Influence of the cement type on its removal quality from the zirconium oxide implant-supported restorations

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Abstract

Purpose: To assess excess cement removal after cementation of implant-supported cement-retained restorations using different cements. Materials and Methods: A model with soft tissue imitation, 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
crown-abutment unit was removed from the model, photographed, and analyzed from 4 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 the cement left and to evaluate the ratio between the area of cement residue and the whole crown-abutment surface. The 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 of the surfaces (all except mesial) was < .05, meaning that the data were statistically significantly different between groups and surfaces. Absolute removal of the cement was impossible in all cases (100%), and in 95% of the cases, cement remnants could not be detected radiographically. **Conclusion:** More undetected cement remains when using resin-modified glass-ionomer cement. It was impossible to remove excess of both types of cements completely. Most of the cement remains on the distal surface. Radiographic examination could not be considered as a reliable method to identify excess cement. *Int J Prosthodont* 2021. doi: 10.11607/ijp.7088

**Introduction**

It has been agreed that residual cement after cementation of implant supported cement-retained restorations is sometimes related to peri-implant diseases [1-5]. Complications could vary from soft tissue inflammation to a severe crestal bone resorption or even implant loss [1, 6]. Despite a growing concern about cement related periimplantitis, prosthodontists still face some clinical situations where cementation is inevitable. Unfortunately, there are no strict worldwide accepted clinical guidelines for safe cementation as the information is still incoherent. It has been declared that deeply placed margins (deeper than 2 or 3 mm) definitely result in undetected cement [7], also that negative undercuts should be reduced to minimum [8]. On the other hand, some authors advise that cement
margins should be absolutely visible to ensure absolute removal of the cement excess [9].

There are quite a lot of cases, especially in the esthetic area for patients with high smile line, when visible cementation margin could cause some esthetical issues. Therefore, it seems that there is still a lack of information about this topic from different perspectives, especially when analysing which luting agent should be selected as there is almost no scientifically based literature about cleaning options of different types of cements. Agar et al, were the first to compare the cleansibility of resin, glass-ionomer and zinc phosphate cements, used for cement-retained crowns delivery, concluding that resin cement is the most difficult to remove. However, one must agree, that single study is far away from enough to have a reliable data [10].

Therefore, the main purpose of this in vitro study was to evaluate the removal feasibility of cement excess after cementing crowns on dental implants while using two different cements. Additional aims were a) to find out if any cement is more likely to be removed completely; b) to determine which surface of the crown/abutment usually contains more cement and c) to determine radiographic examination reliability while trying to detect cement residuals.

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

**Material and methods**

A model with embedded 3.3 mm diameter implant analog 5 mm subgingivally (Institut Straumann AG, Basel, Switzerland) in the position of an anterior tooth was used for the present investigation. All the casts were mounted from type IV dental stone (Heraeus Kulzer GmbH, Hanau, Germany). A-silicone flexible gingival mask GumQuick Plus (Dreve Dentamid GmbH, Unna, Germany) was used for the soft tissue replication. Twenty abutments and fixed dental prostheses all fabricated from Zirconium Oxide (Lava Classic,
3M ESPE, USA) were used in the present research. All individual abutments were made with cementation margin positioned 1 mm subgingivally in all surfaces following the gingival line (Fig. 1). Screw channel access was part of the study design to facilitate cemented crown/abutments from their respective analogue following cementation. This was necessary to ensure the retrievability of the abutment-restoration unit after cementation. Before the cementation the abutment screw opening was covered using teflon tape (PTFE) to prevent cement flow to the screw. Screw access channels were closed with composite material Filtek Ultimate Flowable (3M ESPE, USA) to prevent venting of luting agent during cementation (Fig. 2). Two different cements were used in the present investigation: Self-Adhesive Resin Cement (RX) (RelyX U200, 3M ESPE, USA) and Resin Modified Glass-Ionomer Cement (GC) (Ketac Cem Plus, 3M ESPE, USA).

All steps were performed by one experienced prosthodontist-researcher. Cements were mixed with automix single use tips. A thin layer of the cement was applied to intaglio surface of the crown, distributed equally with a microbrush (Henry Schein Dental, Melville, New York, USA) on all inner walls of the restoration. The exact amount of cement was not quantified as the cementation protocol tried to imitate a real clinical scenario. Then the restoration was positioned on the abutment, using a light constant finger pressure. Restoration was held with the same constant finger pressure while cement was setting, meaning 8 seconds for RX and 20 seconds for GC while light-curing. The same technique has been described and used in a few previous investigations [11]. The taper of the abutment and adjacent teeth were used as guides for precise delivery and positioning (Fig. 3, A, B). Cementation protocol using resin cement 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) cement excess was removed with a stainless-steel probe (Dentsply International Inc., Milford, Delaware, USA), immediately after that the final light
curing was performed 20 seconds on each surface. Final cleaning of the cement excess was done using a stainless-steel probe (Dentsply International Inc., Milford, Delaware, USA) and a dental floss (Curaprox, Kryns, Switzerland) until it was decided that it had been completely cleaned (Fig. 3, C). Cementation protocol using resin modified glass-ionomer cement 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 per each surface) cement excess was removed using the stainless-steel probe. Final cleaning of the cement was performed after 5 minutes with a stainless-steel probe and a dental floss until it was decided that it had been completely removed.

Following those procedures, the implant model was examined radiographically using RVG Windows Trophy 7.0 software (Trophy Radiologie Inc., Paris, France). Radiographic examination was performed so that the x-ray would go through the model conducting a 90 degrees angle with the implant abutment-crown unit. A successful radiograph image was considered when two separate air chambers were observed in the implant analog with a fixed abutment (Fig. 4, A). An unsuccessful image was the one with an occurred oval air chamber (Fig. 4, B). If cement remnants were observed in the radiographic images, they were removed using the same procedures and steps as before, focusing on the area, where cement remnants were visible in the radiographic image(s). Procedure was repeated until no cement excess was visible after the radiographic examination.

After verifying that no residual cement is radiographically detectable, the composite was removed from the buccal screw access channel with a contra-angle handpiece (KaVo Dental GmbH, Biberach an der Riss, Germany) and diamond bur (Komet Dental, Lemgo, Germany). After that the teflon tape was taken out, abutment screw was unscrewed and the suprastructure was dismounted for the final assessment (Fig. 3, D). All steps were performed with both types of cements and for all specimens.
Analysis of removed abutment/crown assembly was performed in a following way. First, all four quadrants (mesial, distal, labial and lingual) of the each specimen were photographed using a specially constructed device to keep the standardized distance (16 cm) between the photo camera (Canon, Lake Success, NY, USA) and the specimen. Camera and the specimen were fixed in the photographing device to keep the same distance everytime the picture was taken. The images were imported and analysed using Adobe Photoshop (Adobe Systems Ltd, Europe, Uxbridge, UK). Each surface area of the specimen was measured manually with the drawing facility (Lasso tool (L)) to outline the boundaries of each surface. The surface area of the entire quadrant was outlined and marked using the Lasso tool (L) (Fig. 5, A). The surface area covered by residual cement was also marked using the Lasso tool (L) (Fig. 5, B). The total surface area was marked and the number of pixels was recorded from the histogram option, the same 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 previously used in a few investigations to detect either ratio of the plaque on the tooth or remaining cement excess on the abutment/crown [12].

Statistical analysis

A statistical analysis was carried out using RStudio IDE and IBM SPSS Statistics v. 23. The ratio of cement residues 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) the ratio of residues depends on the type of the cement (RX or GC) and (2) whether 4 crown surfaces have an impact on the amount of residual cement. The variables were divided into two groups: resin cement (RX) and resin modified glass-ionomer cement (GC). In groups, the distribution of ratios was also measured depending on the surfaces: labial (L), mesial (M), palatal (P), distal (D).
First, the descriptive statistics were performed, data analysed and variables that can negatively affect the regression model and may be a random consequence of measurement errors were identified (Cook's distance). The 3 outliers were discarded from the data (1 maximum value from the RX group, 2 maximum values from the GC). Descriptive statistics was performed after excluding outliers to determine the distribution of the data, also 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 some theoretical distribution such as a normal. According to the plots it could be concluded that the data are close to the normal distribution and that it is reasonable to use linear regression analysis (statistical method assuming that the data was parametric). Therefore, two models of linear regression analysis were constructed. Model1: the ratio of cement dependance only on the type of the cement (RX or GC); Model2: the ratio of cement dependance on the the surface (L, M, P, D) and the type of the cement (RX, GC).

The T-test, the F-test for comparing variables and the coefficient of determination R2 were used to test the validity of the models.

The extremely low F value (6.824x10-14e) indicates that Model2 is more appropriate and better in explaining the results. Therefore, the first model was rejected and Model2 was chosen. The statistically significant difference was considered if \( P \leq 0.05 \) with a confidence interval of 95%.

**Results**

Different amounts of residual cement were found in all samples and on all surfaces (L, M, P, D). Descriptive statistic 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
analysed, depending on both surfaces and cement type (Table 2). For RX, the lowest mean was obtained on the palatal surface (P), the highest on the distal (D) and differed 1.7 times. For GC, the lowest mean value was obtained on the palatal surface (P), the highest on the mesial surface (M) and differed 1.3 times. Comparing palatal surfaces (P) using both cements, the average ratio of RX residue was 4.2 times lower than GC residue. Linear regression Model 2 was constructed if the ratio of residual cement depends not only on the type of the cement (RX or GC), but also on the surfaces (L, M, P, D). The obtained result was the equation used to predict the value of the independent variable (pixels ratio) if the dependent variables (cement and surfaces) would be 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, which showed the relation between the variables. Also, the extremely low value indicates that the relation is not accidental. The obtained values on L, P, D surfaces were p <0.05. There was statistically significant difference between the groups and surfaces meaning that the variables are related. When measuring separately RX and GC groups, the D surface always had the highest ratio of residuals, M surface - 1.1% lower than D, L surface - 2.3% lower than D, and P surface - 2.7% lower than D. The F-test was also used to prove the relation between variables. From the resulting value (> 1) we can state that there was a relation between variables in the Model2.

The distribution of the residual cement ratio is also shown in the diagrams (Fig. 6), there are much 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 markable difference could be stated - there is much more GC cement left.

Twenty radiographic images were made after crowns cementation on implants in order to identify residual cement, which was detected only once on the mesial surface.
during radiographic examination (5% of cases) (Fig. 7). This was followed by a re-cleaning and a radiographic examination again, after which there was no residual cement detectable in the radiographic image. After these procedures planimetric examination was performed, showing that residual cement was present on all surfaces of the crowns and implant abutments, resulting in 100% of the investigated samples.

Discussion

For the present investigation based on its in vitro design, all cases demonstrated residual cement remaining on the surfaces of the restorations. There was a significant difference in cleaning quality between two cements: there was more resin modified glass-ionomer cement left after cleaning when compared to the resin cement samples and the difference was statistically significant. Based on this outcome the null hypothesis must be rejected.

The same findings were presented by Linkevicius et al in in vitro study and later in the clinical study [7, 13], who clearly declared that if the margins are being placed subgingivally absolute cement removal is impossible. Similar results were observed by Korsch et al., who evaluated the possibility to remove the cement after cementation in the implant supported restorations intraorally from the crowns that were cemented not deeper than 1.5 mm subgingivally [14]. After the removal of the crowns it was found that the residues of the cement were present on the implant abutment or in the periimplant tissues in 59.5% of the cases. Lower percentage stated by Korsch could be explained that the cementation margin in some cases might have been supragingival or at the soft tissue level. The present investigations study design was to have 1 mm subgingival margins as a compromise to satisfy both: aesthetics and ability to remove as much cement excess as possible. Even though, 1 mm subgingival position still met the latest requirements and recommendations for a safe cementation [15, 16]. Another study that corresponds to current
findings was performed by Wasiluk et al. [16], who analysed cementation protocol and cleaning procedures using individually CAD/CAM made abutments with the cementation margin placed 1 mm subgingivally. The findings of their investigation demonstrated that there were no cement remnants left in the soft tissues as the individual abutment ensured the emergence profile and eliminated the undercuts, but there was some cement left on the abutment/crown complex in 73.3% of the cases. Once again, it has been proved the importance of the cementation margin depth in comparison to all the other factors.

Furthermore, it could be stated that different cements clean up differently as there was more resin modified glass-ionomer cement left undetected after cleaning than the resin cement. It could be explained by different chemical composition and consistency, also differences in removing their excess according to the instructions. RX cement was much thicker than GC (mixed with a disposable automatic mixer - dispenser). It was also easier to localize and detect cement excess while probing because the residues were hard and solid. GC cement was smoother and 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 resin cement. Cement consistency is also based on different cement curing mechanism. One step (radical polymerization) curing mechanism is observed in the case of resin cement [17] and two steps (two types of reactions: acid-base and radical polymerization) curing mechanism is observed in the case of resin modified glass-ionomer cement [18]. This could explain more complex cleaning procedure of the GC cement [19]. Cement control capabilities have also been evaluated more positively in the case with RX cement, since light curing ensures greater control and obtaining the desired degree of cement in first setting time before the initial cement excess removal.
Dental probe and dental floss were used in order to protect the soft tissue replication as possible [19, 20]. Efforts were made in order to avoid very aggressive cleaning as the study by Agar et al. has revealed that intense cleaning of the cement may result in extensive scratching of the abutment/crown complex [10], which might increase the mechanical attachment of the plaque on the abutment later. The results of the present investigation coincide the previously mentioned study as crowns/abutments which were cemented with RX had much more scratches than the crowns/abutments 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 cause more aggressive residual cement removal using probe. Ultrasonic cement excess cleaning option 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 [21].

Resin cement and resin modified glass-ionomer cement were chosen due to the fact that they have been rated among top 4 cements used in dental schools in USA [22]. In addition, this investigation belongs to a series of the same scientific group published investigations, where the resin modified glass-ionomer cement has been used, therefore there was a need of consistency [7, 8, 13].

It was found out that most of the cement excess was present on the distal surface of the crown/abutment unit. This finding correlates with the results of the study done by Lee et al. in 2019 [23], who found most of the cement excess left mesially or distally. It could be explained by the presence of neighbouring 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 pieces of the cement. This data was also confirmed in a clinical study, which also
proves low efficiency of the radiographic examination to identify residual cement. In the investigation done by Linkevicius et al. residual cement was detectable radiographically in only 7.7% of the cases on the mesial surface and 10.7% of the cases on the distal surface [7]. It is obvious that it is impossible to inspect palatal/lingual and facial/buccal areas due to the obstruction of the implant/abutment complex. In comparison cement residues were not detected in 95% of the cases in dental radiographic images in the current investigation. This is also confirmed in other study, in which it was stated that only pieces of remaining cement larger than 1 or 2 mm in thickness could be detected radiographically [24, 25].

Several limitations of this in vitro study should be mentioned. Firstly, for choosing the most suitable cement there is a need of similar investigation with more types of cement. Secondly, the small sample size could have influenced the results. Thirdly, in order to prove the same results intraorally a clinical study is necessary as in vitro study design could not ensure the same conditions as in in vivo investigations (difference between soft tissue and soft tissue replication, dry/wet conditions in the sulcus around implant abutment etc). And finally, even though the investigation was in vitro, cement amount applied in the crown and 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:

With the limitations of the study it could be concluded:

1. There was more resin modified glass-ionomer cement left undetected after cleaning than the resin cement.
2. None of the cases were absolutely cement free after cementation and cleaning.
3. Most of the residual cement remains on the distal crown and abutment surface.
4. Radiographic examination is not a reliable way to identify residual cement.
REFERENCES


Fig. 1. Experimental model with screwed implant abutment

Fig. 2. A – abutment opening is filled with teflon tape; B – buccal crown opening filled with flowable composite; C – solid crown on implant abutment.
Fig. 3. The sequence of cementation procedure: A – a thin layer of cement applied to all inner crown surfaces; B – crown placed on an implant abutment; C – removal of cement excess; D – implant abutment-cemented crown unit disengaged from the model to assess the residual cement.
Fig. 4. A – acceptable radiographic image, where two separate air chambers are visible in the implant analog with a fixed abutment, B – unacceptable radiographic image, where an oval air chamber is visible in the implant analog with a fixed abutment.

Fig. 5. A – distal surface of the crown-abutment unit marked; B – surface area covered by cement remnants marked on the same crown-abutment
Fig. 6. The box plots showing resin cement (RX) and glass-ionomer cement (GC) ratios depending on crown-abutment unit surface.

Fig. 7. Radiographic examination, residual cement detected mesially.
<table>
<thead>
<tr>
<th>Cement Type</th>
<th>Mean ± SD</th>
<th>Maximum Value</th>
<th>Minimum Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resin (RX)</td>
<td>0.02381 ± 0.0144</td>
<td>0.0682</td>
<td>0.0010</td>
</tr>
<tr>
<td>Glass-ionomer (GC)</td>
<td>0.09325 ± 0.0385</td>
<td>0.1813</td>
<td>0.0393</td>
</tr>
</tbody>
</table>

Table 1. The average ratios of cement residue depending only on the type of the cement.

<table>
<thead>
<tr>
<th>Cement</th>
<th>Surface</th>
<th>Mean ± SN</th>
<th>Maximum Value</th>
<th>Minimum Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>RX</td>
<td>M</td>
<td>0.0245 ± 0.0134</td>
<td>0.0531</td>
<td>0.0092</td>
</tr>
<tr>
<td>RX</td>
<td>L</td>
<td>0.0208 ± 0.0129</td>
<td>0.0408</td>
<td>0.001</td>
</tr>
<tr>
<td>RX</td>
<td>P</td>
<td>0.0186 ± 0.0121</td>
<td>0.0436</td>
<td>0.005</td>
</tr>
<tr>
<td>RX</td>
<td>D</td>
<td>0.0321 ± 0.0174</td>
<td>0.0682</td>
<td>0.0143</td>
</tr>
<tr>
<td>GC</td>
<td>M</td>
<td>0.1053 ± 0.0333</td>
<td>0.1571</td>
<td>0.0602</td>
</tr>
<tr>
<td>GC</td>
<td>L</td>
<td>0.0872 ± 0.0337</td>
<td>0.1597</td>
<td>0.0396</td>
</tr>
<tr>
<td>GC</td>
<td>P</td>
<td>0.0795 ± 0.0531</td>
<td>0.1510</td>
<td>0.0393</td>
</tr>
<tr>
<td>GC</td>
<td>D</td>
<td>0.1029 ± 0.0531</td>
<td>0.1813</td>
<td>0.0403</td>
</tr>
</tbody>
</table>

Table 2. Values of residual cement ratios depending on surface and cement type.