Original Article

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Effect of different materials on marginal accuracy of crown coping fabricated by a CAD CAM system

Somchai Urapepon[1], Vicente O. Medina III[2]

[1] *Department of Prosthodontics, Faculty of Dentistry, Mahidol University, Bangkok, Thailand*
[2] *Department of Clinical Dentistry, College of Dentistry, University of The Philippines Manila, Philippines*

Objective: To compare the marginal gap of the crown coping fabricated from three different materials by the same CAD-CAM system.

Materials and Methods: Thirty crown copings were fabricated from three different materials: Zirconia (Ceramill ZI®, AmannGirrbach, Austria), PMMA (Ceramill PMMA®, AmannGirrbach, Austria) and Wax (Ceramill WAX®, AmannGirrbach, Austria) by the same CAD-CAM system (Ceramill, AmannGirrbach, Austria). The Zirconia crown copings were milled but did not undergo sintering. The marginal gap of the crown copings was evaluated using the low viscosity replica technique. The replicas were cut in mesio-distal and bucco-palatal direction. The marginal gap was measured using an optical light microscope at 50X magnification. The marginal gap data from four positions of cutting were averaged as one datum and statistically analyzed using one-way ANOVA and Game-Howell post-hoc test (α=0.05).

Results: The mean marginal gap was 67.2±19.1 µm for zirconia, 514.3±55.1 µm for PMMA, and 44.9±14.1 µm for wax. The statistical analysis showed that the marginal gap of wax was significantly smaller than zirconia, while PMMA showed the largest gap (p<0.05).

Conclusion: It is concluded that the crown copings that were fabricated from the three different materials milled by the same CAD-CAM system showed a significant statistical difference in their average marginal distance or gap. PMMA showed the worst in marginal gap.

Keywords: CAD-CAM materials, CAD-CAM system, Ceramill, the marginal gap,

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Introduction

The profession of dentistry has a long history of creativity resulting in the invention and continuous development of materials and techniques. The dental materials for prosthetic restorations have been used for more than 50 years now. These prosthetic restorations not only restore esthetics and function but also improve the quality of life of the person. In addition to conventional fabrication processes, new technologies are now available, one of which is the computer-aided design and computer-aided manufacturing (CAD-CAM) technology [1].

CAD-CAM technology has been used in the manufacturing industry for many decades. The past 20 years has seen an increased use of the technology in Dentistry [1]. Nowadays, new CAD-CAM systems are able to produce restorations that have a better fit, stronger and more esthetic than previous CAD-CAM systems [2]. Studies have reported acceptable marginal gaps of crown copings fabricated by CAD-CAM systems [3-6].

CAD-CAM systems by themselves are able to directly produce restorations. However, there is also another way of fabricating restorations which combines CAD-CAM technology and the conventional lost wax casting technique. The CAD-CAM system mills the pattern from

Correspondence author: Somchai Urapepon
Department of Prosthodontics, Faculty of Dentistry, Mahidol University
6 Yothi Road, Ratchathewi, Bangkok 10400, Thailand
Tel.+66 2200 7816 Fax. +66 2200 7818 E-mail: somchai.ura@mahidol.ac.th
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blocks of Polymethyl methacrylate (PMMA) or wax. The pattern made of PMMA or wax is then converted into restorations using the conventional casting technique. This combination technique involves many processes and factors (both from CAD-CAM and conventional casting technique) that could affect the marginal fit of the crown [7]. Early CAD-CAM systems had limitations especially in the CAM side considering that long span metal frameworks could not be fabricated by the milling unit. For this and similar applications, most dental laboratories use the combined or indirect technique by using the patterns (made of PMMA) produced by the CAD-CAM system. The PMMA pattern is then converted into the metal framework via the conventional casting technique. There are some CAD-CAM systems that claim their system can be used for varieties of materials without additional operation, and there are several materials available for their system.

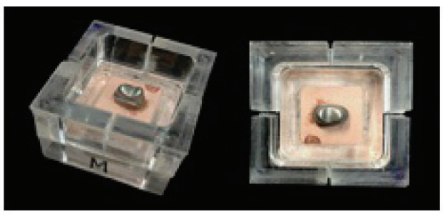
The review of the literature revealed a limited number of studies that have investigated the accuracy of restorations made from different materials fabricated by CAD-CAM systems. The purpose of this in vitro study is to compare the marginal discrepancy of crown copings fabricated with three types of materials by a CAD-CAM system.

Materials and methods

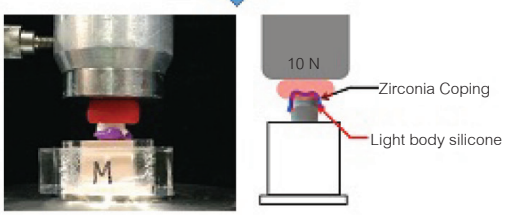
An Ivorine™ tooth (Columbia Dentoform Corp, NY, USA) model of a maxillary right second premolar was used as the abutment for the crown and copings/patterns. The abutment tooth was prepared with a 0.8 mm chamfer finishing line, 1.5 mm occlusal reduction and 6-degree total occlusal convergence, then duplicated and casted with Co-Cr alloy (Vitallium®, Dentsply Inc, PA, USA). The casted die served as the master metal die. The master metal die was then embedded in Type IV dental stone inside a clear acrylic mold.

The metal die and the mold were coated with scanning spray (CEREC Optispray Sirona, Germany) then fixed to a special model holder for scanning to obtain a digital data of the die (Ceramill Map300, Armann Girrbach, Austria). The Ceramill Mind software (Armann Girrbach, Austria) was used for designing the restorations. The cement space was set at 10 µm. The restoration design was sent to the CAD-CAM milling unit (Ceramill Motion1, Armann Girrbach, Austria) to mill the zirconia block (Ceramill Zi, Armann Girrbach, Austria), PMMA block (Ceramill PMMA, Armann Girrbach, Austria) and Wax block (Ceramill Wax, Armann Girrbach, Austria). Since the Ceramill Motion I, is a dry milling machine without water coolant option, all of the specimens were dry milled. The scanner and the milling unit were calibrated at the beginning of the study and recalibrated each time a coping was made. The same scanning, designing and milling procedures were repeated each time for the 10 copings of each group. To eliminate the error from compensation of sintering shrinkage, the pre-sintered zirconia crown copings were not over milled and sintered.

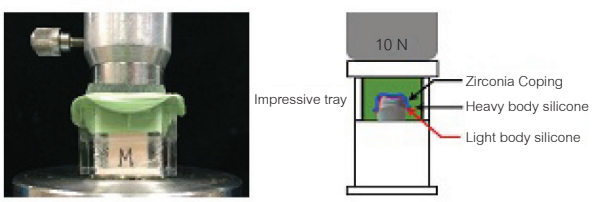
The marginal discrepancy of the crown coping was examined using cross-sectional technique combined with silicone replica technique. Each crown coping was filled with light body silicone (Express XT, 3M ESPE, St. Paul, MN, USA) and placed on the metal die, after which a load of 10 N was applied at the center using a transfer loading device (Mahidol research unit, Bangkok, Thailand) for 6 minutes. After confirmation that the light body silicone has set, the metal die was removed and replaced with heavy body silicone (Penta H quick, 3M ESPE, St. Paul, MN, USA). The heavy body silicone stabilized both the inside and outside surfaces of the crown coping within the acrylic tray. The thickness of the light body silicone film represents the space between the metal die and coping. The schematic picture of the silicone replica technique is shown in Figure 1.



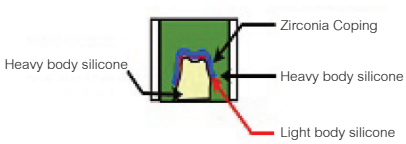
Master die in acrylic block and removable customized acrylic tray



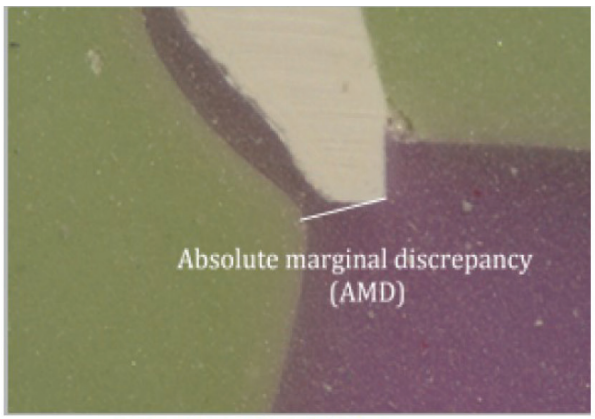
Crown were seating on the die with light body silicone

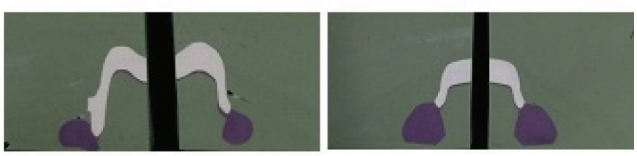


Heavy body silicone was poured to stabilize the crown



The die was removed from the tray and die space was filled with heavy body silicone





The cross sectional silicone at four direction of the crown

The replica silicone was cut mesio-distal and bucco-fingual direction at the prepared slot on the tray

Figure 1 Schematic picture of the silicone replica technique procedure.

The silicone replica was cut in mesio-distal direction and bucco-lingual direction along the guiding slot of the clear acrylic mold. This ensured that each crown was always measured at the same point. The absolute marginal discrepancy (AMD) (shown in Figure 2), as suggested by Holmes et al. [8] was selected for determining the marginal gap in this study. AMD is a parameter that measures the gap from the margin of the restoration to the cavosurface angle/margin of the preparation. The measuring was done using an optical light microscope (Nikon Eclipse E400, Tokyo, Japan) at 50X magnification. The marginal discrepancy at four measurement points were then averaged to one datum for each crown coping. The mean and standard deviations were then calculated. Data were analyzed using one-way ANOVA and Games-Howell test with p-value = 0.05 as the level of significance.

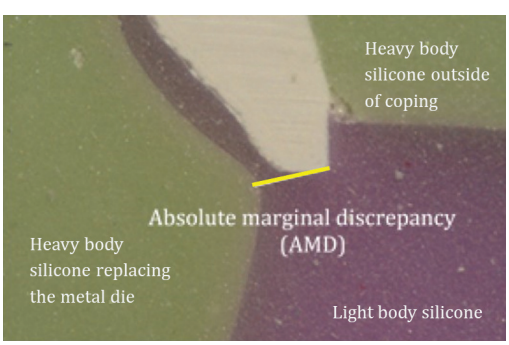


Figure 2 Illustration of measurement point; AMD

Results

The representative micrographs of the crown margins replicated by the silicone replica technique of the different materials are shown in Figure 3. The means of the AMD of zirconia, PMMA and wax were 67.2±19.1 μm, 514.3±55.1 μm and 44.9±14.1 μm, respectively. The statistical analysis using one-way ANOVA showed significant differences for all materials ($p<0.05$). The Games-Howell Post Hoc test showed that the mean AMD among pairs of zirconia-wax, PMMA-zirconia and PMMA-wax groups are significantly different ($p<0.001$). Wax showed the smallest AMD among the three materials, while PMMA showed the highest.

Discussion

Essential requirements for the clinical success of all crown restorations are not only good esthetics and high fractural resistances, but also perfect marginal fit is one of important key of criteria [9, 10]. The marginal integrity less than ideal requirement can occur plaque accumulation easily, thus the development of pulpal and periodontal disease can be followed. All of above is the reason that marginal fit plays an important role in longevity of restorations [11].

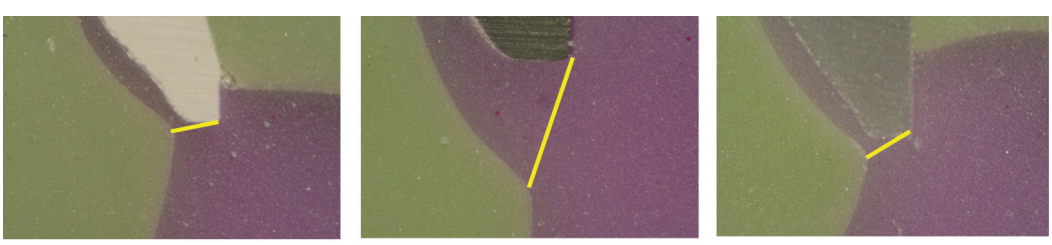


Figure 3 Micrographs of the crown margins replicated by the silicone replica technique of the different materials; (A) zirconia, (B) PMMA and (C) wax

In this study, the marginal gap was determined according to terminology previously reported by Holmes [8]. There are eight misfit terminology; internal gap, marginal gap, overextended margin, under extended margin, vertical marginal discrepancy, horizontal marginal discrepancy, absolute marginal discrepancy and seating discrepancy. The absolute marginal discrepancy, which is a parameter that measures the gap from the margin of restoration to cavo-surface angle of preparation, was chosen for measuring the marginal gap because the former is the angular combination of the marginal gap and both of overextension and under extension and is always the largest measurement of error at the margin would reflect the true total misfit both vertically and horizontally [8]. This study only focused on the differences in marginal gap by comparing different materials in the same CAD-CAM system. The results of this study reject the null hypothesis. It means that there is a significant difference in the marginal gap of three different materials.

A clinically acceptable marginal gap of fixed restorations is difficult to precisely identify [12]. Most investigators continue to use the criteria established by McLean and von Fraunhofer that is less than 120 μm [13]. for evaluating a clinically acceptable maximum marginal gap width. The mean marginal gap of crown copings reported in this study for both zirconia (67.2 μm) and wax (44.9 μm) crowns were in the clinically acceptable range but not for PMMA (514.5 μm). However, the methods of this study were not set as the clinical situation therefore, the results of this study can only represent the accuracy of a CAD-CAM system from three material fabricated crown coping.

Normally, PMMA or resin material was used for lost wax casting technique instead of wax due to its mechanical properties and more thermal stability than wax. Moreover, PMMA is famous resin materials used for long-term provisional prostheses [14]. Therefore, the marginal gap should be as less as possible and within clinically acceptable marginal gap width. Nevertheless, according to the result of this study, the mean of marginal gap of PMMA crown coping showed unacceptable largest value. According to thermal properties of PMMA, the thermal stability of standard PMMA is only 65°C. Heat-stabilized types can endure temperatures up to 100°C. Therefore, resistance to temperature changes is very good. However, PMMA is a combustible material, which continues burning even after the flame is removed [15]. However, due to the Ceramill Motion Cam machine used in this study is a dry milling machine, while the milling bur was cutting on PMMA blank, heat can be generated and affected to shrinkage of PMMA and affected to adaptability of restorations. Therefore, using of PMMA by CAD-CAM process especially dry milling CAM machine should be taken into caution.

According to the mechanical properties of waxes, a simple wax pattern deformation induced by thermal expansion depends on its mechanical properties. Variations in the dimensions of the wax pattern can be compensated by selection of waxes with proper elastic moduli [16]. Although resins, which consist of a fine powder material, are added into synthetic wax used in CAD-CAM materials to improve shrinkage characteristics and increase body and strength [17], the loading of 10 N applied on occlusal surface of sample crown coping may effect to the strain of wax. Overloading can be occurred and effected to the marginal fit. Therefore, wax crown coping showed the smallest marginal gap better than the zirconia did, which are stranger.

Zirconia crown coping showed significantly higher the marginal gap than wax. In this study, partially sintered zirconia blanks did not be compensated the sintering shrinkage to eliminate error of shrinkage in step of design. In addition, zirconia crown copings did not be fired for fully sintering after milling processing, these sample

zirconia crown copings may be less stronger than the fully sintered zirconia coping crown [18]. However, for the achievement of the result, the elimination of any effect factors was necessary.

Finally, there are some limitations of set up protocol in this study. From the result, wax showed the lowest gap production better than the zirconia did, while PMMA showed the extremely worst. The reasons may be because of its properties and dry milling of CAD-CAM processing. Therefore, wet milling would be preferred to mill resin material and should be continuously evaluated and measured in the future study.

Conclusion

Within the limitations of this study, it can be concluded that the crown copings that were fabricated from different materials by the same CAD-CAM system showed a statistical difference on the marginal gap of crown copings. PMMA showed the largest marginal gap.

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Conflict of interest: None
Ethics approval: Non-applicable

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