The manufacturing characterization of zirconia core copings of CAD/CAM systems

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Purpose: The purpose of the present study was to investigate the manufacturing characterization of zirconia copings for abutments. Comparative evaluation was made using five different CAD/CAM systems.
Materials and Methods: The abutment model was fabricated. Five zirconia copings were produced using Procera, Katana, Cercon, and Lava 0.5 and 0.6 by CAD/CAM system dealers. Silicone impression material was placed between the abutment model and a coping to observe the manufacturing characteristics and pressed. The abutment model with impression material was embedded in epoxy resin. The embedded model was cut buccolingually using an automatic precision cutter, and the thickness of silicone impression material was observed using an optical microscope with a scale.
Results: A significant difference was observed in the gap average between Procera and Lava 0.5 ($p<0.01$), and Procera and Lava 0.6 ($p<0.05$) in the buccal margin. For the buccal corner and occlusal chamfer, the gap was significantly larger in Procera compared with the other copings ($p<0.01$). In the palatal margin, the gap was significantly smaller in Lava 0.6 compared with Procera, Katana, and Cercon ($p<0.01$).
Conclusion: Marginal lines were smooth and coincided with abutments for all CAD/CAM systems. Although the gap size varied among the manufacturers, the thickness of impression material was smaller, and the processing quality was even in Lava compared with the other copings. These characteristics are considered to be related to the shape and size of drilling tools of each CAD/CAM system. **(Asian Pac J Dent 2012; 12: 11-16.)**
Key Words: CAD/CAM system, gap, manufacturing characteristics, zirconia copings

Introduction

Zirconia ceramics have been widely applied for crown restoration due to their esthetic appearance, as well as favorable biocompatibility, elastic coefficient, and breaking strength.[1-7] All ceramic restorations vary from molar crowns to bridges. Zirconia ceramics are difficult to handle. Since the mechanical stability and size precision are often affected during the manufacturing processes, such as sintering and molding, it is difficult to produce stable-quality products. In recent years, computer-aided design and manufacturing (CAD/CAM) systems have been introduced in daily practice from designing to processing, to produce stable-quality products. Processing accuracy is considered important to achieve a satisfactory long-term prognosis with prosthetics. Although many reports are available regarding the fit of crowns, the fabrication of zirconia copings requires treatment according to abutment preparation suggested by manufacturers. This fact limits the application in clinical practice. The present study investigated the manufacturing characteristics of zirconia copings that are not based on abutment preparation suggested by manufacturers, but based on the abutment model with minimum preparation. Five CAD/CAM systems were compared, and interesting findings were observed.

Materials and Methods

Fabrication of a zirconia coping

Abutment preparation of the all ceramic crown was performed on the tooth model (Nissin Dental Products Inc. Kyoto, Japan) maxillary right first molar on an assumption that the tooth was vital. The cervical margin of an abutment was chamfer. The axial plane taper was 6°, and the basal plane was 9.0 mm in diameter and 5.5 mm in height. An impression of the prepared abutment was taken using silicone impression material (Duplicone, Shofu, Kyoto, Japan), followed by the fabrication of a working model with improved hard plaster (Fuji Lock, GC, Tokyo, Japan). Fabrications of zirconia copings were assigned to each CAD/CAM system dealer. The types of coping fabricated were Procera (Nobel Biocare, Zurich, Switzerland), Katana (Noritake, Nagoya, Japan), Cercon (Dentsply-Sankin, Tokyo, Japan), and Lava (3M Espe, Seefeld, Germany). There were two types of Lava, including a 0.5-mm framework (Lava 0.5) and 0.6-mm framework (Lava 0.6). Therefore, the total number of zirconia coping types was five. Thickness of coping was 0.5 mm and 0.6 mm for Lava, 0.6 mm for Procera, 0.5 mm for Cercon, and 0.5 mm for Katana.

Fabrication of abutment model made of resin

Impression-taking of an abutment model was performed again using silicone impression material, and 30 abutment models was fabricated using resin. The surface of the resin abutment model was formed using flowable resin (Filtek Supreme XT Flow, 3M Espe), and cured with a light-curing unit (Optilux 400, Sybron Dental Specialties, Washington DC, USA) for 20 s. The multilayer-packing method with 2-mm-layer composite resin (Filtek Supreme DL Universal Restorative, 3M Espe) was performed inside, and every layer was cured using a light-curing unit for 20 s. Each abutment model was further cured with light for 5 minutes using dental polymerization equipment to complete polymerization.

Fit test

Figure 1 shows experimental design. Silicone impression material (Tosicon Pastel Injection, Dentsply-Sankin) was placed between the resin abutment model and coping and pressed with the fingers for 5 minutes. After the impression material was set, copings were removed, and the resin abutment model was embedded with impression materials using epoxy resin (Epofix, Struers, Pederstrupvej, Denmark) (n=6). The embedded model was left at room temperature for 2 days, and cut buccolingually using an automatic precision cutter (Isomet, Buehler, Lake Bluff, IL, USA). Five parts inside the cutting surface (1, Buccal margin; 2, Buccal corner; 3, Occlusal chamfer; 4, Palatal corner; and 5, Palatal margin) were measured using an optical microscope with a scale (reading microscope, Nippon Optical Works Co., Ltd., Tokyo, Japan) to examine the thickness of silicone impression material. Figure 2 shows the measured parts. The average and standard deviation of the obtained values were calculated, followed by one-way analysis of variance and Tukey's multiple comparison.

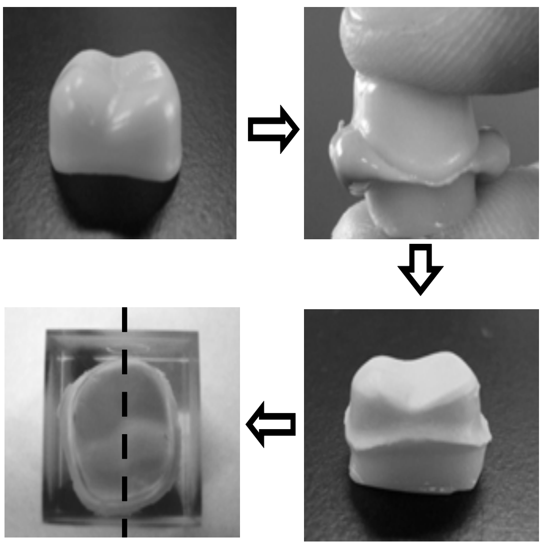

Fig. 1. Experimental design

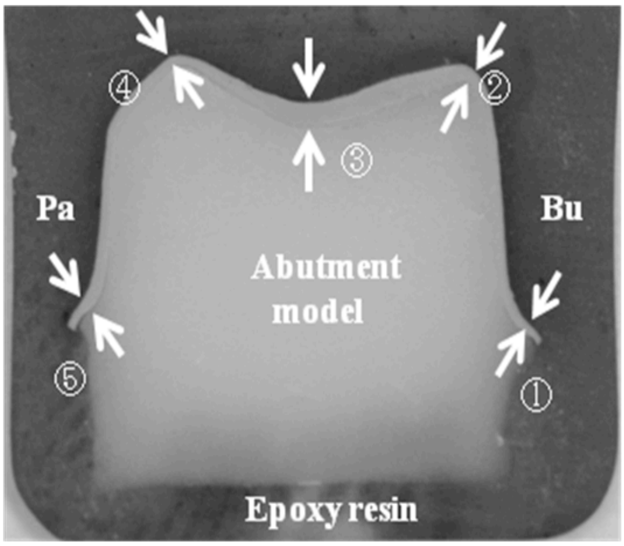

Fig. 2. Measured points in the silicone-abutment model

Observation of inner surface of copings

Silicone impression material (Tosicon Pastel Injection) was applied inside each coping (Cercon, Katana, Procera, Lava 0.5 and 0.6). The coping was placed on the improved hard plaster abutment model that was used to fabricate each coping, and pressed with the fingers for 5 minutes. After the impression material was set, only the coping was removed. Next, oxidized titanium power (Cerec Powder, Vita, Bad Säckingen, Germany) was sprayed on the abutment model with impression materials as a pretreatment for optical impression taking to create a stable reflection ratio. The inner surface morphology was observed by CAD/CAM (Cerec, Sirona, Bensheim, Germany) optical impression taking.

Results

Fitness

Figure 3 shows the results of fitness tests using a reading microscope. The gap of Procera was 247 µm in the buccal margin, 278 µm on the buccal corner, 270 µm in the occlusal chamfer, 177 µm on the palatal corner, and 238 µm in the palatal margin on average. The gap of Katana was 178 µm in the buccal margin, 138 µm on the buccal corner, 147 µm in the occlusal chamfer, 163 µm on the palatal corner, and 240 µm in the palatal margin on average. The gap of Cercon was 162 µm in the buccal margin, 153 µm on the buccal corner, 80 µm in the occlusal chamfer, 96 µm on the palatal corner, and 252 µm in the palatal margin on average. The gap of Lava 0.5 was 133 µm in the buccal margin, 110 µm on the buccal corner, 88 µm in the occlusal chamfer, 100 µm on the palatal corner, and 168 µm in the palatal margin on average. The gap of Lava 0.6 was 140 µm in the buccal margin, 123 µm on the buccal corner, 73 µm in the occlusal chamfer, 100 µm on the palatal corner, and 103 µm in the palatal margin on average. One-way analysis of variance was performed to analyze the gap in each part of the five different copings. Since the results showed a significant difference, a multiple comparison test was performed using the Tukey method. The results are shown in Table 1. A significant difference in the gap average was observed only between Procera and Lava 0.6 ($p<0.05$). The gap on the buccal corner and in the occlusal chamfer was significantly larger in Procera compared with the other copings ($p<0.01$). The gap in the palatal margin was significantly smaller in Lava 0.6 compared with Procera, Katana, and Cercon ($p<0.01$).

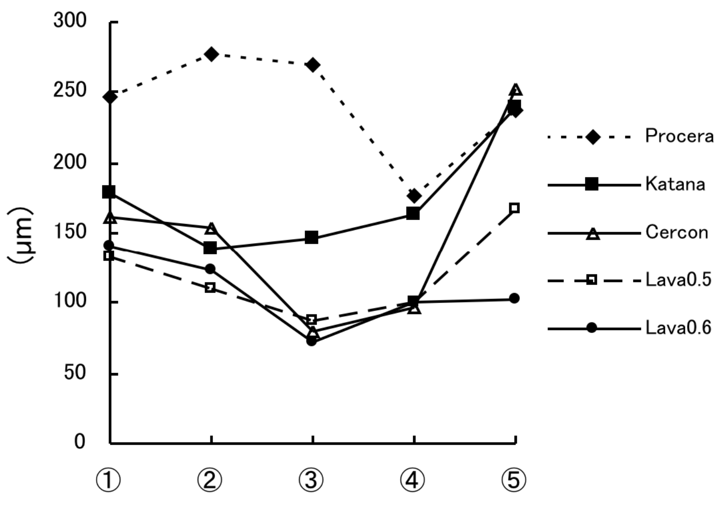

Fig. 3. Means of gap dimensions at five different measurement parts.

Table 1. Significant difference of the gap

Buccal margin

	Procera	Katana	Cercon	Lava0.5	Lava0.6
Procera					
Katana					
Cercon					
Lava0.5	**				
Lava0.6	*				

Buccal corner

	Procera	Katana	Cercon	Lava0.5	Lava0.6
Procera					
Katana	**				
Cercon	**				
Lava0.5	**				
Lava0.6	**				

Occlusal chamfer

	Procera	Katana	Cercon	Lava0.5	Lava0.6
Procera					
Katana	**				
Cercon	**				
Lava0.5	**				
Lava0.6	**				

Palatal margin

	Procera	Katana	Cercon	Lava0.5	Lava0.6
Procera					
Katana					
Cercon					
Lava0.5					
Lava0.6	**	**	**		

**(p<0.01), *(p<0.05)

Observation of coping internal surface

Figure 4 shows the results of optical impression taking. A distinctive cutting mark was observed on the buccal and palatal corners of Katana. Although other copings showed a difference in the gap, no significant change was found in the optical impression, and the inner surface showed a consistent quality.

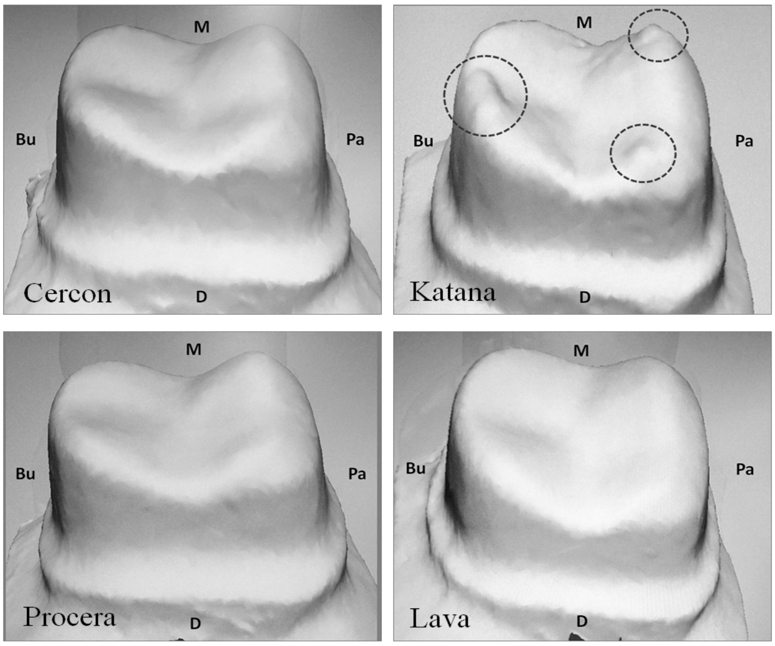

Fig. 4. Optical impressions of coping internal surface were provided by CAD/CAM system.

Discussion

A number of studies have been performed regarding the fit of crown restorations since the marginal and inner gap is key to successful treatment results. The marginal fit markedly influences the prognosis following crown bridge treatment since the poor fit may result in periodontitis, secondary caries, and the dissolution of cement.[8] However, there are no clear criteria to determine the allowance range in clinical application. McLean et al. reported that a marginal gap of less than 120 μm achieves a favorable clinical result.[9,10] Nakamura et al. reported that a marginal gap of less than 100 μm does not affect the treatment results if there is little marginal leak and resistant resin cement is used for crown placement.[11] Beuer et al. reported that cervical marginal fitting was less than 50 μm in the abutment model with a 12° taper during the cementation of a zirconia crown to the model.[12] These reports revealed that the clinical allowance range differs depending on researchers. The results of the present study showed that the biggest gap in Procera compared with the other copings except for the palatal margin. The thickness of silicone impression material was relatively constant, and the obtained values were larger than previously reported results for all copings.

In the present study, abutment preparation was performed not according to the manufacturers' instruction, but according to the clinical procedure to minimize the preparation on the assumption that the abutment tooth was vital. The fit of crowns was examined using rubber-type silicone impression material in the present study since the clinically used fit-checker is not resilient enough. Although relatively high-flowable impression material was selected, the viscosity of silicone impression material was high compared with the high-flowable fit-checker and cement. Therefore, it is considered that silicone impression material with high viscosity tends to clog even in the cement space created in the coping inner surface, resulting in an increase in the gap. Although the average gap was large in Procera, Boening et al. reported that the marginal gap in the molar area of Procera was 90-145 μm on average, and 115-245 μm at maximum.[13] Manufacturer of Procera reported that the fit of Procera is intentionally loose so that the amount of final seating is minimal regardless of the skill of dentists and technicians. This is considered to be the reason for the relatively large gap compared with other manufacturers.

In contrast, the gap was smaller in Lava 0.5 and 0.6 compared with the other products, and there was no significant difference in the marginal gap. The gap was significantly smaller in the palatal margin of Lava 0.6 compared with the other copings. There are three types of milling bur in Lava processing machinery. Specifically, the apical diameter of an inner surface processing bur was the smallest compared with the other manufacturers' burs. This is considered to be very beneficial in milling the inner surface of a zirconia coping. Although cutting burs are accessible from any direction in the outer processing of a coping by CAD/CAM, bur access is restricted depending on the abutment taper in the inner processing. Therefore, a smaller apical diameter of a bur is beneficial to fabricate high-precision copings.

Scanning of the inner surface of a coping by optical impression taking revealed that the gap in the Lava series is relatively small and consistent. Considering a distinctive cutting mark in Katana, the drive system of the cutting machine and type and fatigue condition of cutting tools are considered to influence the processing precision during cutting work. Due to these CAD / CAM characteristics, it is necessary to increase the cutting amount of an abutment and the taper of the axial surface of the abutment to simplify optical scanning of an abutment and the coping cutting procedure. These principles are contrary to "minimal intervention treatment", the basic policy of modern dental treatment proposed by the World Dental Federation in 2000. Although zirconia all ceramic treatment has been widely used as a metal-free treatment, and CAD/CAM performance has markedly improved, further improvement of CAD/CAM is necessary to achieve low-invasive tooth treatment.

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Accepted March 14, 2012.

 Online ISSN 2185-3487, Print ISSN 2185-3479