Precision of Fit of Two Margin Designs for Metal-Ceramic Crowns

Penwadee Limkangwalmongkol, DDS, MS;[1] Gerard J. Chiche, DDS;[2] and Markus B. Blatz, DMD, PhD[3]

Statement of Problem: **Although metal-ceramic restorations are widely used, there is a lack of information about how the fit is affected by margin designs.**

Purpose: **This study measured and compared the precision of fit of metal-ceramic crowns with two margin designs.**

Material and Methods: **Thirty-two extracted human premolar teeth were prepared for complete-coverage restorations with an internally rounded shoulder preparation. Impressions were made from all teeth, and master dies were poured with improved stone type V. MC crowns were fabricated with a porcelain-butt margin on the buccal aspect (n = 32) and a feather-edge metal margin on the lingual aspect (n = 32), which served as a control group. Precision of fit was measured three times at the mid-buccal and mid-lingual margins of each crown with a profilometer. The data were statistically analyzed with the paired *t*-test ($\alpha < .05$).**

Results: **Mean marginal gap size of porcelain-butt margins was 27.93 μm ($\pm$15.84) and of feather-edge metal margins 42.43 μm ($\pm$24.12). The marginal gap size of feather-edge metal margins was statistically significantly greater than that of porcelain-butt margins (p = 0.0045).**

Conclusion: **The marginal fit of porcelain-butt margins was significantly better than that of feather-edge metal margins.**

***Clinical Implications*:** **Porcelain-butt margins in this study had a better marginal fit than feather-edge metal margins, and thus have given clinicians evidence to prefer the use of porcelain-butt margins.**

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INDEX WORDS: fit, metal-ceramic, margins

OPTIMAL MARGINAL fit of dental restorations is essential for their long-term success in the oral cavity.[1-8] It has been suggested that a marginal gap of 120 microns represents the maximum clinically acceptable gap size.[9] Different marginal designs for metal-ceramic (MC) crowns have been proposed, including porcelain-butt margin, feather-edge metal margin, and metal collar. Traditionally, the facial margin of an MC crown was a narrow metal collar,[10] which had to be placed subgingivally to improve the esthetic appearance of the restoration; however, a main disadvantage of a metal-collar margin was that it was difficult to conceal in a shallow crevice or with a thin and translucent gingival margin.[4,11] The introduction of the all-porcelain facial margin, which eliminates any metal collar and can be placed at the gingival level or slightly supragingivally, addressed this problem.[10] The ideal method to fabricate an all-porcelain facial margin would be to perform the porcelain firing cycles directly on the master die,[4] but current die materials cannot withstand the porcelain-firing temperatures. A feather-edge metal margin, which veneering porcelain covers, may provide an alternative, since the metal collar is very thin. Porcelain-butt margin and feather-edge metal margin are the most

[1]*Assistant Professor, Department of Endodontics, Prosthodontics, and Operative Dentistry, University of Maryland, Baltimore College of Dental Surgery, Baltimore, MD.*

[2]*Professor and Department Head, Department of Prosthodontics, Louisiana State University Health Sciences Center, School of Dentistry, New Orleans, LA.*

[3]*Professor and Department Head, Department of Preventive and Restorative Sciences, University of Pennsylvania, School of Dental Medicine, Philadelphia, PA.*

Accepted January 17, 2006.

Correspondence to: Penwadee Limkangwalmongkol, DDS, MS, Department of Endodontics, Prosthodontics, and Operative Dentistry, Baltimore College of Dental Surgery, University of Maryland, 650 W. Baltimore Street, Baltimore, MD 21201. E-mail: Penwadee@umaryland.edu

1059-941X/07

doi: 10.1111/j.1532-849X.2007.00186.x

common MC designs for anterior and premolar regions.[11]

The marginal accuracy of all-porcelain versus feather-edge margin designs has been discussed, especially in light of possible material interactions when porcelain is added to the metal.[12] This phenomenon becomes apparent when metal copings that fit well upon try-in do not fit as well after the porcelain is added.[12] The shrinkage of the porcelain during firing may cause metal contraction that may change the adaptation of the restoration to the tooth.[12] Porcelain application was reported to affect the marginal fit of MC crowns.[13] The permanent deformation in porcelain-metal strips as a result of interfacial shear stress following firing was demonstrated by Shillingburg et al,[12] who stated that the labial margin seems to be most often subject to distortion, because the thickness of the metal is usually minimized for esthetic reasons. Many studies have likewise investigated marginal design, marginal distortion, and marginal discrepancy of MC restorations.[14–34]

Holmes et al[35] defined the measurements of the misfit of crowns at different locations as internal gap, marginal gap, vertical marginal discrepancy, horizontal marginal discrepancy, overextended margin, underextended margin, absolute marginal discrepancy, and seating discrepancy. They concluded that the best alternative measurement was absolute marginal discrepancy, since this distance would always be the largest measurement of error at the margin and reflect the total crown misfit at that point vertically and horizontally. Also, a profilometer was recommended as a nondestructive and highly accurate method to evaluate the absolute marginal fit of crowns.[3]

The purpose of this study was to investigate with profilometry the absolute marginal discrepancies of MC crowns with two marginal designs: porcelain-butt margin on the buccal aspect and feather-edge metal margin on the lingual aspect. The null hypothesis was tested: no difference exists between the marginal fit of porcelain-butt margins and feather-edge metal margins.

Materials and Methods

Thirty-two recently extracted human premolar teeth were included in this study. One experienced prosthodontist performed all tooth preparations for full-coverage crowns in a standardized manner with an occlusal reduction of 2.0 mm, axial reduction of 1.2–1.5 mm, a total convergence angle of 6°, and rounded line angles. The finish line was a 1.2 mm internally rounded circumferential shoulder. Each tooth received a full-coverage MC crown with a porcelain-butt margin on the buccal aspect and a feather-edge metal margin on the lingual aspect. Figure 1 illustrates the margin of the crown.

Figure 1. The margin of the crown; porcelain-butt margin on the buccal aspect and feather-edge metal margin on the lingual aspect.

Impressions were made of each tooth with a vinyl polysiloxane material (Affinis, Coltene/Whaledent Inc., Mahwah, NJ) after the preparations were finished. Light-body impression material was injected around the teeth and then inserted in custom-made trays of heavy-body material. The dies were fabricated in improved stone type V (Die Keen, Columbus Dental, St. Louis, MO) and trimmed under a ×10 power microscope. The dies were then painted with three coats of die spacer (Die Spacer, American Dental Supply, Inc., Easton, PA) to within 1 mm of the margins. The copings were formed with green inlay casting wax, hard-type I, class I (Kerr Corporation, Romulus, MI), and marginal adaptation was refined with a ×10 power microscope. The copings were then sprued and invested in a phosphated bonded investment (Cera Fina, Whip Mix Corp., Louisville, KY) and cast in a semiprecious alloy (Stability, Jensen, North Haven, CT) with an induction casting machine. The castings were assessed and adjusted to fit on the master die. The opaque porcelain (Vita VMK 95, Germany, distributed by Vident, Brea, CA) was then applied to the coping. The coping was dried and fired under vacuum to a specific

temperature. The second application of opaque porcelain was applied to mask the metal and was fired using the same firing cycle as the first application. Afterwards, the margin porcelain (Vintage margin porcelain, Shofu, Kyoto, Japan) was baked onto the buccal aspect to fabricate a porcelain-butt margin using the direct-lift technique. Then the veneering porcelain (Vita VMK 95) was baked onto the copings and fired following the manufacturer's recommendations. The crowns were finished and inspected with a ×10 power microscope. All crowns were fabricated by one dental laboratory technician. The fit of the crowns was assessed on the respective teeth visually and tactually with a dental explorer. The intaglio surface of the crowns was checked for fit with a silicone disclosing medium (Fit Checker, G.C. Dental Industrial Corp., Tokyo, Japan) and the "cookie-cutter" technique. Any discontinuity of silicone medium, which indicated fitting surface interferences, was eliminated with a small carbide bur. The fit of each crown was repeatedly assessed, and the intaglio surface of the crown was adjusted until the fit of the crown was judged to be satisfactory both visually and tactually.

The teeth were embedded in acrylic resin (Technovit, Heraeus Kulzer), and the fully seated crowns were sustained in place with a C-clamp. Marginal openings of each crown were investigated with a profilometer. (TalyScan 150, Sarl Digital Surf, Besancon, France). Two profiles of the mid-buccal and the mid-lingual surfaces of the teeth were digitized on a profiling system. Three measurements were recorded from the mid-buccal of the porcelain-butt margin and mid-lingual of the feather-edge metal margins of each crown. Discrepancy values were calculated as averages of the measurements obtained. The marginal discrepancy values of each marginal design of the 32 teeth in each group were averaged for a marginal discrepancy value of the entire group. The data were analyzed with a paired t-test ($\alpha = 0.05$).

Results

Tables 1 and 2 list results. The mean gap size of porcelain-butt margins was $27.93 \pm 15.84\ \mu$m, and the mean gap of the feather-edge metal margins was $42.43 \pm 24.12\ \mu$m. The marginal gap of the feather-edge metal margin was statistically significantly greater than that of the porcelain-butt margin ($p = 0.0045$).

Table 1. Mean Marginal Gap Values and Standard Deviation of Porcelain-butt Margins and Feather-edge Metal Margins

	n	*Mean Marginal Gap in μm*	*SD*
Porcelain-butt margin	32	27.93	15.84
Feather-edge metal margin	32	42.43	24.12

Discussion

The null hypothesis was rejected, since significant differences in marginal precision of fit were found between the two margin designs. Various techniques for fabricating MC restorations based on different metal coping designs have been advocated. These coping designs include metal collar, collarless, and porcelain-butt margin.[5] Some consider the labial metal collar the ideal design in terms of marginal seal, periodontal health, and rigidity during cementation;[28] however, metal collars are difficult to conceal in the shallow crevice or with a thin or translucent gingival margin.[11] Reduction of the labial metal collar, also known as "triangular formation,"[22] "hairline collar,"[5] or "feather-edge,"[11] permits metal, opaque layer, and porcelain to meet simultaneously on the cervical external edge of the tooth preparation. This design appears attractive, but is technique-sensitive and difficult to achieve without overcontouring the cervical aspect or exposing the opaque layer. Finishing and polishing are difficult,[34] and the surface remains microscopically rough.[11] Marginal adaptation after porcelain firing is subject to distortion, because as the metal collar thickness is decreased, the distortion caused by porcelain firing increases,[15] especially for high-gold alloys. This deformation may be caused by stress relaxation of the casting during its oxidation[16,19] or by the firing shrinkage of porcelain.[14] A wide facial metal collar (0.8 mm) for high-gold alloys offers sufficient rigidity against distortion caused by porcelain shrinkage compared with a feather-edge metal collar.[15] Shoulder preparations are recommended for the feather-edge metal design to provide minimal metal thickness and at least some rigidity in the cervical area.

Table 2. The Analysis Variable

n	*Mean*	*SD*	*t Value*	*Pr > /t/*
32	14.50	26.80	3.06	0.0045

Adding a separate thermal cycle of the metal at the oxidation temperature immediately after casting and either right before divestment or right after divestment was also recommended.[16] This added cycle may limit the potential for metal distortion before the porcelain is added. Firing shrinkage of the porcelain produces significantly less distortion of the metal margin when thermal cycling and stress relaxation of casting stresses precede grinding (cold working) of the castings.[16] It was recommended to avoid grinding and finishing the metal coping before porcelain application.[15] All-porcelain margins have significantly improved the esthetic appearance of MC restorations by increasing depth of translucency in the cervical area;[11] however, veneering porcelain cannot be fired directly on the master die. Therefore, investigators have examined techniques for firing all-porcelain margins with platinum matrices, refractory dies, separating varnish, as well as wax or resin binders.[20,23,25-27,29] Several studies[18,33] demonstrated with conventional porcelain-margin materials that rounded edges with rough and heterogenous surfaces were more likely to occur using direct lift-off techniques than with platinum matrix substrates. The direct lift-off technique requires shoulder-porcelain materials instead of conventional porcelain, because they fuse at a higher temperature (20°C–30°C higher than the regular body) and show greater resistance to pyroplastic flow.[11,15] The cervical margin may be completed separately in three firings prior to body porcelain build-up and yield clinically acceptable results in terms of surface texture, homogeneity, and translucency at the margin.[11,31]

The difference in marginal design for MC crowns may have influenced their precision of fit. Shillingburg et al[12] and Hobo and Shillingburg[21] showed that the high-noble metal coping requires a certain amount of bulk in the cervical area to resist distortion when subjected to repeated porcelain firing cycles. Other studies revealed that this cervical bulk may not be necessary for base-metal alloys.[24,32] A marginal discrepancy of 30–40 μm is clinically acceptable for visually accessible margins.[17] In this study, the mean marginal gap of all-porcelain margins was statistically significantly less than that of the feather-edge metal margin; however, the mean marginal gap values of both margin designs were less than 50 μm, which is well within the maximum clinically acceptable marginal gap of 120 μm.[9]

According to Wanserski et al[31] the metal coping underwent more marginal changes after crown fabrication than the all-porcelain facial margin. The most significant change in marginal adaptation of the metal coping occurred during coping degasification, opacification, and formation of the all-porcelain margin.

All crowns in this study were fabricated by the same dental technician, and tooth preparations and the measurements of marginal fit were performed by the same prosthodontist. Therefore, the data concerning the fit for each marginal design may have been subject to intra-examiner bias. The accuracy in measurements depends on (1) the angle of the surface of the crown margin and (2) the profile readings by the evaluator. Further research will be necessary and should include multiple evaluators to eliminate intra-examiner bias and to increase reliability. A profilometer accurately measures the marginal gap; however, investigators should examine other methods to evaluate marginal accuracy.

Conclusions

The marginal precision of fit of MC restorations is significantly better with a porcelain-butt margin than with a feather-edge metal margin with the alloy and porcelain materials that this study investigated.

Acknowledgement

The authors would like to thank Dr. Donald Mercante for his assistance in statistical analysis.

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