Marginal gap, cement thickness, and microleakage of 2 zirconia crown systems luted with glass ionomer and MDP-based cements

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This in vitro study evaluated the marginal gap, cement thickness, and microleakage of glass-ionomer cement (GIC) and phosphate monomer-containing resin cement (MDP-RC) under 2 zirconia crown systems (Cercon and DC-Zirkon). Forty human premolars were prepared for all-ceramic zirconia crowns with a 1 mm circumferential finish line and a 1.5 mm occlusal reduction. The crowns (n = 10 per group) from each zirconia system were randomly divided into 2 groups and cemented either with GIC (Vivaglass CEM) or MDP-RC (Panavia F 2.0) cement. The cemented crowns were thermocycled 5000 times (5°-55°C). The crowns were immersed in 0.5% basic fuchsine dye solution for 24 hours and sectioned buccolingually and mesiodistally. Specimens were examined under optical microscope (100X). Data were analyzed using Student t-test and chi-square tests ($\alpha = 0.05$). Mean marginal gap values for Cercon (85 ± 11.4 μm) were significantly higher than for DC-Zircon (75.3 ± 13.2 μm) ($P = 0.018$). The mean cement thickness values of GIC (81.7 ± 13.9 μm) and MDP-RC (78.5 ± 12.5 μm) were not significantly different ($P = 0.447$). Microleakage scores did not demonstrate significant difference between GIC ($P = 0.385$) and MDP-RC ($P = 0.631$) under Cercon or DC-Zircon. Considering the cement thickness values and microleakage scores obtained, both zirconia crown systems could be cemented in combination with either GIC or MDP-RC.

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Yttrium-oxide partially stabilized zirconia (hereafter known as *zirconia*) has favorable fracture-toughness and fracture strength when compared with other commercially available dental ceramics, making it suitable for durable reconstructions in dentistry.[1,2] The so-called *transformation toughening mechanism* credited to this ceramic prevents crack propagation. The tensile stress acting at the crack tip induces the phase transformation from the partially stabilized tetragonal phase of zirconia into the monoclinic phase.[1,2] This phase transformation is associated with a volume expansion of 3% to 4% and results in local compressive tension in the material that counteracts the progress of the crack.[1,2]

Cercon (DeguDent GmbH) a zirconia ceramic system that uses partially sintered ceramic, requires conventional waxing techniques to design the zirconia framework. The wax pattern is then scanned.[3] DC-Zirkon (DCS Dental AG) uses fully sintered ceramic containing 95% ZrO_2 partially stabilized with 5% Y_2O_3, and the frameworks are milled from partially sintered blocks.[2-4] Computer-aided design/computer-aided manufacturing (CAD/CAM) machining and grinding procedures tend to cause damage in the microstructure of densely sintered zirconia.[5] However, the significant advantage of using CAD/CAM technology lies in the fact that milling of ceramic blocks manufactured under high quality processes would yield homogeneous structures where voids, flaws, and cracks are reduced to a minimum.[3,6]

Milling a zirconia restoration from a block has a significant impact on the marginal fit of the restoration, which is vital for its long-term success since an inadequate fit is potentially detrimental to both the tooth and the supporting periodontal tissues.[7] The perpendicular measurement from the internal surface of the restoration to the axial wall of the preparation is called the *internal gap,* and the same measurement at the margin is called the *marginal gap*.[8] A clinically acceptable marginal gap limit is <120 μm.[9]

The presence of marginal discrepancies in the restoration exposes the luting cement to the aggressive oral environment. The larger the marginal gap, the more rapid is the rate of cement dissolution.[10,11] The possible microleakage permits the percolation of food, oral debris, and other substances that are potential irritants to the vital pulp.[11-13] The gap between the restoration and the prepared tooth is filled with the cement, decreasing the significance of the gap. Moreover, after full polymerization or setting of the cement, no microleakage should be expected. Luting cements should act as barriers against microbial leakage but different types of luting agents vary considerably in solubility, strength, and ability to adhere to tooth structure.[14,15] Several methods have been used to evaluate the microleakage between tooth structure and restorative materials. Radioactive isotopes, dyes, and bacterial tests are some of the methods that have been successfully used to reveal leakage.[12,16,17]

The purpose of this study was to evaluate the marginal gap, cement thickness, and microleakage of 2 zirconia crown systems, luted with glass ionomer cement (GIC) and phosphate monomer-containing resin cement (MDP-RC). The null hypotheses tested were that there would be no difference in marginal gap, cement thickness, and microleakage between the cements under zirconia frameworks milled from either partially sintered or fully sintered blanks.

Materials and methods

Specimen preparation

Forty freshly extracted human first maxillary premolars without restoration or caries were stored in 0.1% (w/v) thymol-distilled water solution at room temperature from 24 hours to 6 months.[13] Tissue remnants

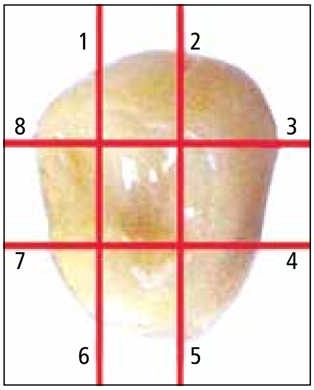

Fig. 1. Representative zirconia crown from occlusal view and 8 measurement points after sectioning.

Table 1. Mean marginal gap for the 2 zirconia systems.

	Marginal gap (μm) Mean (±SD)	P value
Cercon	85.0 (11.4)	0.018*
DC-Zirkon	75.3 (13.2)	0.018*

*$P < 0.05$.

Table 2. Mean cement thickness for the 2 zirconia systems cemented with either glass ionomer or phosphate monomer-containing resin cement.

		Cement thickness (μm) Mean (±SD)	P value
Cercon	Vivaglass CEM	82.9 (15.7)	0.428
	Panavia F 2.0	87.1 (4.3)	0.428
DC-Zirkon	Vivaglass CEM	80.6 (12.6)	0.069
	Panavia F 2.0	69.9 (12.1)	0.069

and debris were removed from the selected teeth with a scaler, polished with pumice, and stored in distilled water at 4°C. Then the roots of each tooth were embedded in autopolymerizing acrylic resin (Meliodent, Heraeus Kulzer) with the acrylic resin extending 2 mm below the cemento-enamel junction. The teeth were prepared in a standardized manner underwater with a surveyor (KaVo EWL, KaVo Dental). Circumferential chamfer finish lines (1 mm) and 1.5 mm occlusal reductions with a total occlusal convergence of 6 degrees were achieved. Then, impressions were made by the putty-wash method using an additional silicone impression material (Affinis, Coltene/Whaledent, Inc.). Type IV gypsum (GC Fuji Rock, GC America, Inc.) was poured into the impressions with the use of a vibrator (Smartmix, Amann Girrbach America, Inc.). When the material set, the dies were removed from the impressions.

Twenty frameworks were fabricated with the Cercon system using a Cercon Brain unit (DeguDent GmbH). The wax copings were prepared and scanned. The copings were grinded, and then sintered in a CERCON Heat sintering furnace (DeguDent GmbH) for 6 hours at 1350°C.

Twenty DC-Zirkon (DCS Dental AG) frameworks were produced with the Precident DCS System (DCS Dental AG) using the corresponding scanner (PRECISCAN), computer station, and milling machine (PRECIMILL). The dies were scanned, the data was transferred to the software, and the copings were milled.

Experimental procedures

Each group of zirconia frameworks was divided randomly into 2 groups (n = 10 per group). Marginal gap was measured using a replica technique.[18] Each crown was filled with light body silicone (Elite H-D Light Body, Zhermack, Inc.), inserted on the respective tooth using a modified parallelometer. After the light body silicone was set, the crown was removed. Since it was not possible to remove the light body silicone from the interior parts of the crown without distortion, a heavy body silicone was used to stabilize the light body silicone. Using a razor blade, the replicas were carefully cut into 8 equal segments. The light body silicone thickness was measured for all replicas, at the marginal area of the crowns, and external surface of the preparations using an optical microscope at (100X) (Leica Optical Microscope, Leica Microsystems).[17]

While 10 crowns were luted with MDP-RC (Panavia F 2.0; Kuraray America, Inc.), the other 10 were luted with GCI (Vivaglass, Ivoclar Vivadent, Inc.) according to each manufacturer's instructions. One blinded operator cemented the crowns in a custom-made alignment apparatus under a weight of 50 N for 10 minutes.[19,20]

After the setting or polymerization of the luting cements following manufacturers' instructions, all specimens were thermocycled 5000 times in distilled water between 5°C and 55°C; dwelling time was 30 seconds and the transfer time from one bath to the other was 15 seconds.

Microleakage analysis

After thermocycling, all specimens were immersed in a bath of 0.5% basic fuchsine solution for 24 hours. Then, the specimens were removed from the solution, dried, embedded in clear self-curing epoxy resin and sectioned in the mesiodistal and buccolingual directions with a 1 mm thick diamond impregnated blade (Buehler). The sections were divided equally in thickness and 8 separate measurements were made: 2 buccal, 2 palatal, 2 mesial, and 2 distal aspects per specimen (Fig. 1). Measurements of cement thickness values and microleakage evaluation were made under the optical microscope (100X). Microleakage values were recorded by 1 operator according to the following scores: Score 0, no leakage; Score 1, leakage toward one-third of axial wall; Score 2, leakage toward two-thirds of axial wall; Score 3, leakage along the full length of axial wall; Score 4, leakage over the occlusal surface.[21,22]

Statistical analysis

Statistical analysis was performed using SPSS 13.0 for Windows (IBM Corporation). Marginal gap and cement thickness data were analyzed using Student t-test and microleakage results were evaluated by using the chi-square test ($\alpha = 0.05$).

Results

Overall, mean marginal gap values for Cercon (85 ± 11.4 μm) were significantly higher than for DC-Zircon (75.3 ± 13.2 μm) ($P = 0.018$) (Table 1). The mean cement thicknesses of GIC (81.7 ± 13.9 μm) and MDP-RC (78.5 ± 12.5 μm) were not significant ($P = 0.447$) (Table 2). Microleakage scores did not demonstrate significant difference between GIC and MDP-RC cements both under Cercon ($P = 0.385$) or DC-Zircon ($P = 0.631$) (Fig. 2, Table 3).

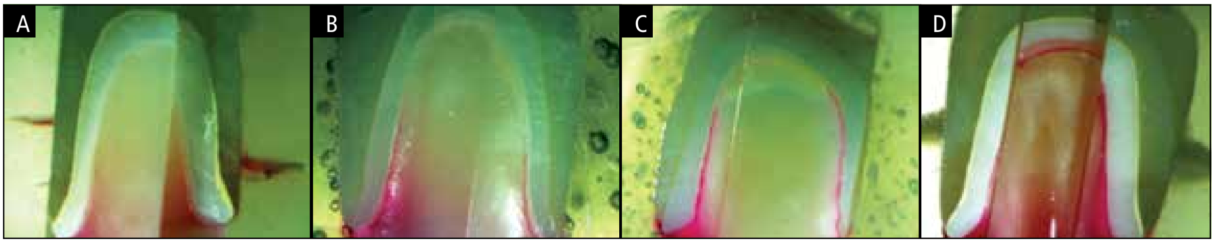

Fig. 2. Representative photographs of Cercon zirconia crowns cemented with Panavia F 2.0 and their respective scores. A. Score 1, leakage toward one-third of axial wall. B. Score 2, leakage toward two-thirds of axial wall. C. Score 3, leakage along the full length of axial wall. D. Score 4, leakage over the occlusal surface.

Table 3. Frequency of microleakage scores for the cements under 2 zirconia systems.

	Micro-leakage score	Vivaglass CEM n (%)	Panavia F 2.0 n (%)	*P* value
Cercon	1	2(5)	5(12.5)	0.385
	2	10(25)	8(20)	0.385
	3	15(37.5)	10(25)	0.385
	4	13(32.5)	17(42.5)	0.385
DC-Zirkon	1	5(12.5)	2(5)	0.631
	2	7(17.5)	6(15)	0.631
	3	16(40)	17(42.5)	0.631
	4	12(30)	15(37.5)	0.631

Discussion

Cementation of zirconia restorations is still an issue of discussion in the dental community. This study evaluated the marginal gap, cement thickness, and microleakage of 2 different zirconia crown systems, luted with GIC and MDP-RC. Among the tested parameters, only the marginal gap values showed significant difference between the zirconia systems. Thus, the null hypotheses that there would be no difference in marginal gap, cement thickness, and microleakage of both cements under zirconia frameworks milled from partially sintered or fully sintered blanks could be partially accepted.

Bonding is essential for the stability of minimally invasive restorative materials. The type of cement used may be less important for mechanically retentive restorations, yet the marginal gap, cement thickness, and microleakage behavior of the cement may still have clinical significance.[23] GICs are thought to adhere to tooth structure by the formation of ionic bonds as a result of ion-exchange between the cement and the enamel and/or dentin.[16] Although it is not a polymerizable cement, Uo et al found that a GIC produced a more superior bond to zirconia ceramic than a phosphate MDP-RC (Panavia 21).[24] On the other hand, the phosphate-ester group of the MDP-RC is reported to directly bond to metal oxides and has been accepted as the gold standard for cementation of zirconia.[25]

In the present study, the mean marginal gap values showed significant differences between partially sintered (Cercon) and fully sintered (DC-Zirkon) zirconia systems, the former exhibiting a higher mean marginal gap value. Bessimo et al also reported that partially sintered frameworks show higher mean marginal gaps due to the shrinkage that occurs during final sintering.[26] The milling process is faster and the wear and tear of hardware is less than the milling from a fully sintered blank.[4] The manufacturers of partially sintered frameworks claim that microcracks may be introduced to the framework during the milling procedure of a fully sintered blank, whereas the manufacturers of fully sintered blanks claim that because no shrinkage is involved in the process, the marginal fit is superior with the latter.[3,4] Not only the sintering shrinkage, but the difference between the milling burs could also be responsible for the variations between the 2 systems. Nevertheless, the importance of the size of marginal gap is a subject of controversy in the dental literature.[27] It is important as it dictates the thickness of the cement and thus the solubility and microleakage. Jacobs & Windeler found no significant difference in the rate of cement dissolution for marginal gaps in a range between 25-75 μm, whereas a gap size of 150 μm demonstrated a significantly increased rate of solubility.[10] The marginal gap values reported in the present study for both Cercon (85 μm) and DC-Zirkon (75.3 μm) crowns were in the clinically acceptable range (<120 μm) according to McLean & von Fraunhofer.[9]

Marginal gap values reported in the present study for DC-Zirkon crowns (75.3 μm) are higher than a previous study (42.9-46.3 μm).[3] Since the cement is not available during gap measurements, slight deteriorations may occur due to the fact that the crown is not secured on the prepared tooth. However, after cementation, no significant difference was found between the cement thickness values of GIC and MDP-RC. It is likely that the irregularities on the inner surface of the crown after milling were filled with the cement. In addition, the aging process during thermocycling might have also contributed to possible expansion of the cements tested.

Microleakage has been associated with postoperative sensitivity after insertion of restorations, and with recurrent caries.[22] If the leakage is severe, bacterial growth occurs along the interface between the restoration and the tooth and even into the dentinal tubules. The toxic products released by such microorganisms may irritate the pulp and cause inflammatory pulpal lesions.[22] There is no universally accepted technique to determine the microleakage behavior of restorative materials.[28] Jacobs & Windeler emphasized that the selection of dyes for in vitro microleakage tests should be stricter than the selection of dyes for in vivo situations.[10] Thus, individual studies looking at microleakage should be considered for ranking materials within 1 study.[28]

In this study, although thermal cycling was performed, no significant difference was determined in microleakage scores between the Cercon and DC-Zirkon crowns cemented with either GIC or MDP-RC. Approximately 31%-38% and 27%-32% of the microleakage in both groups received scores of 3 or 4, indicating that leakage moved along the full length of the axial wall, or reached the occlusal surface, respectively. This result can be explained on the grounds that basic fuchsine dye diffuses more easily than bacteria and their byproducts.[12,21,29] Clinical correlations from retrieved zirconia crowns are needed to verify the validity of in vitro microleakage studies. It should be noted that if a material presents microleakage via dye tests in vitro, it may still perform well clinically.[12,21]

Conclusion

Based on the cement thickness values and microleakage scores obtained in this study, both zirconia crown systems could be cemented in combination with either GIC or MDP-RC.

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