Retentive Strength of Two-Piece CAD/CAM Zirconia Implant Abutments

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ABSTRACT

Purpose: The purpose of this study is to evaluate the retention of two-piece computer-aided design (CAD)/computer aided manufacturing (CAM) zirconia abutments after artificial aging under simulated oral conditions using three different types of resin-based luting agents.

Material and Methods: Twenty-one CAD/CAM-generated zirconia copings (CERCON Compartis, Degudent, Hanau, Germany) were bonded to a prefabricated secondary titanium implant insert (XiVE Ti-Base, Dentsply Friadent, Mannheim, Germany), using three different types of resin-based luting agents: group A: Panavia 21 (Kuraray Co, Kurashiki, Japan); group B: Multilink Implant (Ivoclar Vivadent, Schaan, Liechtenstein); and group C: SmartCem2 (Dentsply DeTrey, Konstanz, Germany). The bonding surfaces of the titanium inserts and the zirconia ceramic copings were air-abraded and cleaned in alcohol. All specimens were stored in distilled water for 60 days and subsequently thermal-cycled 15,000 times (5–55°C). The dislodging force of the copings along the long axis of the implant/abutment complex was recorded using a universal testing machine with 2 mm/min crosshead speed. Data were analyzed descriptively and by performing the Kruskal–Wallis test.

Results: The mean retention values were 924.93 ± 363.31 N for Panavia 21, 878.05 ± 208.33 N for Multilink Implant, and 650.77 ± 174.92 N for SmartCem2. The Kruskal–Wallis test indicated no significant difference between the retention values of the tested luting agents ($p = 0.1314$). The failure modes of all tested two-piece abutments were completely adhesive, leaving the detached zirconia coping and titanium insert undamaged.

Conclusion: The use of resin-based luting agents in combination with air abrasion of titanium inserts and zirconia copings led to a stable retention of two-piece CAD/CAM abutments. The bonding stability of the investigated luting agents exceeded the general limits of fracture resistance of two-piece zirconia abutments. A notable difference between the mean retention values of the tested bond materials was shown. However, the statistical analysis revealed that this difference was not significant.

KEY WORDS: bonding, computer assisted, titanium, two-piece CAD/CAM abutments, zirconia

INTRODUCTION

Crestal bone stability and a healthy mucosa are considered essential to the long-term success of implant-supported restorations. The soft tissue around dental implants serves as a protective barrier between the oral cavity and the underlying bone.[1] The peri-implant tissues are recurrently challenged by numerous hazards that can have adverse effects on implant longevity, such as plaque, mechanical loading, and prosthetic interference. The implant abutment material seems to be of decisive importance for ensuring a high-quality attachment between the mucosa and the abutment surface.[2] Different materials are available for the fabrication of implant abutments. Due to their dark color, metal abutments have been reported to cause a grayish discoloration of the surrounding soft tissues, compromising the esthetic outcome in the anterior region.[3] Ceramic abutments are of increasing interest, due to their tooth-like color and their possible biologic advantages. Although there is currently no consensus that the performance of

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ceramic abutments is superior to that of titanium alloy abutments, the results of human histologic studies indicate that zirconium-dioxide may have a more favorable effect on the health of the peri-implant tissues.[4] Today, zirconia abutments with various implant–abutment connection geometries exist for different implant types. Recent in vitro studies have demonstrated that the type of implant–abutment connection has a critical influence on the technical outcome of zirconia abutments.[5] An internal connection of zirconia abutments can be obtained by means of a secondary metallic component (two-piece) or by the abutment itself (one-piece). Significantly higher bending moments were achieved for computer-aided design (CAD)/computer aided manufacturing (CAM) zirconia abutments with internal connections via a secondary titanium insert (two-piece) than for the ones with external connections.[6] Therefore, the use of a secondary titanium insert might have a beneficial influence on the stability of zirconia abutments and appears to be clinically useful for premolar and molar single-tooth replacement.

Various bonding methods to zirconia ceramic and titanium have been reported.[7] However, limited data are available on the retention of CAD/CAM zirconia copings on secondary titanium inserts. Surface conditioning methods and the size of the luting gap may have a significant influence on the retention of zirconia ceramic abutments bonded to a secondary titanium insert.[8] The retention strength may be influenced by the type of luting material. The application of methacryloyloxydecyl-dihydrogen-phosphate (MDP)-containing resins and resin-modified glass-ionomer luting agents increase the retentive value of implant-supported zirconium dioxide restorations.[9] The aim of the present study was to evaluate the retention of two-piece CAD/CAM zirconia abutments after artificial aging under simulated oral conditions using three different types of resin-based luting agents. The working hypothesis is that the selection of resin-based luting agents has an impact on the retention strength of two-piece zirconia abutments.

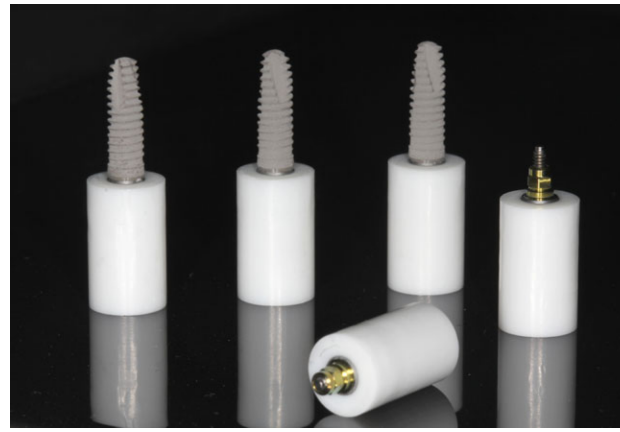

Figure 1 Test specimens: two-piece zirconia abutments connected to internally hexed implants. Zirconia copings were modified for the test setup.

MATERIAL AND METHODS

Twenty-one identical two-piece CAD/CAM customized zirconia abutments with an internal implant abutment connection (XiVE TitaniumBase, Dentsply Friadent, Mannheim/CERCON, Degudent, Hanau, Germany) were fabricated. In that process, CAD/CAM-generated zirconia copings, seven in each group, were bonded to a prefabricated secondary titanium implant insert (Figure 1), using three different types of resin-based luting agents: group A: Panavia 21 (Kuraray Co, Kurashiki, Japan); group B: Multilink Implant (Ivoclar Vivadent, Schaan, Liechtenstein); and group C: SmartCem2 (Dentsply DeTrey, Konstanz, Germany). The zirconia copings were modified for the test setup. For all groups, the bonding surfaces of the titanium inserts and the zirconia ceramic copings were air-abraded with 50 μm aluminum-oxide particles at 2.0 bars pressure (0.25 MPa) for 20 seconds at a distance of 10 mm, after which they were cleaned in alcohol. All specimens were cemented by the same operator, following the manufacturers' instructions. Copings were seated with a device that allowed a known load of 5 kg to be applied along the long axis of the abutment for a 10-minute period. Excess resin was removed from the bonding margins before it became fully set and was light-cured per manufacturer recommendations. All specimens were then stored in distilled water (37°C) for 60 days and subsequently thermal-cycled 15,000 times between 5°C and 55°C with a dwell time of 30 seconds to artificially age the bond interface (Figure 2). Following thermo cycling, a bond strength test was conducted. All samples were subjected to a pullout test using a universal testing machine (Zwick, Ulm, Germany) at a crosshead speed of 2 mm/min. The type of failure mode was recorded. The failure modes were as follows: (i) cement remained on the surface of the zirconia coping and (ii) cement remained on the titanium insert. The load required to de-cement each two-piece zirconia abutment was

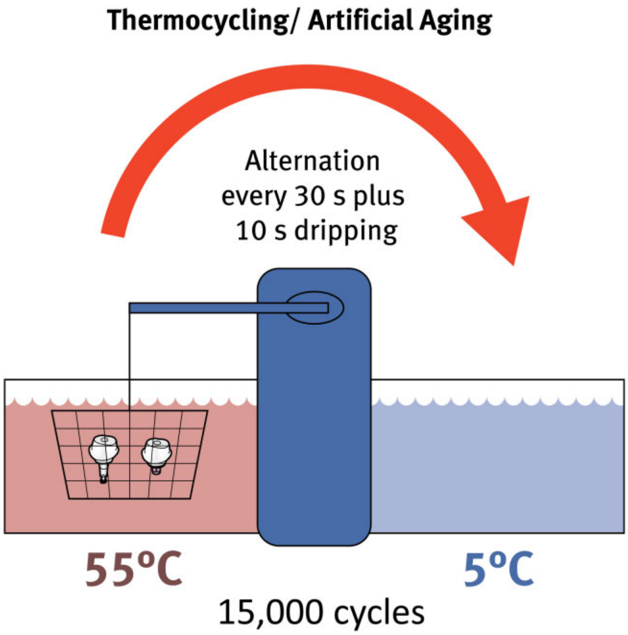

Figure 2 Test setup for thermo-cycling 15,000 times between 5°C and 55°C for artificial aging of bond interface.

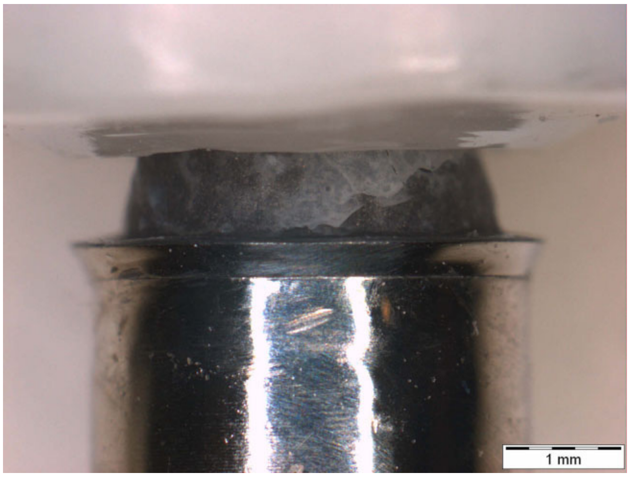

Figure 3 Failure mode of all tested specimens were completely adhesive, leaving the detached zirconia coping and titanium insert undamaged.

recorded, and mean values for each group were calculated. Means and standard deviations of retention at failure were analyzed. Kruskal–Wallis and Mann–Whitney *U*-tests were used for data analysis.

RESULTS

The individual retention values, means, and standard deviations are summarized in Table 1. The mean retention values were 924.93 ± 363.31 N for Panavia 21, 878.05 ± 208.33 N for Multilink Implant, and 650.77 ± 174.92 N for SmartCem2. The Kruskal–Wallis test indicated no significant difference between the retention values of the tested luting agents ($p = 0.1314$) (Table 1). The failure modes of all tested two-piece abutments were completely adhesive, leaving the detached zirconia coping and titanium insert undamaged. The failure mode analysis revealed a complete contact of all cements on the titanium inserts in all specimens (mode 2) (Figure 3). Although the current study demonstrated the highest retention forces for individual measurements of Panavia 21 and Multilink Implant, a high variability within the test series of both cements was found (Figure 4).

DISCUSSION

Zirconium dioxide is commonly used for ceramic implant abutments because of its esthetic advantages in patients with a thin mucosal biotype and its high

TABLE 1 Individual Retention Values, Mean, and Standard Deviations of Two-Piece CAD/CAM Zirconia Copings to Titanium Inserts Utilizing Different Resin-Based Luting Agents

Panavia 21		Multilink Implant		SmartCem2	
Sample No.	Retention (N)	Sample No.	Retention (N)	Sample No.	Retention (N)
1.1	898.48	1.1	545.02	1.1	403.42
1.2	1,261.08	1.2	1,059.14	1.2	522.60
1.3	1,312.92	1.3	831.49	1.3	777.30
1.4	474.76	1.4	1,176.82	1.4	481.30
1.5	1,290.69	1.5	965.14	1.5	833.93
1.6	658.75	1.6	792.85	1.6	771.06
1.7	577.86	1.7	775.89	1.7	765.77
Mean 924,93 ± 363,31 N		Mean 878.05 ± 208.33 N		Mean 650.77 ± 174.92 N	

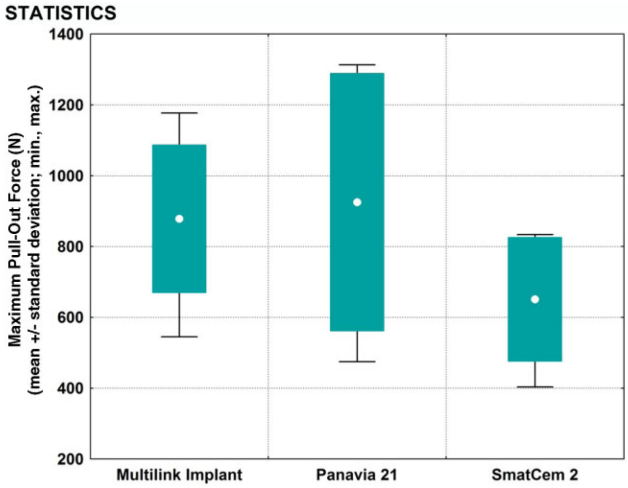

Figure 4 Box-plot diagram and values of maximum pull-out force in N.

fracture resistance. Recent studies have shown that one-piece zirconia abutments have a marginal misfit to the implant that might cause screw loosening, wear of the implant-abutment interface and increased size of the marginal gap subject to bacterial colonization.[10–13] Therefore, the use of a secondary titanium component, bonded to a zirconia coping, has been recommended.[5,6] For these two-piece implant abutments, resin-based luting agents are considered suitable for attaching the ceramic coping to the titanium insert.[9] However, limited data are available on the retention of CAD/CAM zirconia copings on secondary titanium inserts. In the current study, the tested resin-based luting agents showed no statistically significant influence on the bond strength between zirconia abutments and titanium inserts rejecting the working hypothesis (Table 1). Resin-based cements contain an adhesive phosphate monomer (MDP, 10-methacryloyloxydecyl dihydrogen phosphate), which has been shown to have a long-term stable bond to sandblasted zirconium oxide ceramic.[14–17] Setting occurs because of a cross-linking of the polymer chains, which is initiated chemically or by light. In laboratory studies, water storage at a constant temperature and thermal cycling are commonly utilized to simulate aging of resin bonds. As both are considered clinically relevant, water storage was combined with thermal cycling to test the durability of the retention of zirconia copings manufactured with CAD/CAM technology and bonded to titanium inserts using three different resin-based luting agents. The present findings indicate that the tested composite cements were influenced differently by these two parameters. Water storage of the specimens might have led to an absorption of water and an increase in volume (expansion) and, as a consequence, damage to the bonding interface. The higher the hydrophilicity of a composite, the higher its tendency to absorb water and swell.[18] Nevertheless, the study results demonstrate that it is generally possible to achieve sufficient, stable retention between zirconia copings and titanium inserts when airborne particle abrasion is used as a pretreatment. These retention values are different to those obtained when the same cements are used on natural teeth. The material and surface characteristics of the implant abutment are likely responsible for this difference. To estimate the clinical failure risk of two-piece zirconia abutments, their actual bending strength in various restorative concepts must be taken into account. The results of a recent in vitro study demonstrate all over bending moments between 380 and 430 N for zirconia abutments with an internal connection accomplished by a secondary metallic component.[6] In the present study, the mean retentive strength of all investigated resin cements exceeded this limit of fracture resistance. However, a notable but statistically nonsignificant difference between the mean retention values of the tested bond materials was shown ($p = 0.1314$) (Table 1). Although constant in vitro test conditions were utilized, the results demonstrated a high variability of bond strength within the tested cement groups. This might be caused by minimal unnoticeable processing alterations, since one-step (dispensed from an automix syringe) and two-step luting composites (paste-to-paste) were applied in the present study. Air bubbles and voids in the luting agent after manual mixing may have affected its retentive strength. Other causes of bond strength variation, such as operator technique, manual dexterity, and nonuniform air abrasion, come into consideration.

Limited data are available on the long-term clinical behavior of air-abraded zirconia copings. The roughening of the bonding surface of the zirconia coping by airborne particle abrasion, leading to an increase of retention, may also influence the integrity of the material itself.[19] Hence, it can only be assumed that resin luting material has the ability to seal the roughened surface and prevent adverse effects of surface alteration. One of the limitations of this study was using a constant removing force for a long duration. It has been recommended that the retrievability of implant-supported restorations be tested by a high impact and a short duration of force.[20] On the other hand, intraoral occlusal forces have a dynamic nature rather than being monostatic loads. In vitro studies such as this study cannot replace clinical studies, and their outcomes should be interpreted with caution. In addition to the functional aspects of implant abutments, the assessment of dental material biocompatibility is gaining increasing importance for both patients and dentists. The luting gap of two-piece zirconia abutments are in direct contact with the peri-implant mucosa for prolonged periods of time and might influence soft-tissue health. Results from in vitro studies indicate that different types of resin cements differ extensively in their genotoxic and cytotoxic potential and their ability to affect chromosomal integrity, cell cycle progression, and DNA replication and repair.[21,22] Although these results cannot be directly extrapolated to the clinical situation, the potential occurrence of adverse effects caused by the luting agent should be considered when making clinical decisions. Further research evaluating the potential cytotoxic, genotoxic, or carcinogenic risks of resin-based cements for two-piece implant abutments are necessary.

CONCLUSION

Based on the results of this study, the use of resin-based luting agents in combination with air abrasion of the bonding surfaces of titanium inserts and zirconia copings led to a sufficient and stable retention of two-piece CAD/CAM abutments. The failure modes of all tested two-piece abutments were completely adhesive, leaving the detached zirconia chimney and titanium insert undamaged. The bonding stability of the investigated luting agents exceeded the general limits of fracture resistance of two-piece zirconia abutments. A notable difference between the mean retention values of the tested bond materials was shown. However, the statistical analysis revealed that this difference was not significant.

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