CLINICAL ORAL IMPLANTS RESEARCH

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The influence of the cementation margin position on the amount of undetected cement. A prospective clinical study

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Abstract

Objective: To evaluate the amount of undetected cement after cementation and cleaning of implant-supported restorations.

Materials and methods: Fifty three patients were treated with 53 single implant-supported metal-ceramic restorations. The subgingival location of the margin of each implant was measured with a periodontal probe mesially, distally, buccaly, and lingually, resulting in 212 measurements. The data were divided into four groups: equally with tissue level (14 samples), 1 mm subgingivally (56), 2 mm (74), and 3 mm (68) below tissues contour. Metal-ceramic restorations were fabricated with occlusal openings and cemented on standard abutments with resin-reinforced glass-ionomer. After cleaning, a radiograph was taken to assess if all cement had been removed. Then the abutment/crown unit was unscrewed for evaluation. All quadrants of the specimens and peri-implant tissues were photographed and analyzed with Adobe Photoshop. Two proportions were calculated: (1) the relation between the cement remnants area and the total area of the abutment/restoration and (2) the relation between the cement remnants and the total area of implant soft tissue contour. Significance set to 0.05.

Results: Excess on the crown groups: 1 (0.002 ± 0.001); 2 (0.024 ± 0.005); 3 (0.036 ± 0.004); 4 (0.055 ± 0.007). Undetected excess increased when the margin was located deeper subgingivally ($P = 0.000$), significant difference was found among all groups ($P \leq 0.05$). Remnants in the soft tissue groups: 1 (0.014 ± 0.006); 2 (0.052 ± 0.011); 3 (0.057 ± 0.009); 4 (0.071 ± 0.012). The increase of the remnants was statistically reliable ($P = 0.0045$), significant difference was found between group 1 and 2 ($P \leq 0.05$). Radiographic evaluation showed that cement remnants mesially were visible in four cases of 53 or 7.5%, and in six cases of 53 distally (11.3%).

Conclusions: The deeper the position of the margin, the greater amount of undetected cement was discovered. Dental radiographs should not be considered as a reliable method for cement excess evaluation.

Current clinical recommendations allow clinicians to place cementation margins of implant-supported restorations up to 2 mm subgingivally (Andersson et al. 1998). This is commonly done to hide the abutment-crown interface, to accommodate possible peri-implant tissue recession with time or to achieve more natural emergence profile. These advantages have determined that subgingival location of the margin had been the most popular cementation position of implant restorations for years, despite the caution that this may result in incomplete cement removal (Agar et al. 1997).

Luckily, there is an increasing awareness among clinicians that undetected cement might be the cause of delayed peri-implant bone loss, occurring many years after delivery of the restorations (Wilson 2009). This is rather new information, as usually late peri-implant bone loss was attributed to bad oral hygiene (Serino & Strom 2009), smoking (Gruica et al. 2004), history of periodontal infection (Karoussis et al. 2003) or other predisposing factors.

A recent article by Linkevicius et al. (2011) has proved that the deeper the position of the margin, the greater amount of residual cement is left undetected and all cement remnants can be removed only when the margin is supragingival. Furthermore, the greatest amount of cement remnants was left

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when the crown margin was 2 mm or 3 mm below the gingival level – just at the level of existing recommendations. Although these findings may be important, it is not clear if these implications would be valid in a clinical situation, as the *in vitro* study lacked intraoral conditions, like the resistance of mucosa and other. Currently there has been no clinical trial to verify the results of laboratory studies.

Thus, the main aim of this clinical study was to assess the amount of cement left after the cementation and cleaning of implant-supported restorations with various locations of the margins. An additional aim was to find out the reliability of radiographic examination of restorations after cementation. A null hypothesis was formulated stating that subgingival location of the crown margin does not influence the amount of undetected cement.

Materials and methods

This prospective clinical study was performed at Vilnius Implantology Center, Vilnius, Lithuania and included 53 consecutively treated patients (23 men and 30 women) with the age ranging from 20–75 years old (mean 37.40 years old). Patients requiring only single implant restorations were included in the study. The study was approved by the Lithuanian regional bioethical committee (No. 158200-02-457-132) and the patients provided written informed consents with a permission to use their data for scientific purposes.

Prosthodontic treatment started after 2 months of healing in the lower jaw and 4 months in the upper jaw. No temporary implant restorations for tissue conditioning were used. Impressions were taken using a polyvinylsiloxane impression material (Variotime; Hereaus Kulzer, Hannau, Germany) with the open-tray technique. Cement- and screw-retained implant prosthesis was selected as a restorative option for implants, as this technique allows withdrawal of the crown after cementation (Rajan & Gunaseelan 2004) (Fig. 1).

Evaluation of the implant depth mesially, distally, lingually, and buccally was performed after the removal of the healing abutment. The measurements were taken with a 0.5 mm marked periodontal probe (Hu-Friedy, Chicago, IL, USA). In the final data evaluation, the depth of the cementation margin was considered to be the measurement with the probe minus 1.5 mm, as the shoulder of a standard abutment is 1.5 mm above the

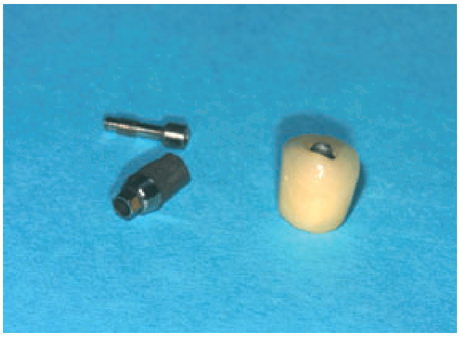

Fig. 1. Cement-and screw-retained restoration. Note metal-ceramic crown with occlusal opening (right) and standard abutment, with predetermined location of the cementation margin 1.5 mm above the implant/abutment connection (left).

implant/abutment connection point and this predetermined location was not altered in any case. Four measurements of the shoulder position were calculated on every restoration: buccally, lingually, mesially, and distally. The data were divided into four groups according to the depth of the margin position: group 1– at the soft tissue margin;-group 2–1 mm subgingivally; group 3–2 mm below marginal level; mm) and group 4–3 mm subgingivally.

The cementation and remnants evaluation technique was very similar to the preceding *in vitro* study (Linkevicius et al. 2011). Before cementation, a standard abutment was torqued to the implant and the screw channel isolated with dental wax (Wax Pak, 3M Unitek; Monrovia, CA, USA) (Fig. 2). 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) was mixed according to the manufacturer's instructions, taking the same ratio (1 little scoup of powder and 1 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 a gentle finger pressure (Fig. 3). When setting cement reached rubbery consistency, the excess was attempted to be removed using 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. Cement removal in all cases was performed by the same prosthodontist with 10 years of clinical experience in implant rehabilitation. Radiographic images were taken with RVG Windows Trophy 5.0 (Trophy Radiologie Inc.,

Fig. 2. Standard abutment connected to implant and screw access covered with wax. Note the different location of the margin proximally and buccaly.

Fig. 3. Metal-ceramic crown with closed occlusal opening via composite is cemented on standard abutment and the excess of the cement around the restoration.

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 and wax were removed, the abutment screw was unscrewed and the suprastructure was dismounted for assessment (Fig. 4). After the removal of the restoration, a photograph of the implant and surrounding tissues was taken perpendicularly using an intraoral occlusal dental mirror (Novus Dental Supplies, Commerce, CO, USA) for evaluation of cement remanants in the tissues (Fig. 5).

All four quadrants (mesial, distal, labial, and lingual) of the crown were photographed using a specially constructed device to keep the standardized 16 mm distance between the photo camera (Canon; Lake Success, NY, USA) and the restoration. The images were imported and analyzed using Adobe Photoshop (Adobe Systems Ltd, Europe, Uxbridge, UK). Each surface area of the prostheses was marked with the drawing facility to outline

Fig. 4. Cement excess and composite, which covered the occlusal hole are removed. The screwdriver will reach the screw and abutment/crown unit will be dismounted for evaluation.

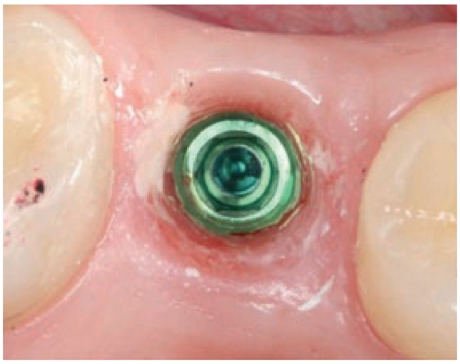

Fig. 5. Occlusal photograph of peri-implant sulcus and cement excess.

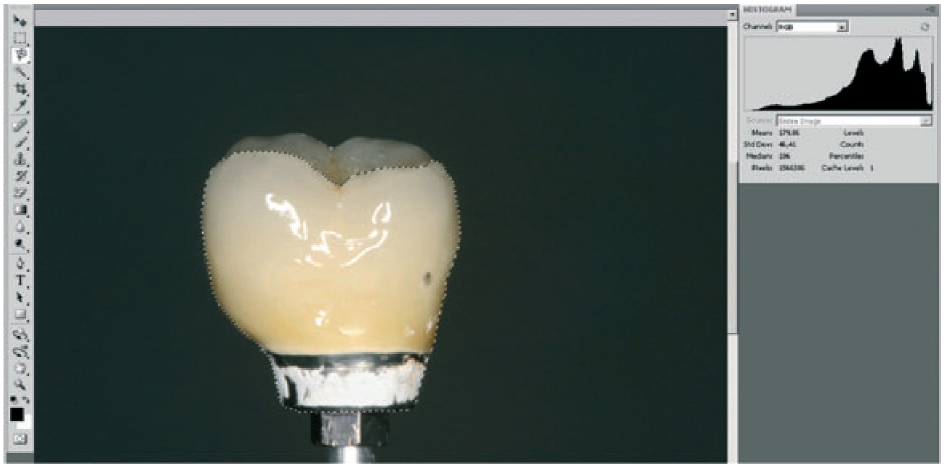

Fig. 6. Total surface area of one quadrant of the abutment/restoration is marked.

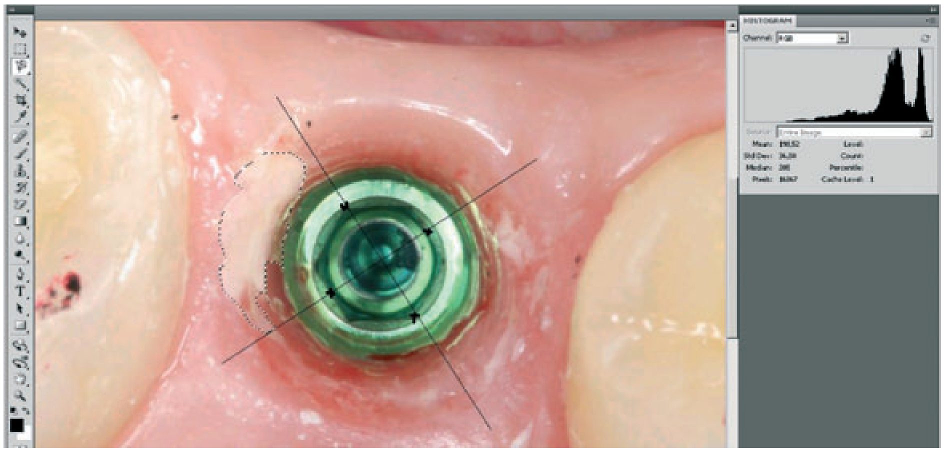

Fig. 7. The area, covered with cement remnants in peri-implant sulcus.

the boundaries of each quadrant. To calculate the area covered with cement remnants, the "pen tool" and "make path" options were used. 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 cement remnants. The ratio between the area covered with cement and the total surface area of the crown was calculated (Fig. 6). Next, the perpendicularly taken photograph of occlusal view of the implant and surrounding tissues was evaluated. Four points, which separate implant hex into four equal parts were marked. Two oblique lines crossing the midpoint of the implant were drawn to divide peri-implant sulcus into four equal quadrants: mesial, distal, buccal, and lingual. Surface area of every quadrant (implant part not included) and cement area were marked to calculate the proportion (Fig. 7).

After the evaluation, the restorations were sent to the laboratory for cement removal and meticulous polishing. The remnants from peri-implant tissues were removed, the implant and surrounding tissues were rinsed with 0.12% chlorhexidine solution (Perio-Aid 0.12%; Dentaid). After the polishing, the same restorations were disinfected and tightened to the implants, the screw access was isolated with polytetrafluoretylene tape, as proposed by Moraguez & Belser (2010), and permanently closed with light-cured composite (Gradia Anterior; GC).

A statistical analysis was carried out using SPSS software for Windows v.17 (SPSS Inc., Chicago, USA). First, the independent K (Kruskall–Wallis) test for nonparametric data was used to find out the influence of the location of the shoulder on the amount of the undetected cement left on the crown and in the soft tissues intraorally. If significant, the Mann–Whitney test was applied to compare the groups, significance set to 0.05.

Results

In total 53 internal hexagon implants (BioHorizons Internal, Birmingham, AL, USA) were installed, 33 in the lower and 20 in the upper jaw. The sample size consisted of 16 implants of 3.5 mm (30%), 30 implants of 4.0 mm (57%), and 7 implants of 5.0 mm (13%) diameter. Subsequently, 53 single metal-ceramic crowns with occlusal openings were fabricated by the same experienced dental technician. Standard prosthetic abutments were selected to support the restorations. Total data consisted of 212 measurements (53 crowns with 4 surfaces) – 14 samples in group 1; 56 measurements in group 2; 74 measurements in group 3 and 42 cases in group 4.

Various amounts of cement remnants were located on all retrieved suprastructures and in peri-implant tissues of restored implants. Proportion of cement/restoration and cement/peri-implant tissues in pixels can be seen in Table 1. Kruskal–Wallis test showed statistically significant increase of excess cement quantity on abutment/restoration complex, as the restoration margins were located deeper subgingivally ($P = 0.000$). There was a significant dependence of cement remnants amount in peri-implant sulcus and location of the margin ($P = 0.0045$) (Table 2).

Mann–Whitney test revealed statistically significant differences among all the groups ($P \leq 0.05$), when the cement excess was evaluated on abutment/restoration complex Table 3) and between group 1 and 2 ($P \leq 0.05$), when cement was evaluated in peri-implant tissues, Table 3). During first radiographic evaluation cement remnants mesially were visible in four cases of 53 or 7.5%, and in six cases of 53 distally or 11.3% (Fig. 8a and b).

Table 3. **Difference between the groups concerning pixels relation between cement excess on the crown and in the soft tissues (Mann–Whitney test, significant when $P \leq 0.05$)**

	Excess of the cement (pixels proportion)	
Group	On the crown	In the soft tissues
1 and 2	$P = 0.000$	$P = 0.005$
2 and 3	$P = 0.014$	$P = 0.439$
3 and 4	$P = 0.003$	$P = 0.491$

Underlined values show statistical significance.

Discussion

The main finding of the study was that despite careful cleaning, various amounts of cement remnants were present on the abutment/restoration complex and in the peri-implant sulcus. The deeper the position of the margin was located, the more undetected cement particles were found after the removal of the restoration. It seems that the null hypothesis must be rejected, as the location of the margin had a statistically significant relation to the amount of undetected cement.

The results of this study strongly correlate with the previous findings from the *in vitro* experiment, which was one of the first to recognize the risks of deep subgingival margins of implant-supported restorations (Linkevicius et al. 2011). It showed that cement can be completely removed only from abutments with visible margins and emphasized the dangers of subgingival cementation line location. The current clinical study overpassed the limitations of a laboratory trial, as cement remnants were cleaned in intraoral environment and its conclusions have direct clinical validation. The biggest amount of cement on the abutment/restoration complex was found in the groups 3 and 4 with the margins positioned 2 mm and 3 mm subgingivally. This raises the question of validity of current clinical recommendations. Based on both studies, it can be suggested that an implant abutment must possess supragingival or equigingival cementation margins for intraoral cementation. This in turn brings the question of aesthetics, as visible margins of titanium or gold abutments have a poorer esthetical outcome (Sailer et al. 2007; Jung et al. 2008). Therefore, the use of zirconium abutments would be advisable.

The current clinical study reported that cement remnants may be found in the peri-implant sulcus, not only adhered to the abutment or restoration. This is quite opposite to the results of the laboratory trial (Linkevicius et al. 2011), where no cement was found in the imitation of soft peri-implant tissues. The results have shown that there was statistically significant increase of excess cement in the peri-implant sulcus as the margin deepened. It shows that even if the cement is detached from the abutment/restoration surface during cleaning, it may reside in the peri-implant sulcus.

Large amounts of uncleaned cement around implants with deep subgingival margins can be explained by the following factors: too deep margin location, properties of luting agent, false convictions of the researcher, and inability of radiographic examination to reveal remnants of cement.

Placing cementation margins subgingivally is a common procedure, encouraged by clinical recommendations, which allow having cement line up to 2 mm below gingival contour (Andersson et al. 1998). The results of this clinical trial conversely state that it is not safe to leave the cementation margin 2 mm subgingivally as there is a very high probability that cement remnants will not be completely removed.

The fact that the researcher was sure that all cement was removed was also registered in previous experiments (Agar et al. 1997; Linkevicius et al. 2011). This presupposes that indeed clinicians feel too confident when removing cement. One of the factors to explain this phenomenon probably lies in the process of conventional cementing restorations on teeth. During seating, hydraulic pressure builds up and cement travels to the direction of least resistance (Patel et al. 2009) – through the margin to the gingival sulcus. However, the perpendicular fiber attachment around teeth provides a sufficient barrier and cement excess

Table 1. **Proportion of cement/restoration and cement/peri-implant tissues in pixels depending on the location of the margin**

Group	Cement/crown proportion in pixels ± SE	Cement/soft tissues proportion in pixels ± SE
1	0.002 ± 0.001	0.014 ± 0.006
2	0.024 ± 0.005	0.052 ± 0.011
3	0.036 ± 0.004	0.057 ± 0.009
4	0.055 ± 0.007	0.071 ± 0.012

Table 2. **The increase of undetected excess (increase of the proportion of the pixels) when margins located deeper ($P = 0.00$) and no statistical dependence of the excess (proportion of the pixels) left in soft tissues and location of the margin ($P = 0.045$) (Kruskal–Wallis test, $P \leq 0.05$)**

Group	N	Median
Groups of cement/crown pixels proportion		
1	14	0.002
2	56	0.009
3	74	0.027
4	68	0.043
Total	212	
$P = 0.000$		
Groups of cement/soft tissue pixels proportion		
1	14	0.000
2	56	0.023
3	74	0.035
4	68	0.035
Total	212	
$P = 0.045$		

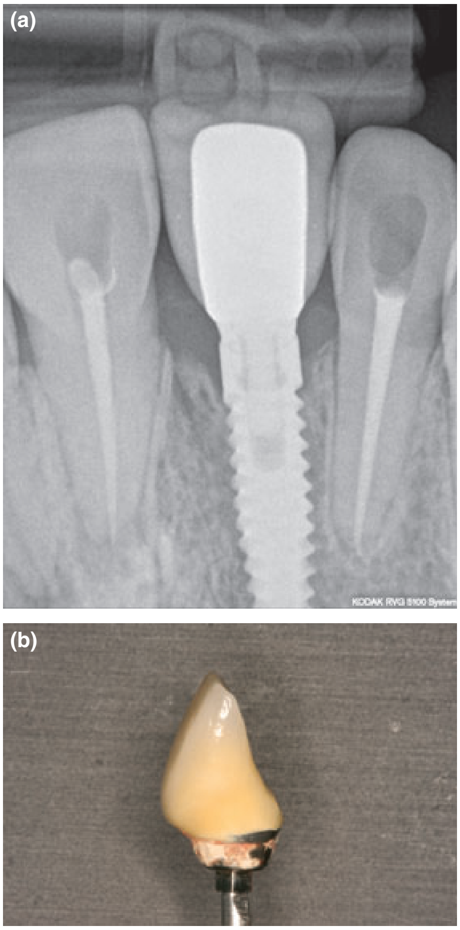

Fig. 8. (a) Radiographic image of restoration without visible cement remnants proximally and buccaly. (b) Cement on mesial and buccal sites of the removed restoration.

does not penetrate further and escapes to the surface of the gingival sulcus, where it is easy to detect. It is well known that peri-implant tissues do not possess similar protective mechanism (Cochran et al. 1997; Hermann et al. 2001) and are less resistant to pressure (Ericsson & Lindhe 1993). Thus, cement excess may be pushed further subgingivally with only a part of it escaping to the surface.

The properties of dental cement may also have had influence on the results of this clinical trial. Almost two decades ago Agar et al. (1997), showed that dental cement containing resins is the most difficult to remove from the surface of abutments. In addition, the removal of such cement resulted in the most extensive scratching of the metal surface. Nevertheless, glass-ionomer modified with resins was chosen for crown cementation in this study, because this luting agent was also used in the preceding laboratory experiment (Linkevicius et al. 2011). Likewise, a recent survey has shown, that glass-ionomer modified with resins is the most popular cement to use for permanent delivery of implant-supported restorations in US dental schools, reaching up to 70% of usage (Tarica et al. 2010). This clinical study could suggest the recommendation that clinicians should select cement with less adhesive characteristics for cementation of implant restorations, like zinc phosphate, whose cleaning properties are much superior to other cements (Agar et al. 1997).

An interesting finding was that radiographic examination cannot be trusted to detect not removed pieces of cement. It is obvious that it is impossible to inspect palatinal/lingual and facial areas due to the obstruction of the implant/abutment complex. Also, cement was visible medially only in four cases and in six cases distally of 53 radiographic images, what makes 7.5% and 11.3%, respectively. A partial explanation to that may be found in the study by Wadhwani et al. (2010), which has proved that radiographic density of implant restorative cements is rather poor and greatly depends on the thickness of the specimens. For example, glass-ionomer and resin cements could be detected only if the fragment was 2 mm or more in thickness, whereas smaller pieces would remain unseen. It means that probably the only way to detect an excess of cement is to use an abutment with a visible margin for cementation. Back in 1966, Christensen (1966) proved that the visibility of the margin plays a crucial role in its evaluation.

Standard abutments were used to maintain an exact place of the cementation margin, as the standard abutments of the implant system which was employed have a predetermined position of the shoulder 1.5 mm from the implant/abutment connection. In addition, fabrication of screw-and cement-retained restorations allows using standard abutments for cementation in the mouth, as they can be removed for cleaning (Rajan & Gunaseelan 2004). This feature was very important in the current study, as it allowed evaluating the amounts of cement remnants. The shape of standard abutments may have also had influence on the amount of undetected cement, as they are usually too narrow and possess undercuts, which aggravates cleaning. However, the exact impact of the abutment diameter or shape on the amount of cement remnants is still to be established. Meantime, the traditional cement-retained restorations individual abutments should be used for intraoral cementation (Dumbrigue et al. 2002; Linkevicius et al. 2011).

A number of methods have been proposed to reduce the cement flow into the sulcus. The use of a copy abutment (Wadhwani & Pineyro 2009), venting of the crowns (Patel et al. 2009) or reduction of luting agent placement into the restorations (Ishikiriama et al. 1981) certainly have advantages, however, complicated control of the procedures may limit their usage in clinical practice.

The role of cement in the development of peri-implantitis is still controversial. Excess cement in subgingival spaces can be described as an "artificial calculus" and may have a similar irritating effect as a calcified calculus on periodontally involved teeth (White 1997). A multicenter 3-year prospective study reported that peri-implant soft tissues responded more favorably to screw-retained crowns as compared with cement-retained crowns (Weber et al. 2006). In contrast Blanes et al. (2007) have shown that peri-implant tissues around cemented restorations were not more inflamed as compared to tissues around screw-retained prostheses. The analysis of current literature shows that several types of peri-implant reactions to undetected excess cement might be distinguished – early peri-implantitis, when swelling, bleeding, and accompanying bone loss develop from a weeks to few months after delivery of restorations (Pauletto et al. 1999; Gapski et al. 2008) or delayed peri-implantitis, when inflammation and bone resorption occur many years after cementation. Sometimes a complete absence of peri-implant tissue response to cement remnants may be expected as well (Wilson 2009). The exact reasons for these differences are still unknown, however, it can be hypothesized that an individual's susceptibility to periodontal infection may also play an important role in the progress of cement-related crestal bone loss. Thus, it can be stated that the previous *in vitro* studies (Agar et al. 1997; Linkevicius et al. 2011) and the current clinical trial confirm that excess cement could remain in subgingival spaces; however, this does not necessarily lead to peri-implantitis occurrence. Another interesting point is that cement remnants in the current study were evaluated straight after cementation. This excluded the possibility for self elimination of cement under regular oral hygiene, what may happen in post-cementation period. Some of the cement particles may escape from peri-implant sulcus reducing the possibility of delayed peri-implantitis development. The method of mathematical ratio calculation between the surface area of cement remnants and the abutment-restoration assembly or peri-implant sulcus was selected. Previously this method was successfully used to estimate dental plaque accumulation on the surface of teeth (Aleksejuniene et al. 2006). Thereafter Linkevicius et al. (2011) has found significant correlation between calculation of proportion and actual weighting of the cement in experimental model.

The present study has several limitations. Not equal distribution of sample sizes between groups could have influenced the results, however, such allotment reflects clinical reality, as the most frequent location of the margins are 1 mm or 2 mm subgingivally. In addition, the diameter of standard abutments might also have impact on quantity of cement remnants, however, this could be the topic of a separate research. The amount of the cement loaded into the crown was not weighted, however, all efforts were put to have as equal conditions as possible – the ratio of liquid/powder was always the same and the application of the cement inside the restoration was alike. On the other hand the consistency of peri-implant tissues should also be kept in mind, as resilience of gingiva in different individuals may vary.

Therefore, in spite of aforementioned limitations, the study has significant theoretical and practical implications.

Conclusions

Within the limitations of the study, the following conclusions could be drawn:

1. The deeper the position of the margin, the more undetected cement could be

found after cleaning, adhered to abutment/restoration complex and in perimplant tissues. Abutments with visible margins could be recommended for intraoral cementation.

2. Radiographic examination should only be a supplementary method for detection of cement excess.
3. The use of standard abutments for cementation with permanent cement should be very careful or completely suspended due to high risk of cement excess.

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