan) was also mixed to fill the inside of the black

Table 1

Locations measured crowns by position.

	Anterior tooth	Premolar tooth	Molar tooth
Maxilla	39	16	6
Mandible	5	19	6
Total	44	35	12

silicone of each crown. After setting, the crown and the two layers of silicone material were separated. No internal grinding of the crowns was performed before obtaining the measurements. Previous studies with a base-to-catalyst ratio identical to that of ours reported that the film thickness of the silicone material was very similar to the film thickness of the zinc phosphate cement mixed at a standard consistency [15,16]. The crowns examined in this study are shown in Table 1. Anterior teeth were most frequently restored (47.8%), followed by premolar teeth and molar teeth.

The black silicone materials obtained from each crown were sectioned into four pieces with a razor blade. They were first cut bucco-lingually and then mesio-distally. Care was exercised to obtain equal sections and to cut perpendicular to the surface.

The sections were placed under a measuring microscope (Profile Projector V-16D, Nikon, Tokyo, Japan), and measurements (at 10×) of each crown's black silicone layer were obtained at the points shown in Fig. 1. Sixteen different points were evaluated on the bucco-lingual and mesio-distal sections of each crown. A total of 91 crowns were measured, and in an effort to avoid errors when choosing starting and ending points of the discrepancies, all measurements were performed by an operator. The marginal gap was measured according to terminology reported by Holmes et al. [17].

All measured data, which was obtained from the bucco-lingual and mesio-distal sections, was averaged based on four locations: the margin, rounded shoulder, axial wall, and occlusal area.

Prior to its commencement, this study was reviewed and approved by the ethics committee of Tsurumi University (No. 501).

Additionally, the data was initially analyzed using two-way ANOVA (SPSS Base10.0, SPSS Inc., Chicago, IL, USA) to identify significant differences among tooth groups and between the marginal and internal gaps at the four locations

Table 2

Mean marginal and internal gaps of NobelProcera crown zirconia by 4 measuring points and 3 regions.

	Anterior	Premolar	Molar	Total (S.D.)
Margin	42.5 (65.5)	41.9 (57.1)	57.4 (74.2)	44.2 (63.7)
Rounded shoulder	215.2 (130.5)	193.4 (136.0)	188.0 (122.4)	203.2(131.8)
Axial wall	84.0 (56.6)	79.9 (63.5)	95.9 (70.8)	84.0 (61.3)
Occlusal area	178.9 (122.3)	156.0 (89.6)	159.4 (68.5)	167.5 (105.0)

Table 3

Results of two-way ANOVA analysis.

Source	Type III sum of squares	D.F.	Mean squares	F-value	P-value
Tooth groups	47566.636	2	23783.318	2.636	0.072
Measuring point	3891739.958	3	1297246.65	143.763	0.000
Tooth groups and measuring point	65407.382	6	10901.230	1.208	0.299

of the measured reference points. If differences were found, they were evaluated using Games–Howell analysis. All analyses were conducted at a 95% confidence level.

3. Results

The results showing the mean marginal and internal gaps of 91 crowns at the four measuring points are presented in Table 2. The mean marginal gap was 44.2 μm , which was the smallest among all reference points. The rounded shoulder and occlusal area tended to have larger gaps.

Based on the two-way ANOVA analysis, only measuring point showed smaller than 0.05, thus there were no significant differences among tooth groups and there were significant differences among 4 measuring points. The interactive effect of the two factors is not significant, indicating that there are no statistical differences in tooth groups and measuring point combinations (Table 3).

4. Discussion

All values were obtained by specimen cross-sectioning, a method used in other *in vivo* studies [2,13,14]. Compared to other studies using the same method, Procera AllCeram crowns (alumina coping) had a mean marginal gap of 34.4 μm [2], and In-Ceram alumina crowns fabricated using the GN-I system were 66.8 μm [13]. Additionally, Procera three-unit fixed partial dentures, composed of the same zirconia used in this study, were 83.3–90.6 μm [14]. However, those fixed partial dentures were fabricated from pre-sintered zirconia blocks; this might be the reason for the differences between crowns and fixed partial dentures. In this study, the mean marginal gap was 44.2 μm , a value close to that of the Procera AllCeram crown [2]. According to McLean et al., this value is a clinically acceptable marginal gap [8].

The NobelProcera coping zirconia (NobelBiocare) is fabricated on an enlarged model to compensate for anticipated material shrinkage (30%) that occurs during the final sintering stage. The difference in marginal gaps between NobelProcera coping alumina and zirconia might be the reason for shrinkage

after the final sintering. When fabricating both alumina and zirconia copings using the Procera system, marginal gaps were the lowest and occlusal gaps were the highest. These results were the same as another CAD/CAM system [13] and another report that used the Procera system [18]; these results might be typical to such CAD/CAM systems.

The highest marginal gaps of the crowns in the anterior, premolar, and molar tooth groups were 319, 309, and 323 μm , respectively. The lowest was 0 μm among the three tooth groups. There were wide ranges of gaps, and many errors have been pointed out which would occur through out the study, and some reports pointed out the inherent errors [19,20]. All seating of copings after pouring the silicone materials was conducted by two of the authors. However, standard deviations (SDs) showed a tendency toward a wide range. In the seating process, finger pressure was applied as uniformly as possible. However, depending on the height and convergence angle of the abutment and the marginal configuration, there will always be the possibility of inaccurate crown placement. Even the *in vitro* studies of Coli and Karlsson [21] showed high SDs from some factors. From the results of this study, the largest gaps were found at the rounded shoulder, which is supported by other studies [13,14]. Clinicians should always be aware that there is a large range of marginal gap, and they should take care to ensure precise seating when cementing the crowns. In general, the height of the anterior tooth group is greater than the molar group, whereas in this study there were no differences in the mean marginal gaps among anterior, premolar and molar tooth groups. Further research on the effect of the abutment height and preparation angle on the marginal gaps of NobelProcera crown zirconia is needed.

The copings were fabricated using the Procera system, in which a scanning probe is attached directly on the die surface. As the diameter of the probe tip is 2.5 mm and it cannot reach the deepest areas during the scanning process, it is possible that the area of the rounded shoulder will not scan precisely. However, the Procera system was able to successfully fabricate the copings in terms of marginal gaps. In fact, after more than 5 years of observation of the Procera AllCeram crowns (alumina), compared to control teeth [22] in which the mean

marginal gap was 34.4 μm and the highest gap was 216 μm [2], there were no second caries and no soft tissue problems. These results confirm that Procera AllCeram crowns, fabricated using the Procera system, show promising clinical results and will have good marginal fit within clinically accepted parameters. The mean marginal gap of NobelProcera crown zirconia was 44.2 μm . This was slightly larger than Procera AllCeram crowns under the same investigation. A prospective evaluation in a clinical situation should be compared with Procera AllCeram crowns after 5 years of function.

On the other hand, Boening et al. [3] reported that compared to anterior crowns, the posterior tooth group tended to have greater gaps. In this study, similar results were obtained, but there were no significant differences in the mean marginal gaps among anterior, premolar, and molar teeth groups. This was the same tendency as Procera AllCeram crowns [2].

5. Conclusions

Within the limitation of this clinical study, the influence of tooth groups on the marginal fit of NobelProcera crown zirconia was rejected, and their marginal gap showed a high precision that might be clinically accepted.

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