Retention Forces and Seating Discrepancies of Implant-Retained Castings After Cementation

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Purpose: *The purpose of this in vitro study was to evaluate the influence of cement type and application technique on seating discrepancies and retention forces of noble alloy castings cemented on titanium abutments.* ***Materials and Methods:*** *Eugenol-free zinc oxide (Freegenol), zinc phosphate (Harvard), glass ionomer (KetacCem), polycarboxylate (Durelon), and self-adhesive resin (RelyX Unicem) cements were used. The inner surfaces of the castings were either completely coated or half-coated with cement. Abutments were used as delivered with a machined surface for the first part of the study. Groups of 8 castings were cemented in both ways. For the second part of the study, the abutments were air-abraded (aluminum oxide, 50 µm particle size), and groups of 8 completely coated castings were cemented with all cements. Marginal discrepancies were measured before and immediately after cementation. Tensile tests were conducted to measure the retention forces. Statistical analysis was performed with pair-wise comparison using the Wilcoxon rank sum test modified by Bonferroni-Holm.* ***Results:*** *Change in seating discrepancies did not differ significantly among the different application techniques. The median retention forces for completely-coated castings were 177 N for eugenol-free zinc oxide, 346 N for zinc phosphate, 469 N for glass ionomer, 813 N for polycarboxylate, and 653 N for self-adhesive resin. With respect to retention force, 3 significantly different groups ($P \leq .05$) were identified: (1) zinc oxide, (2) zinc phosphate/glass ionomer, and (3) polycarboxylate/self-adhesive resin. No differences in retention between the 2 coating techniques were found for any cement. However, air abrading the abutments resulted in increased retention of the castings for some of the cements.* ***Conclusions:*** *Half-coating of the restorations with cements did not result in reduced retention values compared to the complete coating technique, but air abrasion resulted in increased retention with some cements.* (Basic Science) INT J ORAL MAXILLOFAC IMPLANTS 2006;21:519–525

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Implant-supported prostheses are an established treatment option for partially edentulous patients. Crowns and fixed partial dentures (FPDs) are either cemented or screw-retained on the implant abutments. There are several arguments for and against each of these 2 possible methods of fixation, but there is no consensus that 1 method of retention is superior to the other.[1]

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Cementation of implant-retained restorations using techniques similar to those used for tooth-retained crowns and FPDs simplifies treatment planning and clinical procedures. Improvement of esthetics due to the lack of visible screw-access openings and the elimination of the possibility of loosening or breakage of the prosthesis-retaining screw are additional advantages of cementation.[2–4]

However, deep submucosal implant shoulders restrict the use of cemented crowns and FPDs because of the potential for irritation or inflammatory tissue response and the possibility of scratching of the implant surface during removal of excess cement.[5] Furthermore, it has to be taken into consideration that occlusal corrections may be necessary after cementation, depending on the thickness of the cement layer, which means additional chair time.

A severe disadvantage of cementation is that cemented implant restorations cannot be easily retrieved in case of biological or technical complications.[1,6] A provisional luting agent may be used; the retention values of provisional luting agents are smaller than those of permanent luting agents.[7–11] In addition, implant abutments are not at risk for caries. Therefore, the use of provisional cements may be considered to facilitate the removal procedure without damaging the restoration or the implant and its abutment.[12] However, the physical properties of provisional cements, like low tensile strength and high solubility, might result in high risk for loss of retention.

A method of "semipermanent" fixation which provides adequate retention of the restoration yet allows retrievability would be desirable. An effort in this direction is the reduction of retention by the use of petroleum jelly with polyurethane resin.[13] Another option to reduce the retention of permanent cements might be to use a reduced amount of cement. It was thought that if cement were applied only to the cervical portion of the restoration, a marginal seal could be achieved with less cement.

No data have been found in the literature on the effects of reduced cement application. Therefore, the purpose of this study was to evaluate *(1)* whether the retention of permanent cement would be reduced by applying cement only on the cervical half of the inner surfaces of the casting and *(2)* whether retention of provisionally cemented crowns would be increased by air-abrading the abutments before cementation.

The null hypotheses to be tested were *(1)* There is a decrease in crown retention when cement is applied on only half of the inner surfaces of the restoration instead of on all inner surfaces and *(2)* Air abrasion of the abutments before cementation increases the retention of crowns cemented with the complete coating technique. Furthermore, the influence of the different cementation techniques on seating discrepancy was evaluated.

MATERIALS AND METHODS

In the present study 20 standard titanium abutments of the Camlog implant system with a diameter of 4.3 mm and a taper of 5 degrees (Camlog, Wimsheim, Germany) were used. All abutments were shortened from 8.5 to 6 mm in height (Fig 1a). A milled tapered groove (5 mm length, 0.5 mm depth) served as an anti-rotational element. Each screw-retained abutment was attached to an implant analog with 20 Ncm torque using a manual torque controller (Camlog).

Twenty individual wax copings were formed directly on the abutments (smooth casting wax; Bego, Bremen, Germany). For the tensile test a loop was added to the occlusal surface of each coping (Profilwachs, 1.5 mm diameter; Dentaurum, Ispringen, Germany). The patterns were invested in phosphate-bonded investment material (GC Fujivest Super; GC, Tokyo, Japan) and cast with noble alloy (Degulor M; DeguDent, Hanau, Germany). The castings were divested, and the fit to the abutments was checked and adjusted as necessary (Figs 1b to 1d). With a round carbide bur (diameter 0.5 mm) 3 marks were made 1 mm apart (beginning 1 mm from the edge of the cast) for measurement of the marginal fit (Figs 1e to 1g). Castings and their corresponding implant-abutment assemblies were numbered for the purpose of identification during the cementation procedures. In the first part of the study the abutments were used with a machined surface as delivered by the manufacturer. In a second trial all abutments were air abraded with 50-μm aluminum oxide particles at a pressure of 2 bars for 5 seconds. The occlusal access opening and the screw-thread of the abutments were filled with white gutta-percha (gutta-percha in sticks; Dentsply DeTrey, Constance, Germany) prior to cementation (Fig 2a). Castings and abutment-implant assemblies were cleaned in an ultrasonic cleaner for 5 minutes in distilled water and then steam-cleaned. Components were allowed to air dry and were visually inspected for surface cleanliness.

Five cements were evaluated in the present study (Table 1). The cements were used according to the manufacturers' instructions and were applied in 2 different ways:

- Complete coating: The inner surfaces of the casting were completely coated with a thin layer of cement using a small brush.
- Half-coating: The cervical halves of the vertical inner surfaces were coated with a thin layer of cement.

Specimens were cemented to the abutments with machined surfaces using either the complete-coating technique (group CM; n = 8) or the half-coating technique (group HM; n = 8). In the second part of the study, castings were cemented to the abutments with air-abraded surfaces using the complete-coating technique (group CA; n = 8).

Prior to each cementation cycle the inner surfaces of all castings were air abraded with 50-μm aluminum oxide at a pressure of 2 bars for 5 seconds. All castings and abutments were wiped with a cotton gauze drenched in alcohol (96%) and air dried. After application of the cement, castings were subjected to 5 kg load for 10 minutes (Fig 2b). After setting, excess cement was removed using a plastic curette (universal implant deplaquer; KerrHawe, Bioggio, Switzerland). To ensure that changes caused by the cleaning procedures and air abrasion prior to cementation were equal for all cements, castings were ran-

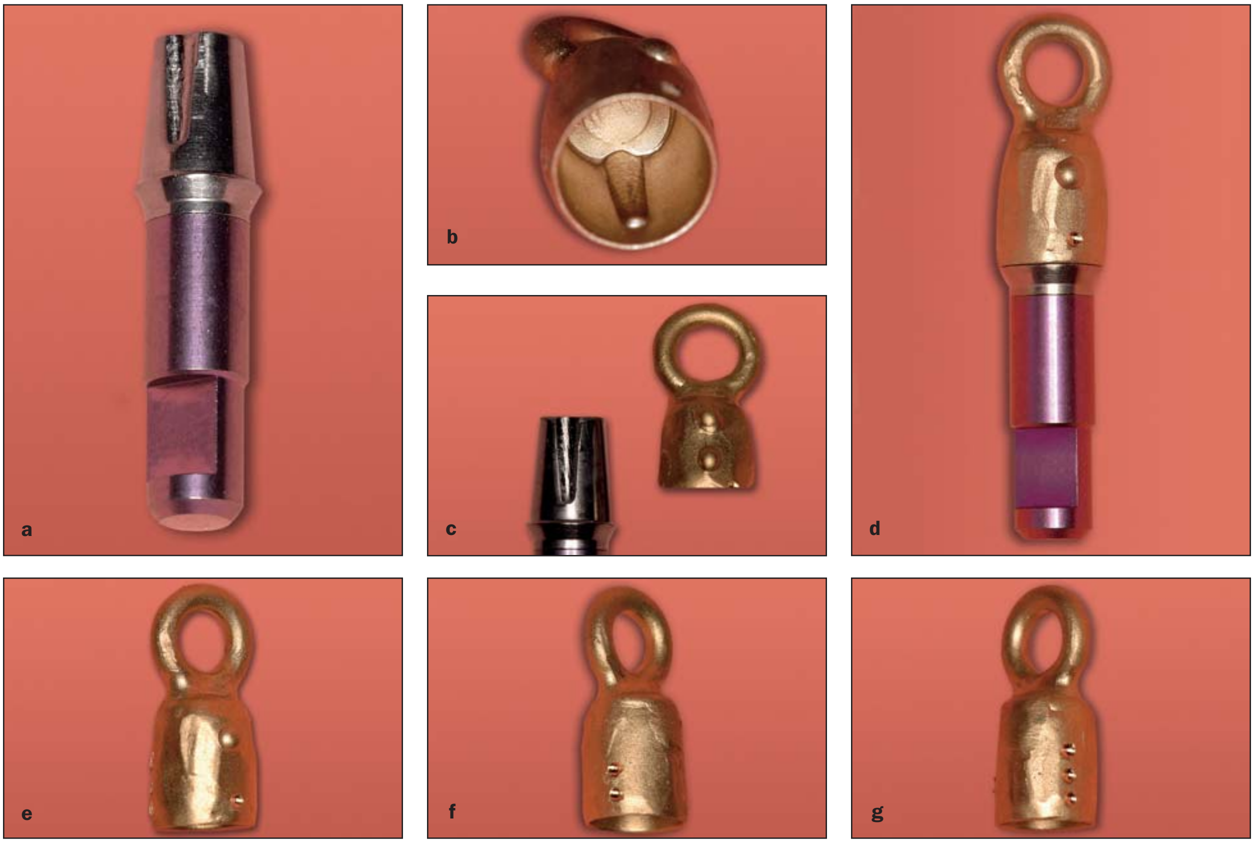


Fig 1 *(a)* Abutments 4.3 mm in diameter and 6 mm in height were used. A milled tapered groove served as an antirotational element. *(b to d)* After divesting and cleaning the castings, the fit to the abutments was checked and adjusted as necessary. *(e to g)* With a round carbide bur, 3 marks were made 1 mm apart beginning 1 mm from the edge of each casting for measurement of the marginal fit.

Fig 2 *(a)* The occlusal access opening and screw thread were filled with white gutta-percha prior to cementation. *(b)* Castings were cemented with 5 kg load for 10 minutes.

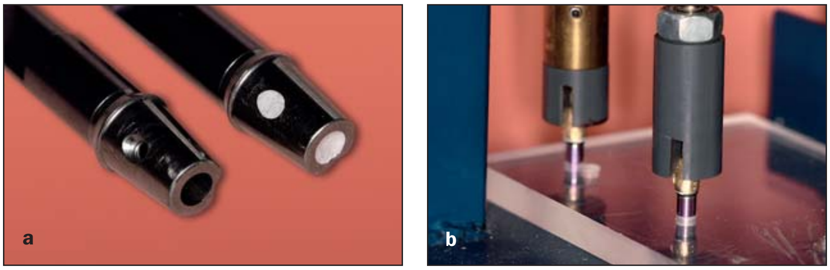


Table 1 Luting Agents

Proprietary material	Type	Manufacturer
Freegenol	Eugenol-free zinc oxide cement; provisional	GC, Tokyo, Japan
Harvard	Zinc phosphate cement	Richter & Hoffmann, Berlin, Germany
KetacCem, Aplicap	Glass ionomer cement	3M Espe, Seefeld, Germany
Durelon, Maxicap	Polycarboxylate cement	3M Espe
RelyX Unicem, Aplicap	Self-adhesive resin cement	3M Espe

Freegenol was the only provisional cement used; all other cements were permanent.

domized to a cement and a cementation technique following the cementation scheme shown in Fig 3. Following this scheme, in the first part of the study, 4 test cycles were conducted. In the second part of the study, only the complete-coating technique was used, and in 2 test cycles, a total of 8 specimens per luting agent were cemented. All specimens were used in every test cycle. The specimens were stored in physiological saline solution for 24 hours at a temperature of 37°C.

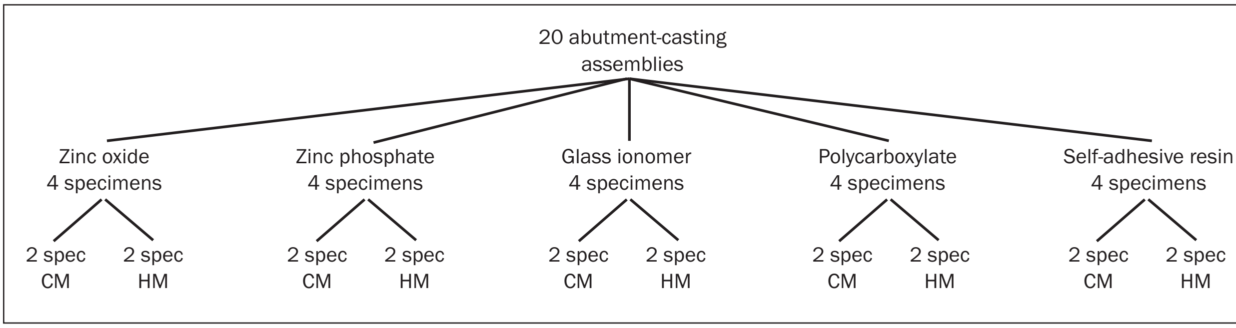
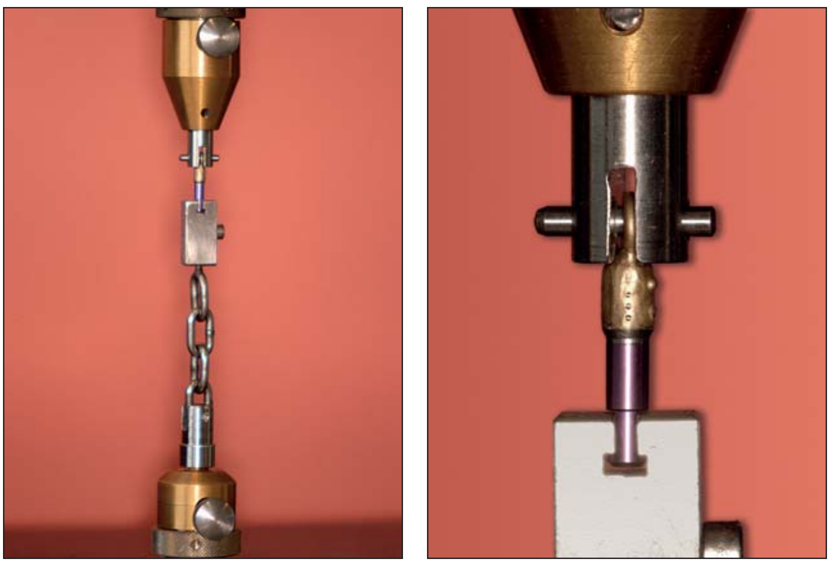


Fig 3 Cementation scheme for 1 test cycle in the first part of the study. This procedure was repeated 4 times to provide a total of 8 specimens per group. In the second part of the study, all abutments were air-abraded, and the complete-coating technique was used for all (2 test cycles, n = 8).



Figs 4 and 4b A Zwick universal test apparatus was used for tensile testing.

Tensile tests were conducted using a universal testing machine (Zwick Z010, Ulm, Germany) at a crosshead speed of 2 mm/min (Fig 4). After tensile testing, the castings of the HM group were visually inspected. The maximum level of cement attached to the vertical surfaces of the insides of the castings was recorded according to the following categories: *(1)* the maximum level of attached cement reached 100% of the vertical inner surface, *(2)* the maximum level of attached cement reached 75% of the vertical inner surface, or *(3)* the maximum level of attached cement reached 50% of the vertical inner surface.

After this evaluation, specimens were placed in an ultrasonic cleaner with a dental luting agent removal solution (Stammopur; Dr H. Stamm, Berlin, Germany) for 5 minutes; afterward the castings were again air-abraded with aluminum oxide at a pressure of 2 bars for 5 seconds. Cement remaining on the abutment surface was removed with a plastic curette if necessary.

The marginal discrepancies were measured at the 3 marked spots with a stereomicroscope (S4E; Leica, Wetzlar, Germany) under 10× magnification before and immediately after cementation. All measurements were conducted by a single examiner, and the values for each mark were recorded separately.

The random error for a single measurement was evaluated independently by 3 investigators. For this purpose 6 specimens (3 before and 3 after cementation) were chosen by random for re-evaluation. Marginal discrepancies were evaluated by each examiner; each examiner was blinded to the others' evaluations. The median of the variance coefficients between the different investigators was 0.15 (random error of 15%).

Since data were not normally distributed (Shapiro-Wilks test), statistical analyses between groups were performed with the Kruskal-Wallis test followed by pair-wise comparison (Wilcoxon rank sum test) adjusted by Bonferroni-Holm for multiple comparisons. In addition, box plots were used to illustrate the obtained results graphically. *P* values ≤ .05 were considered statistically significant.

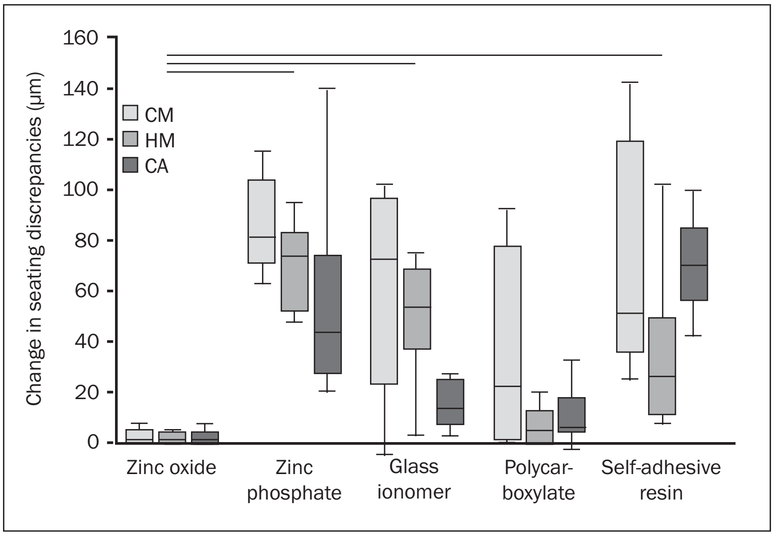


Fig 5 Box plots of the change in seating discrepancy after cementation for the various cements and cementation modes are shown. The median, 25th percentile, 75th percentile, lowest, and highest values are shown. The horizontal lines indicate significant differences ($P \leq .05$ for all; Mann-Whitney test).

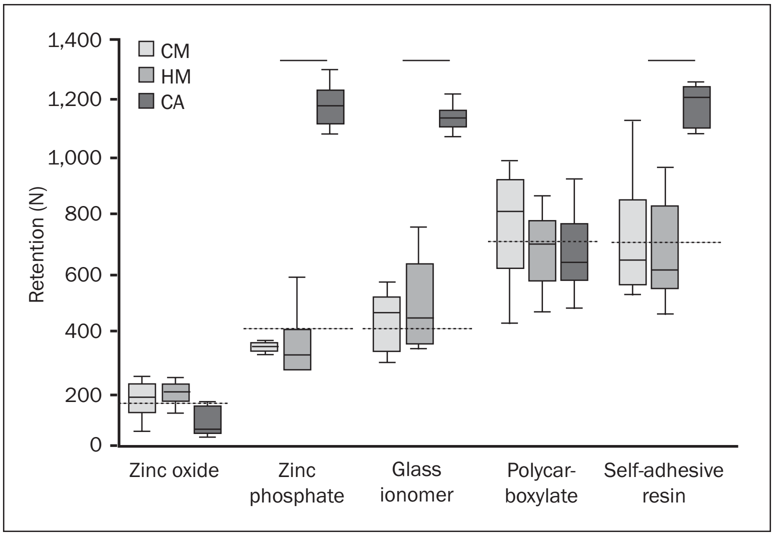


Fig 6 Box plots of the retention forces for the various cements and cementation modes are shown (n = 8). The median, 25th percentile, 75th percentile, lowest, and highest values are shown. The horizontal lines indicate significant differences ($P \leq .05$ for all; Mann-Whitney test).

RESULTS

The changes in marginal discrepancies after cementation are shown in Fig 5. Changes in seating discrepancies did not differ significantly ($P > .05$) between the different application modes and different surface conditions of the abutments within the 5 cements.

It was found that the use of the provisional cement eugenol-free zinc oxide resulted in significantly smaller ($P \leq .05$) changes in marginal discrepancies after cementation than the use of zinc phosphate, glass ionomer, or self-adhesive resin.

The median retention forces for completely-coated castings were 177 N for eugenol-free zinc oxide, 346 N for zinc phosphate, 469 N for glass ionomer, 813 N for polycarboxylate, and 653 N for self-adhesive resin (Fig 6). Statistically significant differences in retention were found between the 5 luting agents ($P \leq .001$; Kruskal-Wallis test). For the CM application mode, 3 distinct and significantly different ($P \leq .05$) groups could be discerned: zinc oxide, zinc phosphate/glass ionomer, and polycarboxylate/ self-adhesive resin. No differences in retention were observed between the HM and CM groups for any of the cements ($P > .05$).

Air abrasion of the abutments resulted in increased retention of the castings when zinc phosphate, glass ionomer, or self-adhesive resin were used ($P \leq .05$). Retention of castings cemented with eugenol-free zinc oxide or polycarboxylate was not affected by this abutment conditioning ($P > .05$).

For all 3 groups (CM, HM, and CA), retention of castings cemented with eugenol-free zinc oxide was significantly less ($P \leq .05$) than that of castings cemented with any other cement.

All specimens of the HM group cemented with each of the 5 cements were assigned to category 1, ie, the maximum level of attached cement reached 100% of the vertical inner surface of the castings in all cases.

DISCUSSION

The present results indicate that there were differences in the marginal fit after cementation using the different cements. Additionally, a trend was found that changes in seating discrepancies after cementation were less in the HM group. Considering that the CM and HM groups were cemented simultaneously (Fig 3) using a standardized seating force, this result shows that not only the type of luting agent but also the amount of applied cement influences marginal discrepancies after cementation.

Great variation in seating discrepancies were observed, which can be partially explained by the aforementioned random error of 15%. Such large variations, however, were not observed with retention values. This can be explained by the fact that the retention capabilities of zinc phosphate cement, resin cement, and glass ionomer cement are not significantly affected by variations in cement film thickness ranging from 25 to 100 μm.[14,15]

It has been stated in the literature that differences in surface roughness of tooth abutments have no effect on marginal discrepancies of metal crowns cemented with zinc phosphate, glass ionomer, or resin cement.[16] The present study confirms this, as no significantly different seating discrepancies were found for machined and air-abraded surfaces that were completely coated with cement.

In the present study, in the CM group, polycarboxylate cement and self-adhesive resin cement showed the highest retention values, followed by glass ionomer, zinc phosphate, and eugenol-free zinc oxide cement. Even though direct comparison is precluded by differences in sample preparation and test design, the results of the present study confirm the general trends found in the literature.[8,10,11]

After tensile testing all specimens were visually inspected. It was found that in the HM group cement was also attached to the coronal half of the inner surface of the castings, similarly to the complete-coating group, although the cement was applied only to the cervical half. This explains the similar retention values of the 2 cementation modes (CM versus HM). Therefore, the half-coating of the cementation surfaces is not suitable to reduce the retention of the cements used in this study. However, using the half-coating technique tended to result in lower marginal seating discrepancies compared to the complete coating technique. Therefore, these results support application of a reduced amount of cement clinically in order to obtain an improved marginal fit without a decrease in retention.

Cement retention increased when the abutments were air-abraded prior to cementation with zinc phosphate, glass ionomer, and resin cement. Other authors have also found that retention values of these cements increased with increasing surface roughness of the restorations or tooth abutments.[14,16–18] However, in the present study the higher surface roughness did not influence the retention values of eugenol-free zinc oxide and polycarboxylate cement. This might be explained by the limited cohesive strength of these cements.[19] Based on these results, air abrasion of the abutments cannot be recommended to improve the retention of provisional cements. However, if retrievability of cemented implant restorations is desired, the use of provisional cements is suggested.[7–11]

Air abrasion of the inner surfaces of the castings with aluminum oxide after each cementation cycle may have decreased the inner fit of the castings throughout the trial, which may have caused different film thicknesses of cement within the groups. The retention values may have been influenced by this factor. In comparable studies this procedure was avoided to prevent changing the castings and abutments.[8,20] However, it must be considered that air abrasion of fixed restorations before cementation is a common clinical procedure. Nevertheless, to eliminate this source of error in the present study, the use of more specimens would have been meaningful.

Unfortunately, the maximum retention force, which still allows clinical retrievability without damage to the restoration, implant, or peri-implant tissues, is not known. Furthermore, retrieval is usually achieved by instruments using high-pressure, high-impact, short-duration force instead of a constant force of long duration, as was applied in the present study. Therefore, further studies are necessary to investigate the relation between the presented retention values and retrievability when using commercially available devices for crown and prosthesis removal. The number of load applications needed to remove the castings and the concurrent damage should be evaluated before clinical recommendations can be given.

CONCLUSIONS

Under the limitations of the study the following conclusions are drawn:

1. Half-coating of the restorations with cement did not result in reduced retention values but improved the marginal fit.
2. The use of eugenol-free zinc oxide cement resulted in the smallest changes in marginal discrepancies after cementation.
3. Polycarboxylate cement showed the highest retention values with small changes in marginal discrepancies after cementation.
4. Air abrasion of the abutments with aluminum oxide increased the retention values of some permanent cements, but not that of eugenol-free zinc oxide or polycarboxylate cements.

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