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Clinical Marginal Gap of Porcelain Fused to Electro-formed Gold Coping Crowns

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Abstract - *This study evaluated the marginal and internal gaps of Auro Galvano Crowns (AGC) in vivo. One hundred AGC crowns were examined using white and black silicone materials; the thickness of the silicone layer was measured at 16 reference points using a microscope. The mean marginal gaps among anterior, premolar and molar teeth, and the mean gaps within the groups were compared by analysis of variance and Dunnett T3 test. The results showed that at the margins, there were no significant differences among the four measuring points within each group, and there were no significant differences in the mean marginal gaps among the three groups. The mean marginal gaps in all groups were within the limits of clinical acceptability*

KEY WORDS: AGC crown, Marginal gap, Internal gap, Fit

INTRODUCTION

Aesthetic demands for individual crown restorations by both patients and dentists have been increasing[1]. In the late 1950s, vacuum-fired, porcelain-fused-to-metal crowns were introduced to the market by Vines *et al*[2]. Since then, various preparation designs, and impression and laboratory techniques with new materials have been advocated to improve the marginal fit, aesthetics and durability. Porcelain-fused-to-metal crowns are currently one of the most predictable and popular types of restorations [3]. However, in cases involving aesthetic restorations, gingival discoloration of the metal copings in contact with the thin soft tissue around the preparation margin has been a significant problem. To overcome this, porcelain-fused-to-metal crowns with porcelain shoulders were developed, and they provided clinically acceptable marginal adaptation [4]. Electroformed gold copings were introduced to dentistry in 1961 by Rogers [5]. This technique, which has been improved since the early 1990s, does not require casting, and the gold coping can routinely be made to a uniform thickness with 24K gold.

Electroformed gold copings enable the porcelain crown to look more natural around the soft tissue, thus improving the aesthetics of the restoration. Other advantages of this technique are that all kinds of cements can be used, any kind of marginal design is acceptable, and the waxing, investing and casting steps are eliminated[6]. Erpenstein *et al.*[7] showed in his long-term results that Auro Galvano Crown (Wieland Edelmetalle KG, Pforzheim, Germany; AGC) restorations were superior to glass-ceramic restorations and comparable to porcelain-fused-to-metal restorations. The durability of AGC crowns was also a very important advantage.

Several studies have reported on the fit of porcelain fused to electroformed gold coping crowns. For example, Setz *et al.*[8] found that the mean cement film thickness at the AGC crown margin was less than 20 µm *in vitro*. In another study [9], the marginal fit of electroformed ceramometal crowns (36 µm) was superior to the fit of conventionally cast ceramometal crowns *in vitro*. Petteno *et al.*[10] reported that the mean marginal fit of AGC crowns was 32 ± 14 µm *in vitro*, which was clinically acceptable. On the other hand, it was found that there were no statistically significant differences in the marginal gap between porcelain-fused-to-galvanized-gold crowns and porcelain-fused-to-metal crowns [11].

There are no clinical reports on the marginal and internal gaps of porcelain crowns on electroformed gold copings. It is commonly believed that the discrepancy between the marginal restoration and the preparation should be as small as possible to ensure long-term clinical success. The purpose of this study was to evaluate the marginal and internal gaps of AGC crowns *in vivo* and to test the hypothesis that the marginal gap of the AGC crowns would be clinically acceptable.

MATERIALS AND METHODS

One hundred AGC crowns were delivered to patients at Tsurumi University Dental Hospital between October 2002 and November 2003. Prior to treatment, the ethics committee of Tsurumi University accepted the study plan, and informed consent agreements were signed by the patients who participated in this study. Patients were selected according to the following criteria: 1) not a heavy bruxer or clencher, 2) less than 70 years old, 3) understood the

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purpose of the study, 4) agreed to participate in follow-up examinations up to 5 years, 5) low caries activity, and 6) periodontally healthy. A total of 46 patients (5 male and 41 female) received an average of 2.2 AGC crowns per person (ranging from 1 to 6). Two dentists treated all the patients, and all the AGC crowns in this study were fabricated in the hospital laboratory by experienced dental technicians. A chamfer marginal preparation was chosen, which required a special preparation bur (All ceramic preparation kit, Shofu, Kyoto, Japan). The minimum occlusal reduction was 1.5 mm, and the chamfer width was 0.8 mm. All line angles of the abutment teeth were rounded to prevent any stress concentration, and then impressions were made using vinyl polysiloxane impression material (Exafine, GC Corp., Tokyo, Japan). The working casts were fabricated with Type IV stone (New Fuji Rock, GC Corp.), and the trimmed dies were coated with two layers (approximately 24 µm thick) of die spacer (Die spacer kit, Benzar-Dental AG, Zurich, Switzerland) to within 1 mm of the finish line.

All electroformed gold copings were conventionally made on dies with a uniform thickness of 0.3 mm using AGC Micro (Wieland, Pforzheim, Germany) as follows: Each die was duplicated using AGC dubli-Gum and hardener. AGC super hard plaster was then poured in the duplicating mould, and the plaster was dried in a microwave oven. The AGC copper rod was fitted into the duplicate die with a small portion of contact adhesive, and the AGC conductive silver lacquer was applied evenly up to the preparation margin. AGC shrink-fit plastic tubing was connected to the copper rod close to the plaster die, and the power level of the AGC Micro was determined. The gold electrolyte was poured into the beaker, the prepared parts were mounted, and the unit was turned on. After the electroforming process was completed, the copper rod was cut, and the plaster die was removed from the crown using AGC plaster remover in an ultrasonic unit. Next, the layer of conducting silver lacquer was boiled out in nitric acid (25%). After deposition of the gold coping, the stone die was cleaned in an ultrasonic cleaner.

The margin of each coping was trimmed back to the proper length with a fine abrasive stone, and the electroformed surface was sandblasted with aluminum oxide. After applying the AGC gold bonder to the surface, it was pre-dried in a furnace kept at 920º. Veneering porcelain (Zeoce light, Yamamoto Precious Metal Co., Osaka, Japan) was fired on each electroformed coping according to the manufacturer's instructions; opaque porcelain was fired from 450º to 920º for 5 minutes in vacuum with a one minute hold at the peak temperature. Dentine porcelain was fired from 550º to 900º for 6 minutes in vacuum with a one minute hold at the peak temperature and then glazing was performed from 550º to 880º for 4 minutes with a one minute hold at a peak temperature using an electric furnace (Austromat 3001, Dekema, Freilassing, Germany).

The proximal contact areas were adjusted at chair side before delivery of the crowns, and the marginal and internal gaps were recorded using white and black silicone materials. No internal grinding of the copings was conducted before testing. White silicone (Fit checker, GC Corp.) was mixed (Base:Catalyst = 1:5) and poured inside the crown, which was held on each abutment tooth for 2 minutes with finger pressure. Five minutes after mixing the silicone material, the crowns were carefully removed from the abutment teeth. Black silicone (Bite checker, GC Corp.) was used (Base:Catalyst = 1:6) to fill the inside of the crown using a syringe so as to completely cover the white silicone. After setting, the crown and silicone were separated from each other.

The silicone block materials were sectioned bucco-lingually first, and then mesio-distally with razor blades. Care was taken to equalize the portions. The sections were placed under a measuring microscope (Profile Projector V-16D, Nikon, Tokyo, Japan) and the thickness of the white silicone materials was measured in the areas shown in *Figure 1*. The 16 different points were evaluated in the bucco-lingual and mesio-distal sections of each specimen. All sections were measured under 10× magnification, as determined by Holmes *et al.*[12].

A two-way analysis of variance (ANOVA) (SPSS Base 10.0, SPSS Inc., Chicago, USA) was used to identify significant differences in tooth groups. Dunnett T3 analysis was used to evaluate the significant differences among the measurement locations. All testing was conducted at the 95% level of confidence.

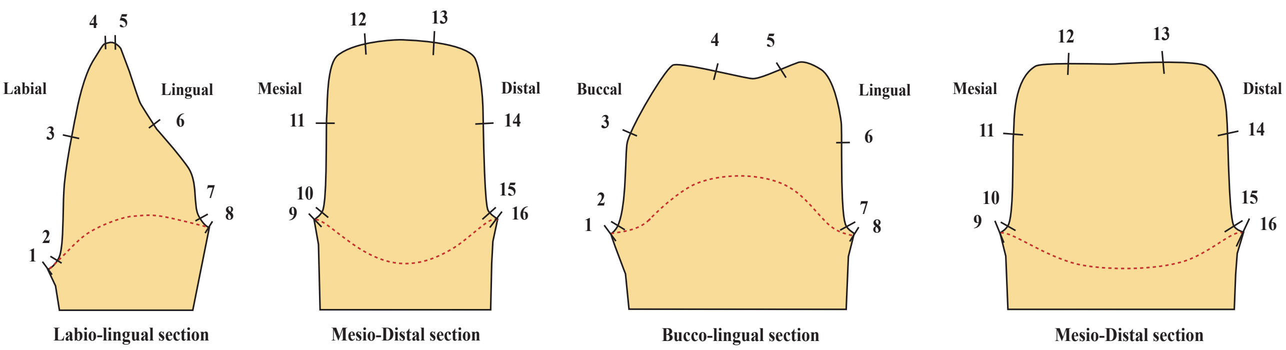

Figure 1. *Diagram of the measuring points.*

RESULTS

The distribution of the restored teeth in this study is shown in *Table 1*. Premolar teeth were the most frequently restored teeth, followed by anterior and molar teeth.

The mean gaps are shown in *Tables 2 and 3*. The mean marginal gaps in the anterior, premolar and molar locations were 38.5±28.2, 42.9±30.4 and 40.9±34.9 µm, respectively. The mean marginal gap of the AGC crowns measured in this study was 40.6 ± 30.3 µm. There were no significant differences at the margins among the four measurement points (1, 8, 9 and 16) within each group, and there were no significant differences in the mean marginal gaps among the three groups. In all groups, the occlusal gaps (4, 5, 12 and 13) were the largest. There were significant differences between the occlusal area and the margin in the anterior and premolar groups (P<.001). The gaps at the axial wall (3, 6, 11 and 14) of each group tended to be smaller compared to the occlusal area and the rounded chamfer.

Table 1. Distribution of AGC crowns

	Anterior	*Premolar*	*Molar*
Maxilla	44	18	6
Mandible	1	19	12
Total	45	37	18

Table 2. Mean marginal and internal gap measurements at each point

Point	*Anterior*	*Premolar*	*Molar*
1	37.8(28.2)	37.4(33.6)	43.7(32.0)
2	87.6(62.4)	86.8(41.9)	74.7(32.1)
3	69.6(48.8)	58.5(28.2)	62.4(35.3)
4	116.4(71.2)	99.1(51.7)	104.2(55.0)
5	116.0(67.1)	100.8(47.0)	125.7(103.1)
6	76.6(39.5)	51.7(23.2)	56.8(19.9)
7	86.7(55.8)	88.5(52.4)	90.2(70.3)
8	34.6(25.4)	45.2(26.3)	30.1(21.1)
9	34.4(25.9)	47.2(27.6)	35.4(24.9)
10	95.0(71.1)	81.1(40.2)	78.6(60.8)
11	63.2(43.5)	53.1(32.2)	66.5(57.1)
12	114.8(67.0)	108.1(59.1)	120.7(105.7)
13	138.1(84.5)	120.1(85.5)	129.8(80.2)
14	60.0(33.1)	56.5(36.5)	82.5(51.8)
15	95.4(74.8)	84.6(43.6)	104.3(78.1)
16	47.3(31.8)	41.7(33.8)	54.3(51.5)

unit:µm
( ):SD

Table 3. Mean gaps at four measuring points

	Anterior	*Premolar*	*Molar*	*Mean*
Margin	38.5(28.2)	42.9(30.4)	40.9(34.9)	40.6(30.3)
Rounded chamfer	91.2(66.0)	85.2(44.4)	87.0(62.5)	88.2(58.2)
Axial wall	67.3(41.8)	54.9(30.2)	67.1(43.7)	62.7(38.7)
Occlusal area	121.3(72.8)	107.0(62.5)	120.1(87.1)	115.8(72.2)
Mean	79.6(63.0)	72.5(50.6)	78.7(66.8)	

unit:µm
( ):SD

DISCUSSION

The size of the marginal gap of crowns is regarded as a determining factor for plaque accumulation, recurrent caries and periodontal disease. This study found mean marginal gaps of 40.6 µm ranging 38.5 to 42.9 µm. Setz *et al.*[8] found that the mean cement film thickness at the margin was less than 20 mµm, which is the smallest value in the published literature. Hämmerle *et al.*[11] found a mean luting cement thickness of 48.5 µm *in vitro*, and Petteno *et al.*[10] reported that the mean marginal gap of the AGC crown was 32 ± 14 µm *in vitro*, which was clinically acceptable; there were no significant differences compared to metal ceramics. These data correlated closely with the data obtained in the present study. However, there is apparently no other clinical study evaluating the marginal and internal gaps of AGC crowns, so there is nothing to compare to the values of the model study. In the study by Petteno *et al.*[10], the gaps were measured on the same model repeatedly, whereas in the present study, the gaps were measured from each specimen obtained *in* vivo. In addition, Petteno *et al.*[10] stated that further studies were required to establish the influence of the margin design, ceramic thickness and shape of the die on the marginal gap. For example, if the ceramic on the posterior teeth is thicker, the deformation of the electroformed gold coping might be greater after the porcelain is fired. On the other hand, Syu *et al.*[13] showed that the marginal and internal gaps were not influenced by the type of finishing line. The effect of margin design on the fit of AGC crowns and the relationships among the other factors have not yet been established.

Other published data[14] showed that the mean marginal gaps for the incisor crowns were 87 µm for metal ceramic crowns, 83 µm for Celay In-Ceram, 112 µm for conventional In-Ceram, and 46 µm for the IPS Empress II layering technique. The marginal gaps for the AGC crowns in all groups were smaller than for other systems *in vitro*. However, these discrepancies were all within the clinically acceptable standard of 120 µm[15]. It was difficult to compare the results of this study with values found in the literature, since this study was conducted without controls, and the measurement process was different. We have already conducted the same type of studies on the clinical marginal and internal gaps of Procera crowns, and In-Ceram crowns fabricated using GN-I system, and concluded that the mean marginal gaps were 32-36 µm[16] and 66.8 µm[17], respectively. These data were obtained using the same type of silicone impression materials. Comparing these data to those of the present study, the marginal gaps of the AGC crowns were the smallest, which means that the fit of electroformed crowns tends to be better than of CAD/CAM-generated all-ceramic crowns.

Electroformed gold copings are less likely to undergo dimensional change during fabrication. After making the impression and master cast, there is no investment and casting procedure required. The electroforming process is completed in the laboratory on the duplicated die, and then any excess gold is removed with a silicon wheel. Hammerle *et al.*[11] found that 87% of the AGC crowns had overhanging margins due to the above-mentioned technical reasons. Clinicians should be aware that overhanging margins may be more harmful than short margins. There is no alloy shrinkage during casting. However, there is the potential for errors during duplication of the master die, application of conductive silver paint and repeating porcelain firing.

In the present study, the clinical gaps were evaluated using silicone impression materials. This method was originally described by Oshima *et al.* [18], who found that the silicone film thickness at the recommended catalyst/base ratio was the same as for the zinc phosphate cement mixed at a standard powder/liquid ratio. When recording the film thickness intraorally, the back pressure of the silicone materials affected the film thickness, although the materials used in this study had low viscosity. Also, there tended to be smaller gaps at the axial wall in the anterior and premolar groups, whereas in the posterior group, the height of the abutment teeth was sometimes less, and there were no significant differences in the film thickness between the occlusal area and margin except for the buccal margin. No loose fit was observed when seating the AGC crowns on the abutments made by casting.[14] The fit of the AGC crowns was excellent because the film thickness of the silicone material was the largest at the occlusal areas in all groups, as it was for the metal ceramic crowns.[19,20] Clinicians must keep in mind that the flow of the luting cement *in* vivo will affect the cement film thickness at the margins, and increasing the convergence angle of the preparation will facilitate the flow of cement[21-23]. Hammerle *et al.*[11] showed that the thickness of the zinc phosphate cement after cementing using finger pressure was 48.5 µm. The flow of the silicone material used in this study was similar to that of zinc phosphate cement. The manufacturer recommended coating the die spacer on each die before duplicating; however, there were no data indicating how much relief is enough and what the best relief method is to produce minimal post-cementation marginal discrepancies[24].

Jacobs *et al.*[25] reported that the rate of zinc phosphate cement solubility was not statistically affected when the marginal openings were 25, 50, and 75 µm in size. However, the 150 µm marginal gap demonstrated a statistically significant increase in cement dissolution *in vitro*. The mean marginal gaps of the AGC crowns in this study are acceptable from the solubility point of view.

The clinical results obtained from the data in this study may predict the limitations of the marginal and internal gaps of electroformed copings. However, clinicians will not detect such small gaps in the subgingival or interproximal areas. The results of this *in vivo* study did not indicate any significant marginal gaps among the buccal and lingual areas, and the mesial and distal areas in all tooth groups. The hypothesis was confirmed that the mean marginal gap of the AGC crowns is within a clinically acceptable value of 40.6 µm in a range of 38.5 – 42.9 µm.

Additional studies should focus on the relationship of several factors that affect the fit of AGC crowns.

CONCLUSIONS

The marginal and internal gaps of 100 AGC crowns were measured using silicone impression materials. Within the limitations of this *in vivo* study, the following conclusions may be drawn:

1. The mean marginal gaps in the anterior, premolar and molar teeth were 38.5, 42.9 and 40.9 µm, respectively.
2. The mean gaps at the margins were the smallest, whereas they were the largest at the occlusal areas in all groups.
3. The mean marginal gap in all groups was 40.6 µm, which was within the limits of clinical acceptability.

MANUFACTURER'S DETAILS

- AGC, Wieland Edelmetalle KG, Pforzheim, Germany
- All ceramic preparation kit, Shofu, Kyoto, Japan
- Exafine, GC Corp., Tokyo, Japan
- New Fuji Rock, GC Corp., Tokyo, Japan
- Die spacer kit, Benzar-Dental AG, Zurich, Switzerland
- Zeoce light, Yamamoto Precious Metal Co., Osaka, Japan
- AGC gold bonder, Wieland, Pforzheim, Germany
- Fit checker, GC Corp., Tokyo, Japan
- Profile Projector V-16D, Nikon, Tokyo, Japan

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