Influence of Cement Type on its Quality of Removal from Zirconium Oxide Implant-Supported Restorations

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Purpose: To assess excess cement removal after cementation of implant-supported cement-retained restorations with different cements. Material and Methods: A dental model with imitation soft tissue, 20 individual zirconium oxide abutments, and 20 zirconium oxide crowns were fabricated. Half of the restorations were cemented using resin cement (RX) and the other half with resin-modified glass-ionomer cement (GC). After cement cleaning, each abutment-crown unit was removed from the model, photographed, and analyzed on four surfaces, resulting in a final sample size of 80 measurements. Radiographic examination and the computerized planimetric method in Adobe Photoshop were used to determine the amount of cement left and evaluate the ratio between the area of cement residue and all abutment-crown surfaces. Significance was set to .05. Results: GC resulted in 7.4% more cement residue on all surfaces (P < .05) than RX. The P value on three surfaces (all except the mesial) was < .05, indicating that the data were statistically significantly different between groups and surfaces. Complete removal of the cement was impossible in all cases (100%), but in 95% of cases, cement remnants could not be detected radiographically. Conclusions: More undetected cement remains when using GC. It was impossible to remove excess of both types of cement completely. Most of the cement remnants were located on the distal surface. Radiographic examination could not be considered as a reliable method to identify excess cement. Int J Prosthodont 2023;36:315–322. doi: 10.11607/ijp.7088

It has been demonstrated that residual cement following cementation of implant-supported cement-retained restorations is sometimes related to peri-implant diseases.1–5 Complications vary from soft tissue inflammation to severe crestal bone resorption or even implant loss.1,6 Despite a growing concern about cement-related peri-implantitis, prosthodontists still face some clinical situations where cementation is inevitable. Unfortunately, there are no strict clinical guidelines accepted worldwide for safe cementation, as the research is still inconsistent. It has been declared that deeply placed margins (deeper than 2 or 3 mm) result in undetected cement7 and that negative undercuts should be reduced to a minimum.8 On the other hand, some authors advise that cement margins should be completely visible to ensure absolute...
removal of the excess cement. There are many cases, especially in the esthetic area in patients with a high smile line, where a visible cementation margin could cause some esthetic issues. Therefore, it seems that there is still a lack of information about this topic from different perspectives, especially when analyzing which luting agent should be selected, as there is almost no scientifically based literature about cleaning options for different types of cements. Agar et al first compared the cleansibility of resin, glass-ionomer, and zinc phosphate cements used for cement-retained crown delivery, concluding that resin cement (RX) is the most difficult to remove. However, a single study is not nearly sufficient to have reliable data.

Therefore, the main purpose of this in vitro study was to evaluate the feasibility of removal of excess cement after cementing crowns on dental implants using two different cements. Additional aims were (1) to assess whether a certain cement is more likely to be removed completely; (2) to identify which surface of the abutment crown usually contains more cement; and (3) to determine the reliability of radiographic examination when trying to detect residual cement.

The null hypothesis was that there would be no difference in cement cleaning quality related to the type of cement.

**MATERIALS AND METHODS**

A model with a 3.3-mm–diameter implant analog (Straumann) embedded 5 mm subgingivally in the position of an anterior tooth was used for the present study. All of the casts were mounted from type IV dental stone (Heraeus Kulzer). A silicone flexible gingival mask (GumQuick Plus, Dreve Dentamid) was used for soft tissue replication. Twenty abutments and fixed dental prostheses all fabricated from zirconium oxide (Lava Classic, 3M ESPE) were used in the present study. All individual abutments were made with the cementation margin positioned 1 mm subgingivally at all surfaces following the gingival line (Fig 1). A screw access channel was part of the study design to facilitate removal of the cemented abutment crowns from their respective analog following cementation. This was necessary to ensure retrievability of the abutment-restoration unit after cementation. Before cementation, the abutment screw opening was covered using polytetrafluoroethylene (PTFE) tape to prevent cement flow to the screw. Screw access channels were closed with composite material (Filtek Ultimate Flowable, 3M ESPE) to prevent venting of the luting agent during cementation (Fig 2). Two different cements were used in the present study: self-adhesive resin cement (RX; RelyX U200, 3M ESPE) and resin-modified glass-ionomer cement (GC; Ketac Cem Plus, 3M ESPE).

All steps were performed by one experienced prosthodontist/researcher (E.V.N.). Cements were mixed with automix single-use tips. A thin layer of cement was applied to the intaglio surface of the crown and distributed evenly with a microbrush (Henry Schein Dental) on all inner walls of the restoration. The exact amount of cement was not quantified, as the cementation protocol attempted to imitate a real clinical scenario. The restoration was then positioned on the abutment using light, constant finger pressure. The restoration was held with the same constant finger pressure while the cement was setting and light curing; 2 seconds for RX and 20 seconds for GC per each surface. This technique has been described and used in previous studies. The taper of the abutment and adjacent teeth were used as guides for precise delivery and positioning (Figs 3a and 3b).

The cementation protocol for RX was done following the instructions for use. RelyX U200 cement is a dual-curing cement with an option for tack light curing of excess cement; therefore, after brief curing (2 seconds per each surface), excess cement was removed with
a stainless steel probe (Dentsply International). Immediately after this removal, final light curing was performed for 20 seconds on each surface. Final cleaning of the excess cement was done using a stainless steel probe (Dentsply Sirona) and dental floss (Curaprox, Kryns) until it was decided that it had been completely cleaned (Fig 3c).

The cementation protocol for GC was done following the instructions for use. Ketac Cem Plus is a self-curing cement with an option for tack light curing of the excess cement; therefore, after brief light exposure (5 seconds for each surface), excess cement was removed using the stainless steel probe. Final cleaning of the cement was performed after 5 minutes with a stainless steel probe and dental floss until it was decided that it had been completely removed.

Following these procedures, the implant model was examined radiographically using RVG Windows Trophy 7.0 software (Trophy Radiologie). Radiographic examination was performed so that the x-ray would go through the model at a 90-degree angle to the implant–abutment crown unit. A radiograph was considered successful when two separate air chambers were observed in the implant analog with a fixed abutment (Fig 4a). An image was considered unsuccessful image if it had an oval air chamber (Fig 4b). If cement remnants were observed in the radiographs, the remnants were removed using the same procedures and steps as before, focusing on the areas where cement remnants were visible in the radiographs. The procedure was repeated until no excess cement was visible after radiographic examination.

After verifying that no residual cement was radiographically detectable, the composite was removed from the buccal screw access channel with a contra-angle handpiece (KaVo) and diamond bur (Komet, Brasseler). Afterwards, the PTFE tape was removed, the abutment screw was unscrewed, and the suprastructure was disassembled for the final assessment (Fig 3d). All steps were performed with both types of cement and for all specimens.

Analysis of the removed abutment crown assembly was performed by following these steps. First, all four quadrants (mesial, distal, labial, and lingual) of each specimen were photographed using a specially constructed device to maintain the standardized distance (16 cm) between the camera (Canon EOS 6D MARK II and EF 100 mm f/2.8L IS) and the specimen. The camera and specimen were fixed in the photographing device to keep the same distance every time the picture was taken. The images were imported and analyzed using Adobe Photoshop. The surface area of the specimen was measured manually with the Lasso tool to outline the boundaries of each surface. The surface area of the entire quadrant was outlined and marked using the Lasso tool (Fig 5a), and the surface area covered by residual cement was also marked using the Lasso tool (Fig 5b). The total surface area was marked, and the number of pixels was recorded using the histogram option. The same process was applied to the area covered with the cement remnants. The ratio between the area covered with cement and the total surface area of the specimen was calculated. The same method has been used previously to detect the ratio of plaque on a tooth and the remaining excess cement on the abutment crown.12
Statistical Analysis

Statistical analysis was carried out using RStudio IDE (Posit) and SPSS version 23 (IBM). The ratio of cement residue in the abutment-crown quadrant (labial [L], mesial [M], palatal [P], distal [D]) was considered as a statistical unit. The following analyses were performed: (1) whether the ratio of residue depends on the type of cement (RX or GC) and (2) whether any of the four crown surfaces have an impact on the amount of residual cement. The variables were divided into two groups: RX and GC. In both groups, the distribution of ratios was also measured depending on the surface: L, M, P, and D.

First, descriptive statistics were performed, data were analyzed, and variables that could negatively affect the regression model and may be the result of measurement errors were identified (ie, Cook distance). Three outliers were discarded from the data (one maximum value from RX, two maximum values from GC). Descriptive statistics were performed after excluding the outliers to determine the distribution of the data as well as the minimum and maximum values in the groups. Q-Q plots were created to assess if a set of data in the groups plausibly came from a theoretical distribution such as a normal distribution. According to the plots, it could be concluded that the data were close to the normal distribution and that it was reasonable to use linear regression analysis, a statistical method assuming that the data are parametric. Therefore, two models of linear regression analysis were constructed:

- Model 1: the ratio of cement dependent only on the type of the cement (RX or GC)
- Model 2: the ratio of cement dependent on the the surface (L, M, P, D) and the type of cement (RX, GC)

To test the validity of the models, t test and F test for comparing variables and coefficient of determination ($R^2$) were used.

The extremely low $F$ value ($6.824 \times 10^{-14}$) indicated that Model 2 is more appropriate and better for explaining the results. Therefore, Model 1 was rejected, and Model 2 was chosen. The difference
was considered statistically significant when \( P \leq 0.05 \) with a 95% CI.

**RESULTS**

Different amounts of residual cement were found in all samples and on all surfaces (L, M, P, D). Descriptive statistical results can be seen in Table 1. The average residual cement ratio for all surfaces using GC was 3.9 times higher than the average for RX. The minimum ratio value for RX (0.0010) was 39 times lower than for GC (0.0393). The maximum value for RX was 2.7 times lower than for GC. Both residual cement ratios were analyzed depending on surface and cement type (Table 2). For RX, the lowest mean was obtained on the P surface and was 1.7 times lower than the highest mean on the D surface. For GC, the lowest mean value was obtained on the P surface and was 1.3 times lower than the highest mean on the M surface.

Comparing the P surfaces with both cements, the average ratio of RX residue was 4.2 times lower than GC residue. A linear regression model (Model 2) was constructed to determine if the ratio of residual cement depended not only on the type of cement (RX or GC)
but also on the surfaces (L, M, P, D). The result was the equation used to predict the value of the independent variable (pixel ratio) if the dependent variables (cement and surface) were changed. For GC, 7.4% more residual cement was found when compared to RX cement ($P = 2e^{-16}$). A $t$ test was applied to the surfaces and cement to show the relation between the variables. The extremely low value indicates that the relation is not accidental. The obtained values on L, P, and D surfaces were $P < .05$. There was a statistically significant difference between the groups and surfaces, indicating that the variables are related. When measuring the RX and GC groups separately, the D surface always had the highest ratio of residuals, the M surface 1.1% lower than D, the L surface 2.3% lower than D, and the P surface 2.7% lower than D. The $F$ test was also used to prove the relation between variables. From the resulting value (> 1), it can be stated that there was a relation between the variables in Model 2.

The distribution of the residual cement ratio in the diagrams (Fig 6) shows that there were significantly more remnants of GC cement. The box plots do not overlap, so it could be stated that there were significantly more GC cement remnants on all surfaces (Fig 6). When comparing only the groups with different cements, a noticeable difference could be identified, as there was much more GC cement left.

Twenty radiographic images were made after crown cementation to identify residual cement, which was detected only once on the M surface during radiographic examination (5% of cases; Fig 7). This was followed by a recleaning and another radiographic examination, after which there was no residual cement detectable in the radiograph. After these procedures, planimetric examination was performed, showing that residual cement was present on all surfaces of the crowns and implant abutments, 100% of the investigated samples.

**DISCUSSION**

In the present in vitro study, all cases demonstrated residual cement remaining on the surfaces of the restorations. There was a significant difference in cleaning quality between the two cements: There was more GC left after cleaning when compared to the RX samples, and the difference was statistically significant. Based on this outcome, the null hypothesis was rejected.

The same findings were presented by Linkevicius et al in an in vitro study and later in a clinical study, which clearly stated that if the margins were placed subgingivally, absolute cement removal was impossible. Similar results were observed by Korsch et al, who evaluated the possibility of intraorally removing cement from implant-supported crowns that were cemented not deeper than 1.5 mm subgingivally. After removal of the crowns, it was found that cement residue was present on the implant abutment or the peri-implant tissues in 59.5% of cases. The lower percentages stated by Korsch et al could be explained by the fact that the cementation margin in some cases might have been supragingival or at the soft tissue level. The present study’s design was to have 1-mm subgingival margins as a compromise to satisfy both esthetics and the ability to remove as much excess cement as possible because the 1-mm subgingival position still met the latest requirements and recommendations for safe cementation. Another study that corresponds to current findings was performed by Wasiluk et al, who analyzed cementation protocols and
cleaning procedures using individually made CAD/CAM abutments with the cementation margin placed 1 mm subgingivally. Their findings demonstrated that there were no cement remnants left in the soft tissues, as the individual abutment ensured the emergence profile and eliminated the undercuts; however, in 73.3% of cases, there was some cement left on the abutment crown complex, stressing the importance of the cementation margin depth in comparison to all other factors.

Furthermore, it could be stated that different cements clean up differently, as there was more GC left undetected after cleaning than RX. This could be explained by differences in chemical composition, consistency, and instructions for excess removal. RX cement was much thicker than GC (mixed with a disposable automatic mixer-dispenser). It was also easier to localize and detect excess cement while probing because the residues were hard and solid. GC cement was smoother, with more liquid in the consistency. It was more difficult to remove GC residual cement because the remains started to crush. In addition, it has been observed that this cement is more difficult to localize with a probe because its residues are finer and more scattered around the crown and implant abutment compared to RX.

Cement consistency is also based on different cement curing mechanisms. A one-step (radical polymerization) curing mechanism was observed in the case of RX, and a two-step (two types of reactions: acid-base and radical polymerization) curing mechanism was observed in the case of GC. This could explain the more complex cleaning procedure of the GC cement. Cement control capabilities have also been evaluated more positively in the case with RX cement because light curing ensures greater control in obtaining the desired degree of cement in the first setting time before the initial excess cement removal.

Dental probes and dental floss were used to protect the soft tissue replication as much as possible. Efforts were made to avoid very aggressive cleaning, as the study by Agar et al. has revealed that intensive cleaning of the cement may result in extensive scratching of the abutment crown complex, which might increase the mechanical attachment of the plaque on the abutment later. The results of the present study coincide with the previously mentioned study, as abutment crowns that were cemented with RX had many more scratches than the abutment crowns cemented with GC. Scratches were observed in 82.5% of the cases using RX and in 70% of the cases using GC. It could be assumed that the more accurate and easier localization of residual cement causes more aggressive residual cement removal when using a probe. Ultrasonic cleaning of excess cement has been rejected. Previous analysis of zirconia surfaces treated by different ultrasonic scaling systems demonstrated some deeper scratches, whereas zirconia instrumented with various types of periodontal curettes exhibited smaller mechanical damage.

RX and GC cements were chosen due to the fact that they have been rated among the top four cements used in US dental schools. In addition, this study belongs to a series of published studies using GC by the same author group; therefore, there was a need for consistency.

Findings showed that most of the excess cement was present on the distal surface of the abutment crown unit. This finding correlates with the results of the study done by Lee et al., who found that most of the excess cement was left mesially or distally. This could be explained by the presence of neighboring teeth on both proximal surfaces of the evaluated implant in the study model.

An interesting finding was that radiographic examination could not be trusted to detect all the residual cement. This was also confirmed in a clinical study that proved the low efficiency of radiographic examination to identify residual cement. In the study done by Linkevicius et al., residual cement was detectable radiographically in only 7.7% of cases on the M surface and 10.7% of cases on the D surface. It is impossible to inspect the palatal/lingual and facial/buccal areas due to obstruction of the implant-abutment complex. In comparison, cement residues were not detected in 95% of cases in dental radiographs in the present study. This was also confirmed in other studies where only remaining pieces of cement larger than 1 or 2 mm in thickness could be detected radiographically.

Several limitations of this in vitro study should be mentioned. First, to select the most suitable cement, there is a need for similar studies with more types of cement. Second, the small sample size could have influenced the results. Third, to prove the same results intraorally, a clinical study is necessary, as an in vitro study design could not ensure the same conditions as in vivo studies (e.g., differences between soft tissue and soft tissue replication, dry/wet conditions in the sulcus around the implant abutment, etc.). And finally, even though the study was in vitro, the amount of cement applied in the crown and the restoration loading force while seating were not standardized, which might have influenced the final results. This was done to imitate a real clinical situation.

**CONCLUSIONS**

Within the limitations of the present study, the following could be concluded:

1. There was more GC left undetected after cleaning than RX.
2. None of the cases were absolutely cement free after cementation and cleaning.
3. Most of the residual cement remained on the distal crown and abutment surface.
4. Radiographic examination was not a reliable way to identify residual cement.

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REFERENCES