Marginal Adaptation and Microleakage of Procera AllCeram Crowns with Four Cements

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Purpose: This study investigated the effect of different cements on microleakage and marginal adaptation of porcelain crowns. ***Materials and Methods:*** Eighty extracted molars were divided into two groups. Teeth in one group were prepared to receive Procera AllCeram crowns, whereas the other group was prepared to receive metal-ceramic crowns. Copings were made following standard techniques, and groups were divided for cementation with zinc phosphate, glass-ionomer, resin-modified glass-ionomer, or resin cement. Specimens were subjected to thermocycling prior to microleakage testing, then sectioned. Microleakage was scored using a five-point scale; marginal adaptation was assessed with a traveling microscope. ***Results:*** A significant association was found between cement type and degree of microleakage. With zinc phosphate, 76% of Procera AllCeram and 90% of metal-ceramic copings exhibited extensive microleakage. With glass-ionomer, 49% of Procera AllCeram and 66% of metal-ceramic copings had 0 microleakage scores; with resin-modified glass-ionomer, 10% of Procera AllCeram and 84% of metal-ceramic copings had 0 microleakage scores. With resin cement, 34% of Procera AllCeram and 96% of metal-ceramic copings exhibited 0 microleakage. Procera AllCeram copings had a significantly larger mean marginal gap (54 μm) compared to metal ceramic (29 μm). ***Conclusion:*** In both types of crowns, the use of resin cement resulted in the highest percentage of 0 microleakage scores, whereas the zinc phosphate cement resulted in the highest percentage of extensive microleakage. *Int J Prosthodont 2004;17:529–535.*

Metal-ceramic (MC) crowns have been used in dentistry since the late 1950s.[1,2] They are generally indicated when esthetic demands are coupled with the need for maximum strength. While original MC crowns were made with metal margins, techniques have been developed to conceal metal display in esthetically demanding locations.[3,4] Over the last few years, increasing interest in more esthetically pleasing and metal-free restorations has prompted the demand for the development of all-ceramic restorations. A number of systems are currently available, including Procera AllCeram (PAC; Nobel Biocare), which employs sophisticated computer-aided design/manufacturing (CAD/CAM) technology to fabricate a coping of densely sintered high-purity aluminum oxide.[5] PAC has desirable characteristics such as biocompatibility, color stability, good esthetics, low thermal conductivity, and a radiographic contrast similar to that of dentin, making it possible to diagnose changes in the underlying tooth structure.[6] A 5-year clinical trial that involved 100 PAC crowns placed on anterior and posterior teeth reported an overall survival rate of more than 90%, with all failures caused by fractures occurring on posterior teeth.[6]

An in vitro study on extracted incisors showed the fracture strengths of different types of all-ceramic crowns to be similar to that of MC crowns when cemented with resin cement.[7] However, aging through chewing and thermocycling devices resulted in a significant decrease in fracture strength, suggesting that prolonged exposure of the cement to simulated oral

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conditions may lead to the deterioration of its integrity. Cement breakdown may lead to ingress of fluids and microorganisms along the tooth-restoration interface, causing marginal discoloration, pulpal irritation, and secondary caries. Causes of microleakage related to crowns may also include lack of adhesion of the luting cement to tooth structure,[8] shrinkage of the cement on setting, and mechanical failure of the cement.

Different types of luting agents vary considerably in solubility, strength, and ability to adhere to tooth structure. Previous studies have found significant differences among luting agents in their ability to prevent interfacial leakage between the luting agent and tooth structure.[8,9] A recent in vitro study that examined microleakage of IPS Empress-2 all-ceramic crowns (Ivoclar Vivadent) cemented with three different types of cement concluded that the use of adhesive resin composite cement minimizes microleakage.[9] Both Empress-2 crowns and MC crowns, used as a control, had extensive microleakage when zinc phosphate cement was used.[9]

The objective of this study was to investigate the in vitro microleakage and marginal adaptation of PAC copings, using the MC coping as a control, with four different cements: zinc phosphate, glass-ionomer, resin-modified glass-ionomer, or resin cement. The null hypothesis was that there would be no difference in microleakage scores among the four cements when either type of coping was used, and that there would be no difference in marginal adaptation between the two types of copings cemented with any of the four cements.

Materials and Methods

A pilot study was conducted to determine the sample size required to achieve 90% power and 5% significance. Based on these results, 80 recently extracted human molars were collected from the offices of local oral surgeons and subjected to gamma radiation for sterilization.[10] The teeth were then cleaned and divided into two equal groups—PAC and MC—and prepared in a standardized manner with a parallel preparation device (Parallel-a-prep, Dentatus). The PAC specimens were subjected to a moderate chamfer (1.5-mm circumferential) and 2.0-mm occlusal reduction, whereas the MC control group featured a shoulder preparation on the buccal aspect (1.5 mm), a chamfer preparation on the lingual aspect (0.5 mm), as well as a 2.0-mm occlusal reduction. Following impression making and die fabrication, the dies for the PAC group were scanned with a Procera Sandvik Scanner (MOD 40: 10866-1, Nobel Biocare), which has a sapphire ball tip that reads the die shape by circular scanning. The copings were ordered 0.6-mm thick to provide a substructure with optimal support for the veneering porcelain. The MC copings were manufactured following standard techniques using a gold alloy (Jelenko Microfine Olympia Alloy).

All specimens were subjected to simulated veneering porcelain application by cycling in a porcelain furnace (Jelenko Flagship VPF). Each group of prepared teeth was then divided into four subgroups ($n = 10$) and cemented with Fleck's zinc phosphate cement (Mizzy), Fuji I glass-ionomer cement (GC), Rely-X resin-modified glass-ionomer cement (3M/ESPE), or C & B Metabond resin cement (Parkell) according to each manufacturer's recommendations. A stylus with a 5-mm diameter was placed on the tip of a surveyor arm and used to apply a constant 5-kg load for the recommended initial setting time of each cement used. It has already been demonstrated that marginal adaptation is not improved with a seating force in excess of 5 kg.[11,12] Following 24 hours of water storage, specimens were subjected to thermocycling between 5 and 55°C for a total of 500 cycles. The teeth were sealed for microleakage testing and immersed in basic fuchsin dye solution for 24 hours. Specimens were then rinsed thoroughly in water, embedded in clear acrylic resin blocks, and sectioned buccolingually twice using an Accutom microsaw (Struers). Each side of the section was examined under 30× magnification (model TM-201, Toolmakers Microscope, Mitutoyo) to assign microleakage scores using a five-point scale at both buccal and lingual aspects of each section:

- 0 = no leakage
- 1 = leakage up to one third of axial wall
- 2 = leakage up to two thirds of axial wall
- 3 = leakage along entire length of axial wall
- 4 = leakage extending onto occlusal aspect

Using an intraoral video camera, images of the tooth sections were captured and printed in color. Microleakage scoring was then performed a second time from the printed images of the sections by the same observer.

Marginal adaptation was assessed with a traveling microscope at 30× magnification (Toolmakers Microscope). A straight line connecting the lowest point on the coping margin to a point just axial to the finish line on the tooth was used to represent the amount of marginal opening. This was done at eight different points along the coping margins (two per surface of each tooth section).

The SPSS software package (SPSS) was used to perform statistical analyses. The microleakage data were cross-tabulated and subjected to chi-square analysis. Logistic regression was used to predict the probability of microleakage occurring. Intraobserver variability

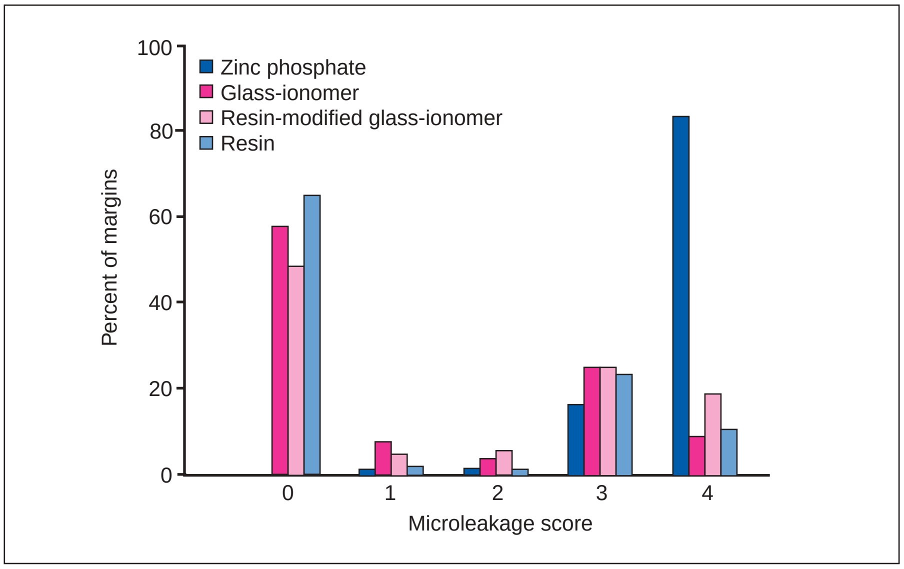


Fig 1 Percentage of Procera AllCeram and metal-ceramic coping margins showing various microleakage scores according to cement type.

(kappa) was also computed for microleakage scoring. The marginal adaptation data were analyzed using analysis of variance (ANOVA) and Scheffé tests. Pearson's correlation coefficient test was used to assess the relationship between microleakage and marginal adaptation.

Results

Figure 1 reports the percentage of microleakage scores for the two crown types with the four different cements. PAC copings exhibited significantly more microleakage than MC copings ($P < .001$). Moreover, logistic regression analysis revealed that the risk of marginal microleakage was 11 times higher for PAC copings than for MC copings when adjusted for cement type and margin location (odds ratio 11.0; 95% confidence interval 7.0 to 17.2).

There was a significant association between cement type and microleakage score ($P < .001$). Fleck's exhibited the highest percentage of 4 scores (microleakage extending to the occlusal surface) in both the PAC and MC groups, whereas C & B Metabond showed the highest percentage of 0 scores (no microleakage). Seventy-six percent of PAC specimens and 90% of MC specimens exhibited extensive microleakage; no specimens showed 0 microleakage when Fleck's was used. With Fuji I, 49% of PAC specimens and 66% of MC specimens demonstrated 0 microleakage scores; with Rely-X, 10% of PAC specimens and 84% of MC specimens displayed 0 microleakage scores. With C & B Metabond, 34% of PAC specimens and 96% of MC specimens exhibited 0 microleakage. Figures 2 to 9 show representative sections of teeth with the two types of crowns cemented with the four different cements. Figure 10 shows a section of a tooth that received a PAC coping cemented with C & B Metabond with evidence of leakage along the coping-cement interface but without leakage along the tooth-cement interface; this was observed in about one third of the PAC specimens. Microleakage scores were recorded twice by the same observer, once under microscopic magnification and a second time from printed color photographs of the sections. There was 86.7% agreement ($\kappa = 0.87$) between the two sets of data.

A statistically significant difference in marginal adaptation was found between the two types of copings ($P < .001$). PAC copings had a significantly greater mean marginal gap (54 µm) than did MC crowns (29 µm). Significant differences in gap size were found to be related to cement type ($P < .001$). For PAC copings, mean marginal gaps were 47 µm, 57 µm, 53 µm, and 58 µm for C & B Metabond, Rely-X, Fuji I, and Fleck's, respectively. For MC copings, mean marginal gaps were 25 µm, 16 µm, 27 µm, and 47 µm, respectively. A modest but statistically significant association of 26.3% was found between microleakage and marginal adaptation ($r = 0.26$; $P < .001$).

Discussion

Zinc phosphate cement does not bond to dentin, whereas glass-ionomer, resin-modified glass-ionomer, and resin cements are capable of bonding to dentin either chemically or micromechanically. The bond

Fig 2 Representative specimen of a tooth section that received MC coping cemented with zinc phosphate, after immersion in basic fuchsin solution; original magnification × 30.

Fig 3 Representative specimen of a tooth section that received PAC coping cemented with zinc phosphate, after immersion in basic fuchsin solution; original magnification × 30.

Fig 4 Representative specimen of a tooth section that received MC coping cemented with glass-ionomer, after immersion in basic fuchsin solution; original magnification × 30.

Fig 5 Representative specimen of a tooth section that received PAC coping cemented with glass-ionomer, after immersion in basic fuchsin solution; original magnification × 30.

strength between resin composite and dentin is the highest among all cements. The minimal microleakage displayed by the resin cement subgroups in the present study was due to superior attachment of the cement to the conditioned dentin surfaces through the primer/bonding agent.[13] The severe microleakage that took place with zinc phosphate cement was most likely due to lack of adhesion to dentin. This finding is in agreement with similar findings reported in other studies.[9,14–19]

The specimens in the present study were stored in water at body temperature for 24 hours before thermocycling. This is a brief period compared to the life expectancy of crown restorations; however, it was sufficient to reveal significant differences in microleakage scores among the four cements. Over the long term, the water-soluble cements (zinc phosphate, glass-ionomer, and resin-modified glass-ionomer) could further deteriorate, with subsequent deleterious effects; the insoluble resin cement would absorb water, which may help relaxation of internal stresses caused by polymerization shrinkage.[20,21] This may decrease the potential of interfacial failure of the resin cement during thermocycling.[15] Other studies have also shown resin cements to result in substantially less microleakage.[22,23] Minimal solubility, superior strength,

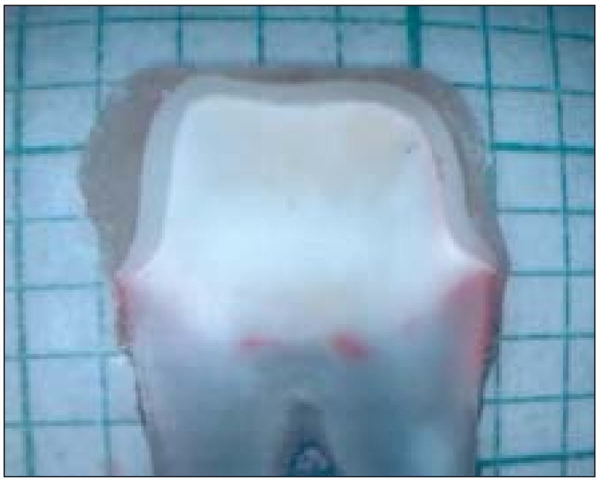
Fig 6 Representative specimen of a tooth section that received MC coping cemented with resin-modified glass-ionomer, after immersion in basic fuchsin solution; original magnification × 30.

Fig 7 Representative specimen of a tooth section that received PAC coping cemented with resin-modified glass-ionomer, after immersion in basic fuchsin solution; original magnification × 30.

Fig 8 *(right)* Representative specimen of a tooth section that received MC coping cemented with resin, after immersion in basic fuchsin solution; original magnification × 30.

Fig 9 *(below)* Representative specimen of a tooth section that received PAC coping cemented with resin, after immersion in basic fuchsin solution; original magnification × 30.

Fig 10 *(below right)* PAC coping specimen shows microleakage at cement-coping interface; original magnification × 30.



and improved retention are other advantages of bonded resin materials.[24–27]

Microleakage can also occur at the coping-cement interface, which may result in loosening of the restoration,[28] with potential for subsequent recurrent caries because of the infiltration of microorganisms along the cement space. This microleakage was observed in 32% of the PAC margins in the present study, whereas no microleakage occurred at the coping-cement interface in the MC group. The manufacturer of PAC does not specify the required preluting treatment of the fit surface of the crown. Results of the present study indicate that a surface treatment of the PAC coping might be beneficial to improve its bond to the cement. One recent study reports no change in the morphologic microstructure of fit surfaces of PAC specimens when treated with hydrofluoric acid etching and airborne-particle abrasion with 50-μm aluminum oxide.[29] However, in another recent study, a resin cement used in combination with a silane coupling agent resulted in significantly higher bond strength to PAC specimens; this bond strength was sustained over 6 months, with monthly thermocycling, when surfaces of the specimens were air abraded with 50-μm aluminum oxide.[30]

Thus far, there is no universally accepted technique used to determine the microleakage patterns of restorative materials. Some authors argue that microleakage tests conducted with dyes are not clinically relevant. They advocate the use of clinically relevant materials such as lipopolysaccharides or cell wall materials that have been shown to provoke inflammatory reactions in the pulp. Several studies suggest that various leakage detection methods do not yield equivalent results and therefore should not be compared.[31,32] Conversely, it was found that the use of either a dye or isotope is equally effective in demonstrating microleakage, and both penetrate the tooth-restoration interface to a similar degree.[33]

In vitro microleakage tests carried out with dyes are considered stricter than those carried out in the oral cavity[28] for a number of reasons, such as: *(1)* the dye is more easily diffused than bacteria and their byproducts; *(2)* the buildup of proteins in the marginal opening may improve the seal; and *(3)* the dentinal fluid in vital teeth may contrast molecular penetration.[34] On this basis, if a material responds positively to in vitro dye tests, it is likely to respond even better clinically.[34,35]

Marginal gap values reported in this study for PAC (47 to 58 μm) were in agreement with those reported in a previous study (56 to 63 μm).[36] However, they were smaller than values reported elsewhere for PAC (80 to 120 μm).[37,38] In addition, marginal adaptation results in the present study revealed significant differences between PAC and MC copings. For the same crown type, a difference in marginal gap size did not always correlate well with microleakage scores. For example, while MC copings cemented with resin had a mean marginal gap (25 μm) comparable to that obtained with MC copings cemented with glass-ionomer cement (27 μm), microleakage scores for this MC/resin group were superior to those of the MC/glass-ionomer group. This may be due to the difference in the nature of dentinal adhesion, one being chemical (glass-ionomer) and the other micromechanical (resin). However, when crown type is taken into consideration, more microleakage was associated with the PAC specimens than with the MC ones. This occurred in spite of the fact that while marginal gaps were greater in the PAC specimens, both MC and PAC specimens were all within clinically acceptable limits.[39]

In vitro assessment provides useful information to aid manufacturers and researchers in choosing materials for prosthetic restorations before their introduction to the clinical setting. In this work, attempts were made to simulate standard clinical procedures; however, this is not a substitute for the complex oral environment. While in vitro testing might be limited in its ability to predict clinical survival, the results of this study provide useful information to help clinicians choose cement materials best suited for their restorations. It seems that zinc phosphate cement should be avoided when cementing PAC crown and fixed partial denture work because of its great potential for microleakage, whereas resin cements should be considered first in such situations because of their great potential to reduce the risk of microleakage; however, clinicians must familiarize themselves with the specifics for mixing and handling these cements to avoid problems and ensure good results. Glass-ionomer and resin-modified glass-ionomer cements should be considered as alternatives to resin cement.

Conclusions

Under the conditions of testing of this study, the following conclusions may be drawn:

1. PAC copings exhibited significantly more microleakage than MC copings.
2. In both types of crowns, the use of resin cement resulted in the highest percentage of 0 microleakage scores, whereas the use of zinc phosphate cement yielded the highest percentage of microleakage.
3. Some PAC copings exhibited microleakage at the coping-cement interface.
4. PAC copings had a significantly larger mean marginal gap (54 μm) compared to MC copings (29 μm). However, both values were within clinically acceptable limits.

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