

Retentiveness of Dental Cements Used with Metallic Implant Components

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There is limited dental literature evaluating the retentive capabilities of luting agents when used between metal components, such as cast metal restorations cemented onto machined metal implant abutments. This study compared the retentive strengths of 5 different classes of luting agents used to cement cast noble metal alloy crowns to 8-degree machined titanium cementable implant abutments from the Straumann ITI Implant System. Sixty prefabricated 5.5-mm solid titanium implant abutments and implants were used; 30 received the standard surface preparation and the other 30 received an anodized surface preparation. Anodized implant components were used to reflect current implant marketing. Sixty castings were fabricated and randomly paired with an abutment and implant. A total of 12 castings were cemented onto the implant-abutment assemblies for each of the 5 different luting agents (zinc phosphate, resin composite, glass ionomer, resin-reinforced glass ionomer, and zinc oxide-non-eugenol). After cementation, the assemblies were stored in a humidior at room temperature prior to thermocycling for 24 hours. Each casting was pulled from its respective abutment, and the force at which bond failure occurred was recorded as retentive strength. A statistically significant difference was found between the 5 cements at $P \leq .001$. Of the cements used, resin composite demonstrated the highest mean retentive strength. Zinc phosphate and resin-reinforced glass-ionomer cements were the next most retentive, while glass ionomer and zinc oxide-non-eugenol cements demonstrated minimal retention. In addition, retention was not altered by the use of an anodized abutment surface. (INT J ORAL MAXILLOFAC IMPLANTS 2001;16:793-798)

Key words: cemented implant restorations, dental cements, dental implants

The use of screw-retained versus cement-retained implant restorations has been the subject of controversy in the literature.¹ The main advantage of a screw-retained restoration is retrievability. However, loosening and/or fracture of occlusal or abutment screws remains a complication and concern.²⁻⁸

Cemented restorations have become a popular alternative and exhibit potential advantages over screw-retained restorations. These advantages include elimination of prosthesis screw loosening, better esthetics, easier control of occlusion, simplicity, lower cost, and passivity of fit. Because of the desire to reduce the cost and maintenance associated with screw-retained restorations, cement-retained restorations have gained favor among many practitioners.⁹⁻¹²

While cementation may have advantages over screw retention, non-retrievability remains problematic for some practitioners. Controversy exists as to whether a provisional or permanent luting agent should be used. There is very little evidence to support the selection of one luting agent over another when retrievability versus "permanent cementation" is the goal in a metal-to-metal situation. Some authors advocate the use of a provisional cement to maintain retrievability,^{13,14} based on the assumption that provisional cements are less retentive than permanent ones and will thus ensure retrievability of the restorations. Data on the retentive strengths of cements used between metal components are sparse, however, and the cementation of metal castings to

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Fig 1 ITI implants with anodized abutment (A) and non-anodized abutment (B).

titanium abutments of varying tapers may not correlate with established data on the retentive strengths of luting agents to natural teeth or to a metal core in an endodontically treated tooth.

The choice of cement for an implant-supported restoration should be based on the need or desire for retrievability, the anticipated amount of retention needed, the ease of cement removal,^{15,16} and cost. Several authors have provided what little information exists on luting agents as they relate either to cementing implant abutments to implants or cementing cast restorations to implant abutments. The studies examining luting agents used to cement implant abutments onto implants have been inconclusive as to which cement to use, because the protocols vary and the implant systems used have not been the same.^{13,14,17-19} In addition, the majority of the implant systems used today utilize either a screw to attach an abutment externally to an implant or an abutment that is screwed internally into the implant. Other authors have examined the issue of retentive strengths of luting agents used between metal castings and machined titanium abutments.^{9,13,20-24} Again, the results of these studies revealed no standardized rules for cementation, because each author used different cements, different protocols, and different implant systems.

While these studies have provided some relevant information, most were conducted with an external implant-abutment connection using parallel-sided abutments. The applicability of these studies to implant systems that use an internal connection and/or tapered abutments may not be valid. In addition, anodized or coated titanium components have become increasingly commonplace with several

implant manufacturers. The effect of anodization or coating on cement retentive strengths has not been described in the literature.

The aim of this study was to provide data on the relative retentive characteristics of five commonly used dental cements when cementing cast noble metal alloy crowns to 8-degree tapered machined titanium abutments with anodized and non-anodized surfaces.

MATERIALS AND METHODS

Sixty implant/abutment assemblies were used for this study. Standard 5.5-mm-long, 8-degree tapered, machined abutments were torque-tightened to 35 Ncm into standard 4.1-mm solid-screw ITI implants (Straumann USA, Waltham, MA). Half of the abutments ($n = 30$) retained the "as-machined" surface, while the other half were anodized to simulate current product variations (Fig 1). Using prefabricated plastic burnout copings and analogs for the solid abutments, 60 wax copings with occlusal wax rings were formed. The wax rings were added to the occlusal portion of the waxed coping for retentive testing (Fig 2a).

The wax patterns were sprued, invested in a phosphate-bound investment (GC VEST-G; GC Corporation, Tokyo, Japan; batch no. L072996), and cast in a metal-ceramic alloy (JP-I; Jensen Industries, North Haven, CT). After divestment and ultrasonic cleaning, the internal aspect of the castings was inspected under a microscope, and surface irregularities were removed with a small round bur. The shoulders of the castings were milled with a beveled internal reamer according to the manufacturers' recommendations (Fig 2b). Castings were numbered and arbitrarily paired to one of the 60 implant/abutment assemblies. All castings were ultrasonically cleaned in mild detergent for 30 minutes, air abraded with aluminum oxide (50- μ m particle size; Ivoclar North America, Amherst, NY) to remove investment, and steam-cleaned prior to the cementation procedure.

Five cements were evaluated in this study (Table 1). Each one of the 60 metal castings was cemented, allowing for 6 castings cemented to the anodized surface and 6 castings to the non-anodized surface for each of the 5 cements. The inner surfaces of the castings used to evaluate cement #2 were tin plated prior to cementation, according to the manufacturer's instructions. Cement #2 has a special dispensing system and was chosen for its unit dosing, which allowed repeatable and consistent mixing. The oxygen barrier provided with cement #2 was used after the samples were cemented to avoid an oxygen-inhibited layer.



Fig 2a (Left) Castings used for cementation showing ring added for retentive testing. A standardized pressure jig was used to cement castings.

Fig 2b Internal surface of castings showing flat side and milled beveled shoulder.



Table 1 Luting Agents Tested

Cement no.	Cement type	Brand	Manufacturer	Lot no.
1	Zinc phosphate	Fleck's	Mizzy, Cherry Hill, NJ	
2	Resin composite	Panavia 21 EX	J Morita USA, Tustin, CA	61213
3	Glass ionomer	Fuji I	GC America, Alsip, IL	270584
4	Resin-modified glass ionomer	Fuji Plus	GC America	261277
5	Zinc oxide–non-eugenol	ZONE	Cadco, Oxnard, CA	52180

Cements #3, #4, and #5 are all available in single-dose forms and were also chosen for their ease of use, as well as for optimal consistency in mixing of the cement. Cement #1 was the only cement unavailable in unit dosing, but it was carefully measured and mixed on a clean glass slab by a single examiner precisely to the manufacturer's instructions. All cements were mixed by one examiner, and all of the samples were cemented onto the abutments by the same examiner. A thin layer of cement was painted on the inner surface of each casting with a disposable brush, seated with finger pressure until hydraulic pressure was fully relieved, then placed under a 10-kg weight for 10 minutes at room temperature (Fig 2a). After 10 minutes, the excess cement was removed. After cementation, samples were placed in a humidior at room temperature for at least 24 hours prior to thermocycling and tensile testing.

To simulate the oral environment, all 60 samples were thermocycled between 5.1°C and 56.1°C with a 34-second dwell time for 24 hours before tensile testing was performed. After thermocycling, each specimen was placed in a Universal testing machine (Instron, Canton, MA) using a jig fabricated specifically to ensure the application of vertical forces only (Fig 3). Using a 50-kg load cell at a crosshead speed

of 0.5 cm/minute, each casting was pulled from the abutment, and the force at which retentive failure occurred was recorded.

Statistical analysis was conducted using an analysis of variance (ANOVA) with *P* values reported. Pairwise comparisons were tested at the $P \leq .05$ level using the Scheffe multiple-comparisons test.

RESULTS

Results of the ANOVA demonstrated a statistically significant difference between the 5 cements at $P \leq .001$. There was no statistically significant difference observed in retentive strengths with the addition of the anodized surface treatment ($P = .7185$). Each of the cements did not respond in the same way to the anodized surface ($P \leq .002$ for the interaction term), and while the retentive strengths may have decreased for one of the cements, they increased for the others, with no specific or consistent trend. It appears, therefore, that retentive strengths were not altered by the use of anodized abutment surfaces.

Multiple-comparison analyses suggested that of the cements used, resin composite demonstrated the highest mean retentive strength ($P < .05$) with both



Fig 3 Jig used for retentive testing in Instron universal testing machine.

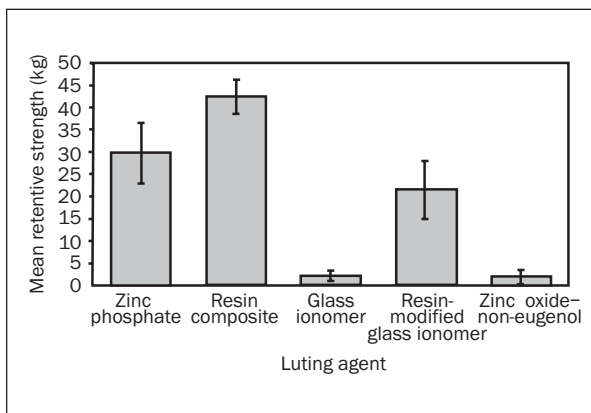


Fig 4a Retentive strengths with non-anodized abutments.

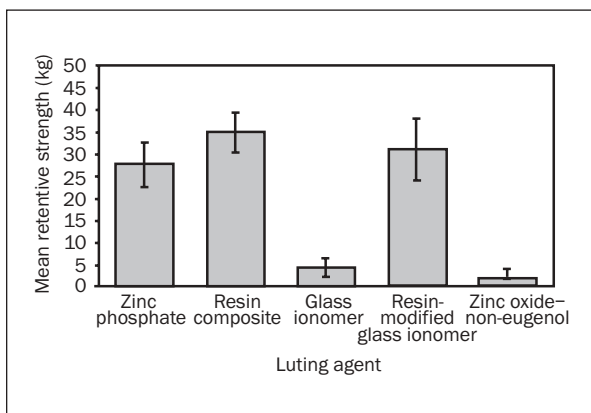


Fig 4b Retentive strengths with anodized abutments.

anodized and non-anodized abutment surfaces. The next most retentive cements were zinc phosphate and resin-reinforced glass ionomer, which were different from all other cements ($P \leq .05$) but not from each other for both the anodized and non-anodized surfaces. Glass ionomer had retentive strengths similar to zinc oxide–non-eugenol for both the anodized and non-anodized surfaces. These cements had the lowest retentive strengths recorded (Figs 4a and 4b).

Cement failure in the resin composite and resin-reinforced glass ionomer occurred within the cement itself. Cement was found to remain partly on the abutment and partly in the metal casting after tensile testing. This was true for both anodized and non-anodized abutments. The zinc phosphate, glass ionomer, and zinc oxide–non-eugenol all failed at the cement–abutment interface; all of the cement remained inside the metal casting, leaving the abutment surface clean.

DISCUSSION

This study examined the use of cements with an 8-degree tapered titanium abutment. Clayton and coworkers¹⁷ used a similar selection of permanent and provisional cements with the CeraOne abutment (Nobel Biocare, Göteborg, Sweden) and recorded higher retentive values for zinc phosphate than for resin cement. The differing results between that study and this one may be related to the difference between the 0-degree taper in the CeraOne abutment and the 8-degree taper in the ITI abutment. With a parallel-sided abutment, compressive strength of the cement may play a more important role than in a situation with a tapered abutment, where the effects of adhesion and tensile strength become increasingly important.

The ITI implant abutment has an 8-degree taper, which differs from the implant abutments used in other studies to date. With human teeth, a decrease in cement retention has been demonstrated with increasing preparation taper.^{25–27} Whether this holds true for cementation between metal components may be assumed but is still unknown. There are presently no studies evaluating the change in retention when cementing metal castings to implant abutments of varying taper. The question arises, then, as to how much retention is necessary when cementing implant restorations. Retention is based not only on the cement used, but also on the roughness of the inner surface of the casting, the taper, the surface texture of the abutment, and the surface area available to the cement.¹⁴ The decision to use provisional versus permanent cement should be based on how retentive a given cement is and the degree of retention needed.

The retentive values of the luting agents used in this investigation can be compared only loosely to those obtained with cementation of conventional fixed restorations to natural teeth. First, the metal abutment cannot be precisely compared with dentin as a surface to which castings are cemented. In addition, while the abutment taper and height were fixed in this study, the studies that compared retentive strengths of cements on natural teeth each used natural tooth preparations of different tapers, heights, and surface areas. Depending on the study design, the values for retentive strength reported for the different classes of dental luting agents in the literature²⁸⁻³⁸ were similar to those obtained in this study, except for the glass-ionomer cement.

In this study, the zinc oxide–non-eugenol cement performed as predicted for natural teeth and was minimally retentive. The resin composite, resin-reinforced glass ionomer, and zinc phosphate also performed as expected and were highly retentive. Surprisingly, though, the glass-ionomer cement, which is used routinely as a permanent cement for natural tooth structure, did not perform as anticipated and was minimally retentive with metal implant abutments.

The variation of the results with regard to the large standard deviations seen here is most likely the result of the variations in cements and film thicknesses. Because the groups were all uniform with a 5.5-mm height and an 8-degree taper, variation of retentiveness was probably related to cement properties and not to the study design.

The location at which cement failure occurs may be another important consideration in the selection of a cement when retrievability is desired. A cement that adheres to the abutment may be difficult to remove, and attempts to do so may damage the abutment surface. Furthermore, there may be decreased retention resulting after cementing over that abutment again, if cement remains permanently attached to the abutment. In this study, failure in the resin cement and the resin-reinforced glass-ionomer cement occurred within the cement itself. Thus, these 2 cements may prove difficult to use clinically for the aforementioned reasons.

It is unlikely that the alloy type used in this investigation is as important as the surface treatment of the metal. That is, the surface roughness caused by sandblasting of the internal aspects of the castings, rather than the type of metal, is more likely to be the critical factor in retention of the castings to the abutments. In this investigation, cast noble metal alloy was used to simulate the castings that are routinely used for high-quality patient restorations.

The retrievability issue and the possible need for recementation of loosened crowns demonstrate the

difference between new, clean surfaces versus recementation of previously cemented components. Previous studies^{13,14,17,21-24} included the reuse of paired abutments and castings for tensile testing. The effect of repeated use of components on retentive values of cements is unknown, but there is a possibility that changes occur on the inner surface of the metal castings or on the machined abutment surfaces after cementation and removal that alter subsequent retention between the same components. This study examined only initial retention, as each casting and abutment pair was used only once.

Thermocycling of test specimens to evaluate the retention of luting agents used with metal implant components has been examined once previously. GaRey and coworkers¹⁹ found that thermocycling had minimal effect on retentive strength when cementing abutments into threaded implants. Clayton and associates¹⁷ thermocycled samples between 5°C and 55°C for 1,000 cycles before performing tensile testing of gold cylinders cemented to CeraOne abutments. Zinc phosphate was found to be the most retentive cement for the 0-degree tapered CeraOne abutment. All specimens in their study, however, were subjected to thermocycling, and thus the effect of thermocycling on retention could not be examined. The present study followed a similar protocol that subjected all specimens to thermocycling, and as a result, did not examine this effect either.

Finally, the results of this investigation found that anodization, or coating, of the abutment surface was not a factor in cement retentive strengths. To the authors' knowledge, this is the first study to report on this feature, and future studies will be needed to determine conclusively whether this finding is reproducible. In addition, future studies will need to determine whether coating of the abutment plays an important role or interferes in any other way with the implant/abutment assembly.

CONCLUSIONS

Within the framework of this study:

1. Resin cement demonstrated the highest mean retentive strengths.
2. Glass-ionomer and zinc oxide–non-eugenol cements exhibited the lowest mean retentive strengths.
3. Zinc phosphate and resin-reinforced glass ionomer showed intermediate mean retentive strengths.
4. Use of an anodized abutment surface does not appear to affect retentive strength.

5. Resin and resin-modified glass-ionomer cements failed cohesively, leaving residual cement on the abutment and the implant shoulder.

ACKNOWLEDGMENTS

The authors wish to thank Institute Straumann AG (Waldenburg, Switzerland) for providing the implant components for this study and Dr Walter Psoter for providing the statistical consultation.

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