Clinical Factors Influencing Removal of the Cement Excess in Implant-Supported Restorations

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ABSTRACT

Background: The depth of the cementation margin has an influence on the amount of cement remnants around implants. However, the role of other clinical factors is still not clarified.

Purpose: The aim of the study was to evaluate the correlation between undetected cement and (i) location of the implant, (ii) implant diameter, and (iii) undercut.

Materials and Methods: Sixty-five patients were treated with single metal-ceramic restorations on implants. The undercut between the restoration and the tissue was measured. After cementation, the restoration-abutment unit was unscrewed. All quadrants of the specimens were photographed and analyzed. The ratio between total restoration area/peri-implant tissue area and area of cement remnants was calculated in pixels. Significance was set to 0.05.

Results: Sixty-five metal-ceramic restorations were placed on 65 implants (39 molars, 22 premolars, 4 anteriors; 21 implants had a diameter of 3.5 mm, 34 of 4.0 mm, 10 of 5.0 mm). An undercut of 1 mm was found in 118 sites, 2 mm in 96 sites, and 3 mm in 46. The percentages of soft tissue and restoration, respectively, covered by cement were as follows: molars 4% and 7%; premolars 3.8% and 7.3%; anteriors 3% and 3.4%; 3.5 mm diameter 3.3% and 7.4%; 4.0 mm 7.7% and 7.7%; 5.0 mm 3.9% and 2.1%; 1-mm undercut 3.5% and 5.4%; 2-mm 4% and 8.1%; 3-mm 4.8% and 8.4%. The relationship between amount of cement remnants and implant location was insignificant ($p > 0.05$) for both soft tissue and the specimen, but significant relationships with amount of cement remnants were found for diameter ($p = 0.026$ for soft tissue, $p = 0.600$ for specimen) and undercut ($p = 0.004$ for soft tissue, $p = 0.046$ for specimen).

Conclusion: If cemented crown restoration is desired, undercuts should be reduced to a minimum for better removal of cement excess, irrespective of the diameter and location of the implants in the mouth.

KEY WORDS: cement cleaning, cement excess, cement-related peri-implantitis, cement-retained implant restorations, implant diameter, undercut

INTRODUCTION

Due to their simplicity, similarity to natural teeth, and solid and aesthetic occlusal surface, and as a solution to problems with improperly inclined implants, cement-retained implant crowns and fixed partial dentures have become the most often-used restorations in implant dentistry.[1–5] In addition, it is supposed that cement-retained suprastructures are more passive due to the cement layer between the framework and implant abutment.[6–8] On the other hand, recent scientific articles show that it may be difficult to remove the cement excess if margins are placed subgingivally.[9–11] It has become apparent that the deeper the implant's abutment shoulder is placed, the greater the amount of residual cement left subgingivally after cleaning. The excess cement on the implant or abutment may act as a foreign body and provoke an inflammatory response, which might result in crestal bone resorption or even implant loss.[12–14] The depth of the cementation margin can result in inadequate removal of the cement excess; however, the role

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of other clinical factors such as location of the implant (anterior or posterior), implant diameter, and the undercut around the implant is still not clarified in this regard. Hence, the main aim of this clinical study was to evaluate the correlation between those factors (implant position, diameter, and undercut) and the amount of undetected cement. The hypothesis was that none of those factors influence the quality of cement removal.

MATERIALS AND METHODS

This prospective clinical study was performed at a private practice (Vilnius Implantology Center, Vilnius, Lithuania) and included 65 consecutively treated patients (30 male and 35 female), with the age ranging from 20 to 75 years old (mean 38 ± 1.8 years old). The study was approved by the Lithuanian institutional review board (no. 15,8200,0245,7132), and the patients provided written informed consent with permission to use their data for scientific purposes. Patients requiring only single-implant restorations were included in the study and therefore received a corresponding number of internal hexagon implants (BioHorizons Internal, Birmingham, AL, USA).

The surgical and prosthetic protocol was the same as in the previous clinical study by Linkevicius and colleagues.[15] Prosthodontic treatment started after 2 months of healing in the lower jaw and 4 months in the upper jaw. No temporary implant-supported restorations for soft tissue conditioning were used. Impressions were taken using polyvinylsiloxane (Variotime, Heraeus Kulzer, Hanau, Germany) with an open-tray technique. Cement-screw-retained implant prosthesis was selected as the restorative option for implants, as this technique allows withdrawal of the crown after cementation (Figure 1A–C).[13] In total, 65 single metal-ceramic crowns with occlusal openings (Figure 1C) were fabricated by the same dental technician. Standard prosthetic abutments were selected to support the restorations because it was important to have the same distance to the cementation shoulder for each implant (Figure 1A).

The technique used for cementation and remnant evaluation was very similar to that used in the preceding in vitro study and clinical study.[11,16] Before cementation, a standard abutment was screwed down to the implant and the screw channel isolated with dental wax (Wax Pak, 3M Unitek, Monrovia, CA, USA). The occlusal openings of the crowns were closed with composite material (Gradia Anterior, GC, Tokyo, Japan) to prevent venting of luting agent during cementation. Resin-modified glass ionomer cement (Fuji Plus, GC, Tokyo, Japan) was mixed according to the manufacturer's instructions, using the same ratio (one little scoop of powder to one drop of liquid, as recommended by manufacturer) for each crown. A thin layer was applied to all the internal surfaces of the crowns and seated onto the abutment with gentle finger pressure. Cement excess before removal and the temporarily closed occlusal opening can be seen in Figure 2. When the setting cement reached a rubbery consistency, the excess was removed with a stainless steel explorer (Dentsply International Inc., Milford, DE, USA), dental floss (Vitis, Dentaid, Barcelona, Spain), and super-floss (Curaprox, Kriens, Switzerland) until the researcher decided it had been completely cleaned. Radiographic images were taken with RVG Windows Trophy 5.0 (Trophy Radiologie, Paris, France) using a paralleling technique with Rinn-like film holder in high-resolution mode. If residual cement was detected on a radiograph, cleaning procedures were repeated until a radiographic evaluation showed no cement remnants. Then the composite

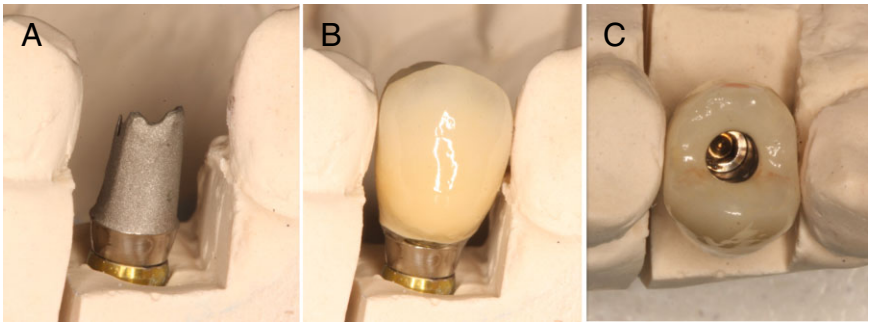

Figure 1 *A*, No alteration of the shoulder on the standard abutment. *B*, Metal-ceramic cement-screw-retained implant-supported crown. *C*, Occlusal opening of the crown.

Figure 2 Determination of the undercut mesially and distally.

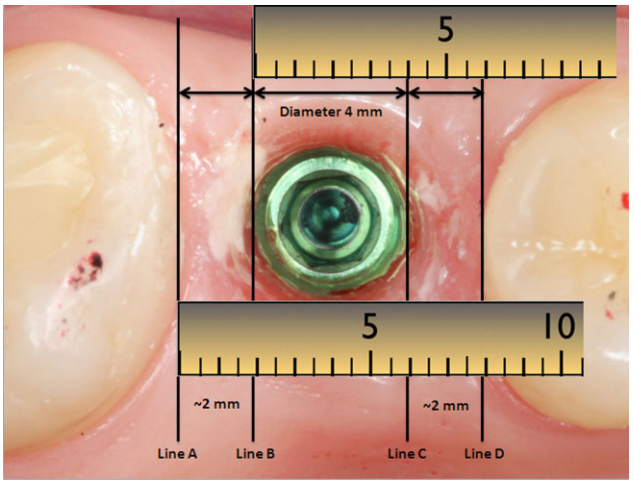

Figure 4 Cement excess before cleaning and temporarily closed occlusal opening.

and wax were removed, the abutment screw was unscrewed, and the suprastructure (abutment cemented to the crown) was dismounted for the final evaluation (Figure 3). After the removal of the restoration, a photograph of the implant and surrounding tissues was taken perpendicularly (the picture was considered appropriate when all six angles of the internal implant hex were clearly visible) using an intraoral occlusal dental mirror (Novus Dental Supplies, Commerce, CO, USA) for evaluation of cement remnants in the tissues.

According to the Glossary of Prosthodontic Terms, an undercut is defined as an angle formed by any surface of the tooth below the survey line of the height of contour with the selected path of insertion of the prosthesis.[14] However, in this study, the undercut was specified to be the distance from the most marginal implant neck point (Lines B, C, F, and G) to the gingival margin of the restoration's emergence profile (Lines E and H) or to the adjacent teeth (Lines A and D) in the horizontal plane (Figure 4 and 5). This undercut was measured in four locations, as distance from the most marginal point on the implant neck to the adjacent tooth mesially and distally (from A and B and from C to D) and as distance from the most marginal point on the implant neck to the outer margin of the soft tissues buccally and lingually (from E to F and from G to H). Measurements were performed on a perpendicularly taken intraoral picture of an implant (the picture was considered appropriate when all six angles of the internal implant hex were clearly visible). Implant diameter was chosen as the parameter with which to calibrate the pictures. Evaluation was performed with Microsoft PowerPoint for Windows 2010, using grids, digital ruler, and guide options. The digital ruler was calibrated according to the implant diameter. The ruler was added to the picture, and in that way the distances from the implant's most

Figure 3 Determination of the undercut buccally and lingually.

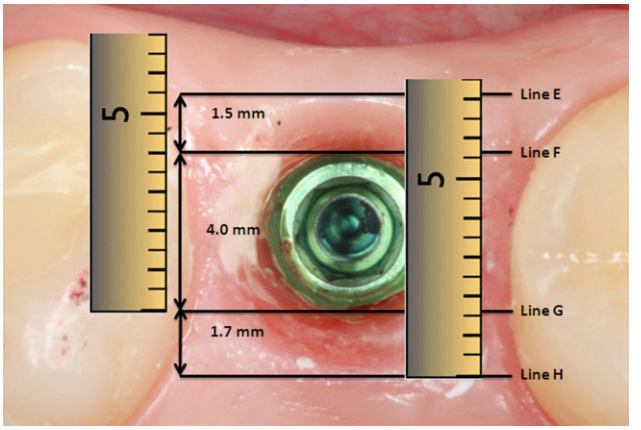

Figure 5 Retrieved crown/abutment complex.

Figure 6 Four quadrants (mesial, distal, buccal, and lingual) of the abutment/crown complex.

marginal point to the adjacent teeth were measured mesially and distally (Figure 4). Buccal and lingual undercut were measured from the most buccal and lingual points on the implant margin to the outer soft tissue line visible in the picture, buccally and lingually (Figure 5). Therefore, four measurements of the implant position were taken for every restoration: buccal, lingual, mesial, and distal. All four quadrants (mesial, distal, buccal, and lingual) of the abutment/crown complex were photographed (Figure 6) using a specially constructed device to maintain the standard 16 mm distance between the camera (Canon, Lake Success, NY, USA) and the restoration. The images were imported and analyzed with Adobe Photoshop (Adobe Systems Ltd, Europe, Uxbridge, UK). The surface areas of the prostheses were marked with the drawing tool to outline the boundaries of each quadrant (Figure 7). To calculate the area covered by cement remnants, the pen tool and the "make path" option were used. The total surface area was marked, and the number of pixels was recorded with the histogram option; the same was done for the area covered by cement remnants. The ratio between the area covered by cement and the total surface area of the crown was calculated. Next, the perpendicularly taken photograph showing an occlusal view of the implant and surrounding tissues was evaluated. Four points separating the implant hex into four equal parts were marked. Two oblique lines crossing the midpoint of the implant were drawn to divide the peri-implant sulcus into four equal quadrants: mesial, distal, buccal, and lingual (Figure 8). The surface area of every quadrant (implant not included) and the cement area were marked to calculate the proportion.

Figure 7 Evaluation of the total surface area boundaries of one quadrant of the specimen.

After the evaluation, the restorations were sent to the laboratory for cement removal and meticulous polishing. The remnants from peri-implant tissues were removed, and the implant and surrounding tissues were rinsed with 0.12% chlorhexidine solution (Perio-Aid 0.12%, Dentaid, Barcelona, Spain). After polishing, the restorations were tightened to the implants, and the screw access was isolated with polytetrafluoroethylene tape;[17] the porcelain was prepared and permanently closed with light-cured composite (Gradia Anterior, GC, Tokyo, Japan).

A statistical analysis was carried out using SPSS for Windows v. 17 (SPSS Inc., Chicago, IL, USA). Implant quadrant was selected as the statistical unit due to the fact that individual implants had different undercuts in different locations. Data were found to be nonparametric according to the histograms. First, the independent Kruskal–Wallis test for nonparametric data was used to find out if there was a relationship between increasing implant diameter or undercut and the amount of

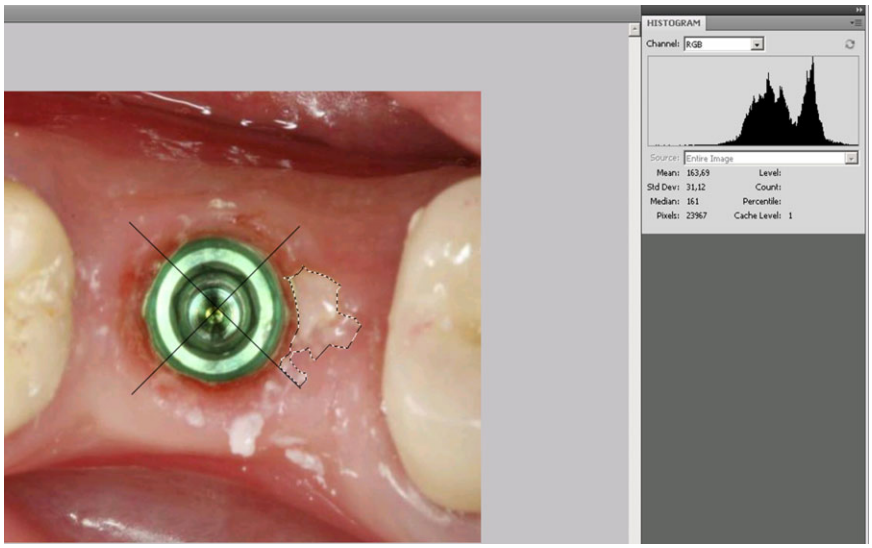

Figure 8 Two oblique lines crossing the midpoint of the implant.

undetected cement left. Then, if p was significant, the Mann–Whitney U test was used to compare the groups. Implant diameter and undercut were considered to be ordinal variables. In the analysis of the relationship between location and residual cement, only a Mann–Whitney U test was performed to compare each location with the others, as the data were considered to be nominal. If the value was significant, the Mann–Whitney U test was applied to compare the groups, with significance set to 0.05.

RESULTS

Sixty-five internal hexagon implants (BioHorizons Internal, Birmingham, AL, USA) were installed in 65 patients, 35 in the lower jaw and 30 in the upper. The location of the implants was as follows: 4 in the anterior region (incisors and canines) (6.2%), 22 premolars (33.8%), and 39 molars (60%). The sample (65 implants) consisted of 21 implants of 3.5 mm in diameter (32.3%), 34 implants of 4.0 mm (52.3%), and 10 implants of 5.0 mm (15.4%). The data for undercuts (65 single crowns with four measurements = 260 data points) were divided into three groups according to the extent of the undercut: up to 1 mm (118 data points), from 1 to 2 mm (96 data points), and 3 mm and more (46 data points). Results for absence of cement on the abutment and in the soft tissues can be seen in Table 1. However, the amount of residual cement excess found on the crown/abutment complex and that found in the peri-implant tissues after cleaning and retrieving the suprastructure were different. Ratios of the area covered by residual cement to the area of the crown/abutment complex and that of the peri-implant tissue with respect to implant location, implant diameter, and undercut are shown in Table 1. There was no statistically significant difference between the amount of residual cement found on the abutment and that found in the soft tissues according to the location of the implant (all p values were greater than 0.05). A statistically significant decrease in the amount of cement remaining in the soft

TABLE 1 Ratios between the Area Covered by Cement and the Total Surface Areas of the Restoration and Soft Tissues

	Cement/Crown (Pixel Ratio ± SE)	Cement/Soft Tissues (Pixel Ratio ± SE)
Implant location		
Anteriors	0.030 ± 0.008	0.034 ± 0.012
Premolars	0.038 ± 0.004	0.073 ± 0.011
Molars	0.040 ± 0.004	0.070 ± 0.009
Implant diameter (mm)		
3.5	0.033 ± 0.004	0.074 ± 0.013
4.0	0.077 ± 0.004	0.077 ± 0.009
5.0	0.039 ± 0.008	0.021 ± 0.007
Undercut (mm)		
1	0.035 ± 0.004	0.054 ± 0.009
2	0.040 ± 0.004	0.081 ± 0.010
3	0.048 ± 0.012	0.084 ± 0.022

tissues was found for wider implant diameters ($p = 0.026$); however, there was no significant relation between amount of cement left on the abutment and implant diameter ($p = 0.600$). Moreover, all the groups were compared separately, and a statistically significant difference was found with regard to soft tissue between implants with diameters of 4.0 mm and those with diameters of 5.0 mm ($p = 0.009$). Finally, there was a strong relationship between undercut and residual cement, not only in the soft tissues ($p = 0.004$) but also on the crown/abutment complex ($p = 0.046$). Greater amounts of undetected cement were found in both groups as the undercut got greater, but this was only statistically significant from 1 to 2 mm (soft tissue, $p = 0.002$; crown/abutment complex, $p = 0.005$).

DISCUSSION

The main finding of the study was that cement remnants were still present in almost all cases despite meticulous cleaning of the abutment/crown complex after cementation. The null hypothesis must be partially rejected, because some of the analyzed factors had in fact influenced the amount of undetected cement. Unfortunately, no comprehensive data could be found in the literature about the influence of those factors on the quality of the cement removal.

Based on this study, it is clear that the location of the implant did not influence the amount of residual cement. This means that clinicians must meticulously clean cement excess in any area of the mouth. Additionally, the anterior area is especially important because any peri-implant tissue inflammation associated with cement excess may result in severe aesthetic problems. However, the numbers of anterior and posterior implants were different in this study; therefore, future investigations focusing on this aspect are highly recommended.

Most of the existing scientific articles analyze the relationship between the depth of the cementation shoulder and the amount of excess cement left in the soft tissues, and are therefore not directly comparable with our study. Fortunately, many researchers agree that the most distinct disadvantage of cement-retained restoration is the possibility of cement extrusion into peri-implant tissues.[7,9–13,18,19] Caudry and colleagues., in their 2009 study, stated that the location of the abutment collar margin is very important not only to achieve a good aesthetic result but also to ensure total cement removal.[12] Another study by Blatz and colleagues says that they typically place the marginal finish line about 0.5 mm below the gingival margin.[18] Nevertheless, in the aesthetic area they accept placement from 1 to 1.5 mm subgingivally, which according to Agar and colleagues is precarious. They found a lot of undetected cement when margins were located 1.5 mm buccally or lingually and 3 mm interproximally below soft tissue level.[10] Linkevicius and colleagues' suggestions, based on the findings of a study on safe cementation, are even more rigorous. They found that all cement excess was eliminated only when the cementation margin was visible, and the greatest amount of cement remnants was left when the crown margin was placed 2 or 3 mm below the gingival level.[11] The same findings were also made in the clinical study.[11] Therefore, their recommendation is to select an individual abutment with visible margin for cementation when a cement-retained crown is required.

Surprisingly, no studies analyze the influence of undercuts on cement removal. Nevertheless, it seems that the impact of this factor is obvious. The study data show that the greater the undercut, the more undetected cement will be left after cleaning. Even though the amount of cement remnants increased when the undercut became greater, statistical significance was detected only between 1 and 2 mm in both areas examined (on the abutment and in the soft tissues). Our study found that the amount of undetected cement was greater when the undercut was >2 mm, and that was the case even when the cementation margin was not deep. This proves that the usage of standard abutments to support cement-retained implant restorations must be strictly avoided, because the shoulder of the standard abutment does not follow the line of the gingiva or the emergence profile of the implant. Greater implant diameter reduced the amount of the cement in soft tissue. However, a statistically significant difference was found only between implant diameters of 4.0 mm and 5.0 mm. This is because of the fact that implant diameter is directly associated with undercut. A greater implant diameter shortens the distance to the adjacent teeth and to the outer gingival margin. However, this should not be interpreted as a recommendation to place implants of larger diameter. Individual abutments could be an advantageous tool to solve this problem.[20,21]

It is also important to mention the impact of cement remnants on the health of peri-implant tissue. It has already been documented in the scientific literature

that cement excess left after cementation has an effect on the health of the tissues surrounding the dental implant.[11,15,19] Wilson found a strong relation between undetected cement and peri-implant disease, which could occur from 4 months to more than 9 years after final delivery of the cement-retained implant-supported restoration.[19] Linkevicius and colleagues, in their recent retrospective study, proved that the development of peri-implantitis was more frequent for patients with a history of periodontitis if cement excess was present. For patients having no history of periodontitis, remaining cement excess did not cause any inflammatory response.[22] On the other hand, Nissan and colleagues published an article comparing the long-term outcomes of cemented and screw-retained implant-supported partial restorations and found that cemented implant-supported restorations were superior clinically and biologically.[23] The superior biological qualities of the cemented prostheses could be explained by the fact that they used temporary cement, which is soluble, and the excess had been washed out.[24] On the other hand, if temporary cement dissolves in the mouth, it can result in mechanical problems with the restoration. Lee and colleagues admit that cementation with temporary cement is very unpredictable; the crown can be either very strongly cemented or prematurely loosened.[25]

CONCLUSIONS

If cemented crown restoration is desired, undercuts should be reduced to a minimum for better removal of cement excess, irrespective of the location of the implants in the mouth.

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