CLINICAL ORAL IMPLANTS RESEARCH

Tomas Linkevicius
Egle Vindasiute
Algirdas Puisys
Vytaute Peciuliene

The influence of margin location on the amount of undetected cement excess after delivery of cement-retained implant restorations

Authors' affiliations:
Egle Vindasiute, Algirdas Puisys, Tomas Linkevicius, Vilnius Research Group, Vilnius, Lithuania
Egle Vindasiute, Algirdas Puisys, Tomas Linkevicius, Vilnius Implantology Center, Vilnius, Lithuania
Vytaute Peciuliene, Tomas Linkevicius, Institute of Odontology, Faculty of Medicine, Vilnius University, Vilnius, Lithuania

Corresponding author:
Tomas Linkevicius
Institute of Odontology
Faculty of Medicine
Vilnius University
Zalgirio str. 115/117
LT- 08217, Vilnius
Lithuania
Tel.: +370 687 72840
Fax: +370 527 60725
e-mail: linktomo@gmail.com

Key words: cast abutments, cement cleaning, cement excess, cement-retained implant restorations, subgingival margins

Abstract

Objectives: The aim of this study was to evaluate the amount of the residual cement excess after cementation and cleaning of implant-supported restorations with various positions of the margins.

Material and methods: Twenty-five casts with embedded implant analogs and flexible soft-tissue imitation were used in the study. Individual abutments with different position of the margin – from 1 mm supragingivally to 3 mm below the gingival level – were modelled and divided equally into five groups. The same amount of polished metal crowns was luted to prosthetic abutments, excess cement was cleaned and the restorations were removed for evaluation of the undetected cement remnants. All quadrants of each specimen were photographed for calculation of the ratio between the cement remnants area and the total specimen area using Adobe Photoshop. Afterwards, cement remnants were cleared from each specimen and weighed with analytical balances.

Results: The measurements in all the groups consisted of (1) the relation between the cement remnants area and the total area of the specimen; and (2) cement excess weight in grams after cleaning: group 1 (0.0111 ± 0.021; 0.0003 ± 0.0001 g); group 2 (0.0165 ± 0.019; 0.0008 ± 0.0003 g); group 3 (0.0572 ± 0.028; 0.0013 ± 0.0005 g); group 4 (0.1158 ± 0.054; 0.0051 ± 0.0013 g); and group 5 (0.1171 ± 0.059; 0.0063 ± 0.0021 g). Results showed significant increase of undetected cement quantity, as the restoration margins were located deeper subgingivally, using weighting ($P = 0$) and calculation of proportion ($P = 0$). There was a significant correlation between evaluation techniques ($r = 0.889$; $P = 0$).

Conclusions: The amount of residual cement after cleaning increased as the restoration margins were located more subgingivally.

The use of cement-retained restorations has become a standard of care in prosthetic rehabilitation of dental implants (Jung et al. 2008). Simple fabrication, low cost and similarity to tooth-borne prostheses have made this way of implant restoration the method of choice in hands of many clinicians (Michalakis et al. 2003). However, besides many advantages, cemented restorations posses a number of shortcomings, including the difficulty to completely eliminate the excess cement from soft peri-implant tissues around the implant (Chee et al. 1999).

Several case reports have been published revealing complications, caused by residual cement, ranging from acute severe bone resorption (Pauletto et al. 1999) to implant loss (Gapski et al. 2008). In addition, a recent study by Wilson (2009) has established a strong relation between residual cement and the development of chronic peri-implant disease. It seems that the influence of excess cement, as a factor in aetiology of peri-implantitis, needs to be researched more thoroughly.

One of the possible reasons for cement remnants in tissues may be the common practice to place implant restoration margins subgingivally. Buser and colleagues have recommended to leave the margin 1–2 mm subgingivally and this position is still a reference point for many clinicians (Belser et al. 1998). Furthermore, Andersson et al. (1998)have suggested that crown margins should be even deeper than 2 mm to achieve a better crown emergence profile. In contrast, Agar et al. (1997) have demonstrated that it is impossible to clean all the cement if a margin is located 1.5–3 mm below the peri-implant tissue level. Consequently, a clinician faces the following problem: aesthetic paradigms require leaving the crown margin subgingivally, which, in turn, may lead to incomplete cement clean-up and development of iatrogenic peri-implant disease.

Date:
Accepted 26 October 2010

To cite this article:
Linkevicius T, Vindasiute E, Puisys A, Peciuliene, V. The influence of margin location on the amount of undetected cement excess after delivery of cement-retained implant restorations.
Clin. Oral Impl. Res. **22**, 2011; 1379–1384.
doi: 10.1111/j.1600-0501.2010.02119.x

© 2011 John Wiley & Sons A/S

At present, there is a lack of certainty over the depth of the margin that would not pose a threat of leaving cement undetected after cleaning. Thus, the aims of this study were the following: (1) to assess the amount of the cement left after the cementation and cleaning of implant-supported restorations with various locations of the margins; (2) to compare two methods of evaluation: the computerized planimetric technique of cement amount assessment and weighing. A null hypothesis was formulated stating that subgingival location of the crown margin does not influence the amount of undetected cement.

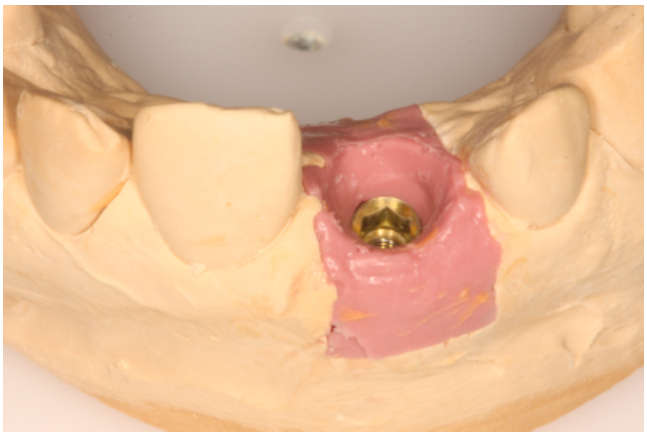

Fig. 1. Experimental model with implant analog and flexible gingiva mask.

Material and methods

Twenty-five models with embedded 3.5 mm diameter implant analogs (BioHorizons Internal, Birmingham, AL, USA) in the position of an anterior tooth were used in this study. An impression was taken from the patient, with an implant positioned approximately 5 mm below the gingival level. All the casts were mounted with type IV dental stone (Heraeus Kulzer GmbH, Hanau, Germany). A-silicone flexible gingiva mask Gum Quick Plus (Dreve Dentamid GmbH, Unna, Germany) was used for the soft-tissue imitation (Fig. 1).

Twenty-five individually casted abutments and the same number of metal crowns were fabricated using Starbond CoS alloy (S&S Scheftner GmbH, Mainz, Germany), consisting of Co 59%, Cr 25%, W 9.5% and Mo 3.5%, by the same operator. The abutments were modelled with various positions of the margin for the restorations (five groups of five specimens): group 1 (control) – 1 mm above the gingival level; group 2 – at the soft-tissue margin; group 3 – 1 mm below the marginal level; group 4 – 2 mm below the gingival level and group 5 – 3 mm subgingivally (Fig. 2).

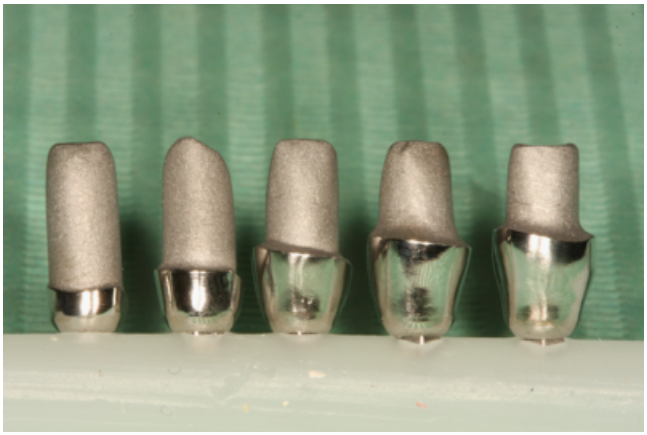

Fig. 2. Individually casted prosthetic abutments with different location of cementation margins.

Palatal openings were made in the crowns in order to have access to the abutment screw after cementation. This was necessary to ensure the retrievability of abutment-restoration system. Crowns and the part of the abutment contacting soft tissue were polished with rubber dental polishing wheels Polysoft (Renfert, Hilzinger, Germany) of 3 mm in thickness and 22 mm in diameter.

Resin-modified glass-ionomer cement Fuji Plus (GC, Tokyo, Japan) was selected as a luting agent in this study. Before cementation, the top of each prosthetic abutment was covered using dental wax – Wax Pak (3M UNITEK, Monrovia, CA, USA) – to protect the abutment screw. The palatal openings were closed with composite material Gradia Anterior (GC) to obturate the screw access space and prevent venting of luting agent during cementation. The cement was mixed according to the manufacturer's instructions; a thin layer was applied to all internal surfaces of the crowns and seated onto the abutment with a gentle finger pressure (Fig. 3). After setting, the excess was removed with a stainless steel explorer (Dentsply International Inc., Milford, DE, USA) and super-floss (Curaprox, Kriens, Switzerland) until the researcher decided it had been completely cleaned (Fig. 4). Then, the composite and wax were removed, the abutment screw was unscrewed and suprastructure was dismounted for assessment (Fig. 5).

Two techniques were selected to evaluate the excess of cement left after cleaning – the computerized planimetric method of cement assessment and weighing. First, all four quadrants (mesial, distal, labial and lingual) of the specimens were photographed using a specially constructed device to keep the standardized distance between the photo camera (Canon, Lake Success, NY, USA) and the specimen. 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 to outline the boundaries of each quadrant. To calculate the area covered with cement remnants, the ''pen tool'' and ''make path'' 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 (Fig. 6). The ratio between the area covered with cement and the total surface area of the specimen was calculated. A surface of the specimen was considered as a statistical unit, therefore each specimen had four measurements, resulting in sample size of 20 for each group.

The second method was to weigh the cement remnants removed from each specimen. Analytical digital scales Vibra (Shinko Denshi, Tokyo, Japan) with a readability of 0.0001 g were chosen for that purpose. A specimen was considered as a statistical unit, thus we had five specimens in each group.

A statistical analysis was carried out using SPSS software for Windows v.16 (SPSS Inc., Chicago, IL, USA). First, mean values with standard deviation were calculated. Owing to small sample size, independent K (Kruskall–

© 2011 John Wiley & Sons A/S

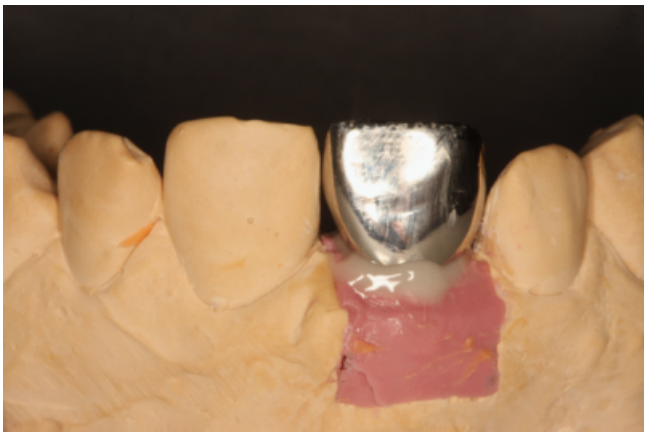

Fig. 3. Cement excess after seating of implant restoration.

Fig. 4. Tissues around implant restoration after meticulous cleaning of the cement.

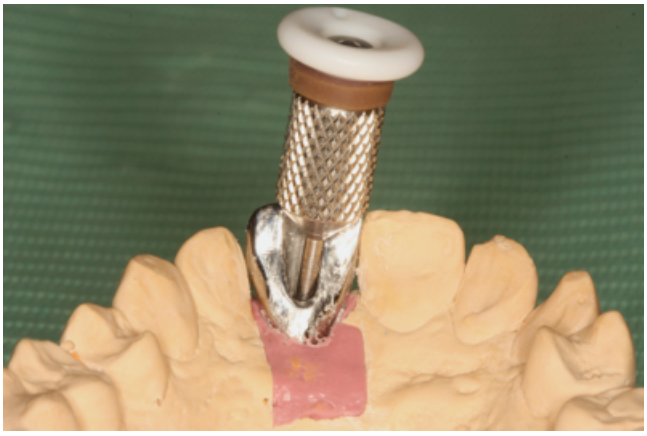

Fig. 5. Abutment screw is accessed through cleaned palatal opening to dismount the suprastructure for evaluation.

Wallis) test for nonparametric data was used to determine the influence of margin location on the amount of the undetected cement. If significant, Mann–Whitney test was applied to compare the groups. Simple scatter plot graphical visualization and Spearman's correlation coefficient were used to determine the relation between the two assessment techniques. Level of significance was set at $P = 0.05$.

Results

Various amounts of cement remnants were found on all specimens. The results in all groups consisted of (1) the weight of cement remnants in grams and (2) the proportion between the surface covered with cement excess and the total surface of the specimen quadrant (Table 1). Kruskal–Wallis test showed significant increase of undetected cement quantity, as the restoration margins were located deeper subgingivally, using weighting ($P = 0$) and calculation of proportion ($P = 0$) (Table 2).

***Table 1*. Cement remnants dependence on the location of the margin**

Group	Cement weight ± SD (g)	Proportion ± SD
1	0.0003 ± 0.0001	0.0111 ± 0.0212
2	0.0008 ± 0.0003	0.0165 ± 0.0192
3	0.0013 ± 0.0005	0.0572 ± 0.0288
4	0.0051 ± 0.0013	0.1158 ± 0.0547
5	0.0063 ± 0.0021	0.1171 ± 0.0594

***Table 2*. The increase of cement remnants in weight ($P = 0$) and proportion ($P = 0$) as the restoration margins were located deeper subgingivally (Kruskal–Wallis test, $P \leq 0.05$)**

	Depth	*N*	Mean rank
Proportion	−3	20	74.3
	−2	20	76.6
	−1	20	53.98
	0	20	27.53
	1	20	20.1
	Total	100	
Weight	−3	5	21.4
	−2	5	19.6
	−1	5	12.6
	0	5	8.4
	1	5	3
	Total	25	
Statistics		Proportion	Weight
χ^2		64,476	21,825
df		4	4
Significance		0	0

Mann–Whitney test revealed statistically significant differences between all the groups ($P \leq 0.05$) except groups 4 and 5 ($P \geq 0.05$), when the cement excess weight was evaluated (Fig. 7, Table 3). Assessment of proportion showed statistically significant differences between all the groups ($P \leq 0.05$), except groups 1 and 2, and groups 4 and 5 ($P \geq 0.05$) (Fig. 8, Table 3). The greatest amount of the undetected cement was found, when the margin was positioned 2 and 3 mm below the gingival level, the smallest – when the margin was visible – 1 mm above the soft-tissue level. Simple scatter graphic revealed positive distribution of the measurements (Fig. 9) and Spearman's correlation coefficient showed significant relation between both measuring techniques ($r = 0.889$; $P = 0$).

Discussion

Despite the efforts of the researcher, entire removal of cement remnants failed to be successful. It was impossible to clean excess cement around the implant restorations with subgingival margins, especially those positioned 2 mm or deeper.

© 2011 John Wiley & Sons A/S

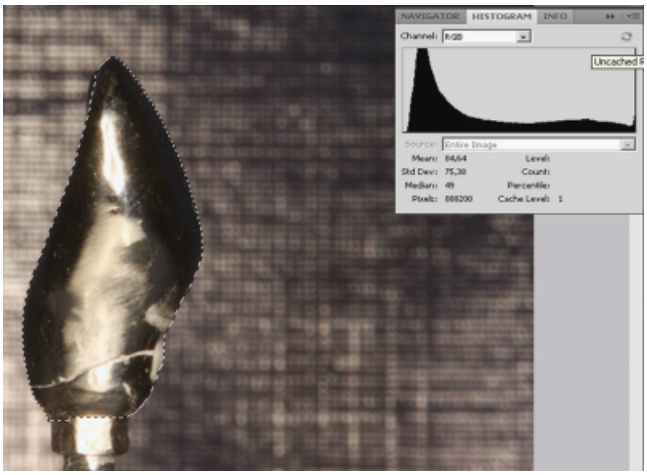

Fig. 6. Calculation of the proportion between area covered with cement remnants and the total surface of the specimen.

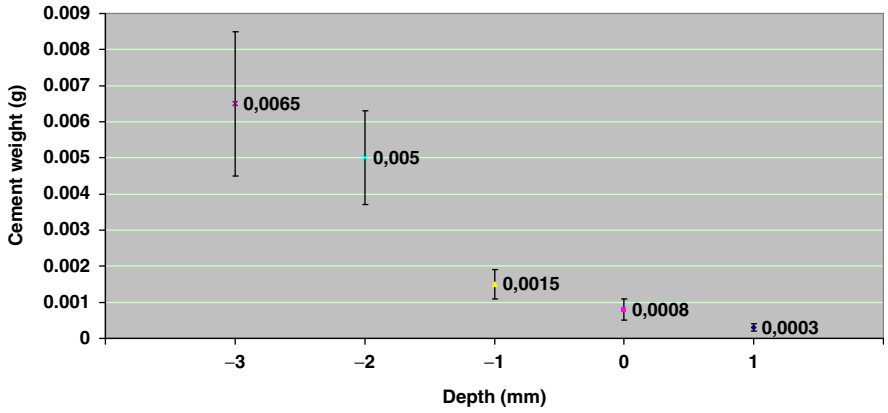

Fig. 7. The dependance of undetected cement remnants (weight in grams) on the location of the margin.

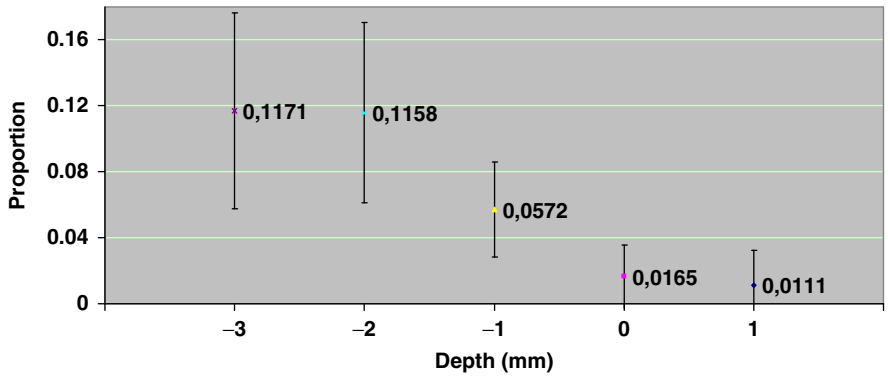

Fig. 8. The dependance of undetected cement remnants (proportion of pixels) on the location of the margin.

In contrast, the restorations with visible margins – 1 mm supragingivally or at the tissue level had almost all cement removed. Therefore, it can be concluded that the deeper the margin of the restoration was positioned, the more cement remnants were left overlooked. Thus, the data support the rejection of the null hypothesis, as the location of the margin had a statistically significant relation to the amount of undetected cement after cleaning.

The results of our study correlate with the findings of Agar and colleagues, who were the first to state that cementation of the prostheses with 1.5–3 mm subgingivally placed margins may lead to insufficient cement removal. In addition, the study has revealed that cleaning of cement may result in extensive scratching of the abutment (Agar et al. 1997).

***Table 3.* Difference between the groups (Mann–Whitney test, significant when $P \leq 0.05$)**

Group	Cement weight	Proportion
1 and 2	$P = 0.008$	$P = 0.054$
2 and 3	$P = 0.025$	$P = 0$
3 and 4	$P = 0.009$	$P = 0$
4 and 5	$P = 0.344$	$P = 0.91$

Bold values show statistical significance.

In the current experiment, residual cement was most present around the abutments with margins positioned 3 mm subgingivally; however, no statistical difference was determined with the case of the 2 mm margin abutment. It can be suggested that 2 mm below the gingival level is a dangerous choice for a restoration margin to be located and the existing recommendations to have margins at that depth should be abandoned.

An interesting finding of the study was the fact that some cement was left around restorations, although the researcher was convinced to have removed all the cement. A similar observation was made in a previously mentioned *in vitro* study, where six researchers were confident that they had cleaned the cement; however, the specimen examination showed considerable amounts of undetected luting agent around abutments and restorations (Agar et al. 1997). This corresponds to the result of a clinical investigation which showed that over 80% of implant restorations contained residual excess cement, although, as it can be expected, operators thought that they had removed it (Wilson 2009). It is obvious that clinicians are prone to overestimate their ability to completely remove excess cement from the restorations with subgingival margins.

The properties of dental cement may also have had influence on the results of the study. It was shown that luting agent with resin component is the most difficult to remove from polished abutment surface (Agar et al. 1997). Glass-ionomer modified with resins was chosen for specimen cementation and that may facilitate the explanation why the cleaning of residual cement adhered to abutment/crown surface at the deep subgingivally margins was not effective. It seems that clinician should select cement with less adhesive properties for cementation of implant restorations.

The current standpoint recommends placing the margin of an abutment below the soft-tissue level for aesthetic reasons (Belser et al. 2004a, 2004b; Higginbottom et al. 2004). This is commonly performed to hide the abutment–crown interface and to accommodate possible peri-implant tissue recession with time. A review by Buser and colleagues has suggested that under normal conditions, the implant shoulder should be positioned 1–2 mm apically to the labial cemento-enamel junction of adjacent teeth,

© 2011 John Wiley & Sons A/S

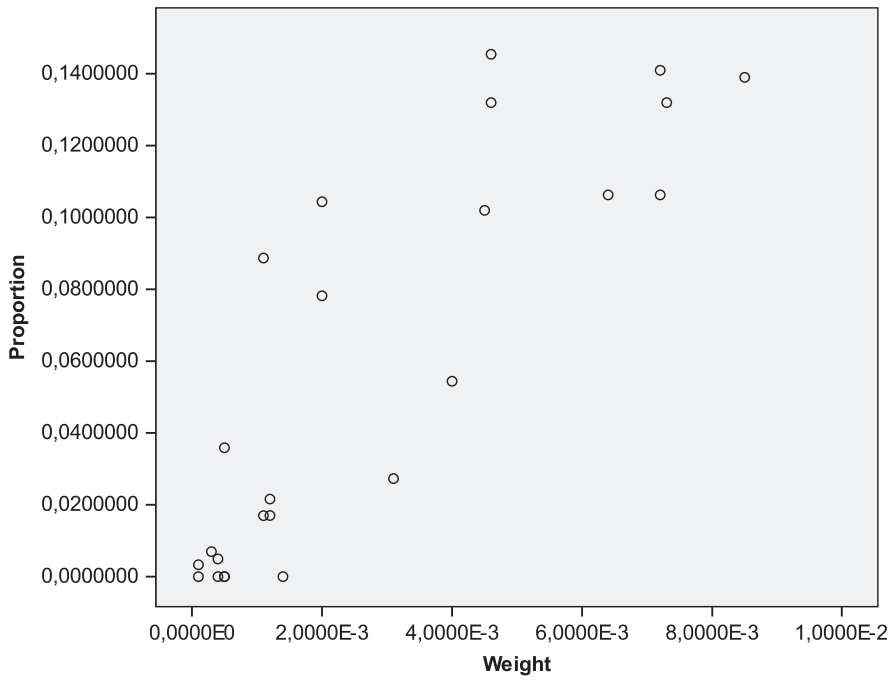

Fig. 9. Scatter plot of the measurements data.

thus the restoration margin originates 2–3 mm subgingivally (Belser et al. 1998). In sites of aesthetic concern, it is suggested that the submucosal implant shoulder location should not exceed 2 mm at the labial aspect, as recommended in another review paper (Belser et al. 2000). It must be noted that in such cases, interproximal crown margins are located even more subgingivally and are impossible to reach during cement cleaning or daily hygiene procedures.

The result of the current study contradicts the proposed criteria for crown margin location, suggesting that cemented implant restoration should have a more coronal position. Andersson with colleagues were probably the first to alert that deep subgingival margins can lead to insufficient cement removal. The authors have recommended careful placement of margins deeper than 2 mm below gingival level, as the risk of leaving the cement is not eliminated (Andersson et al. 1995).

It is interesting to note that the specimens with cementation margins located supragingivally or equally with gingiva had the least excess of luting cement after cleaning. This seems to be a logical outcome as the finish line was clearly visible and the investigator could remove the excess without difficulties. It is obvious that margin visibility plays a crucial role in cement elimination. This can be compared with the study of Christensen, who tested marginal fit of gold inlay castings with visible and not visible clinical examination margins. It was concluded that an explorer examination of visually accessible gold inlay margins is superior to and more reliable than an explorer or radiographic examination of visually inaccessible margins (Christensen 1966).

The role of cement in the aetiology of peri-implantitis is not completely clear. It is proposed that cement remaining can act as an additional irritant to soft tissues, like calculus around roots of periodontally involved teeth (White 1997), in addition to microbiological contamination (Tan et al. 2004) or possible toxic reaction of the cement to peri-implant tissues (Schedle et al. 1998). A number of case reports demonstrate the occurrence of acute peri-implantitis, manifesting in tissue swelling, inflammation, fistula formation around implants within few months after the delivery of cement-retained prostheses (Pauletto et al. 1999). After flap elevation, the authors reported cement remnants around implants, usually accompanied by rapid and profuse bone loss. In contrast, a clinical study has shown that cement excess in subgingival spaces was found in 81% of implants showing signs of peri-implantitis. Interestingly, some of the implants were restored 9 years ago, showing delayed response to the residual cement (Wilson 2009). It may be speculated that the development of acute or chronic peri-implant disease depends on the proximity of the cement remains to the bone – the closer the luting agent is leaked to the bone, the more acute is the reaction of the peri-implant tissues. In addition, individual host susceptibility to periodontal infection may also play an important role in progress of cement-related crestal bone loss as well.

In contrast, Giannopoulou et al. (2003) have shown that intracrevicular restoration margins did not cause any negative peri-implant host and microbial interactions. However, the publication failed to identify what kinds of crowns, screw- or cement-retained, were used in the study.

It is likely that screw-retained prostheses should evoke more favourable response of peri-implant tissues as cement is not required in those cases; however, there are many studies reporting no adverse peri-implant tissue reaction to cement-retained implant prostheses. Blanes et al. (2007) have shown that peri-implant tissues around cemented restorations were not more inflamed as compared with tissues around screw-retained prostheses. Keller et al. (1998) and Assenza et al. (2006) have shown that the microbiological and histological parameters of peri-implant tissues around both types of prostheses do not differ. Finally, a retrospective 8-year private practise study did not show a higher biological complication rate of cemented restorations (Nedir et al. 2006). However, the absence of peri-implant bone loss does not prove that cement remnants are not present around luted restorations in subgingival spaces (Wilson 2009). The lack of tissue response cannot be fully explained, but it is obvious that cement deposits irritate peri-implant tissues, although the reaction may be delayed.

Casted individual abutments were chosen for the study to reflect a clinical situation as closely as possible and to control the position of the shoulder. In addition, the use of individual abutments with a restorative margin, which follows the contour of cemento-enamel junction, was advocated as a method to minimize excess luting agent after cementation (Dumbrigue et al. 2002). However, according to the results of this study, the depth of the margin was more important than the shape of the abutment.

Another suggested method to reduce the cement flow after seating of the crown is to use a copy of abutment. The intaglio surface of implant restoration is lined with cement and crown is placed onto abutment model. The excess cement is wiped off and the implant restoration is cemented on implant abutment intraorally (Wadhwani & Pineryo 2009). Venting of the crowns (Patel et al. 2009), placing luting agent only in occlusal or cervical thirds of the restoration (Ishikiriama et al. 1981) might also be considered to avoid gross extrusion of cement into peri-implant tissues. However, the difficulty to determine the exact amount of the cement required and possible too little or incomplete sealing of the margins may reduce efficiency of proposed approaches in clinical practise.

Finally, the study found statistically significant correlation linking the weight of cement

© 2011 John Wiley & Sons A/S

excess to the mathematical ratio between the surface area of cement remnants and the abutment-restoration assembly. Previously, this method was used to estimate dental plaque accumulation on the surface of teeth (Aleksejuniene et al. 2006). Therefore, it could be helpful in clinical trials if the difficult process of weighing is to be avoided.

In summary, it could be concluded that it is difficult to remove all cement excess after cementation if the margins are located subgingivally. The deeper the position of the margin, the greater amount of undetected cement can be undetected. All cement remnants were removed only when the margin was visible. The greatest amount of cement remnants was left when the crown margin was 2 or 3 mm below the gingival level. It could be advised to use individual abutments with clinically visible margins and easy cleanable cement for luting cement-retained restorations or give preference to screw-retained prostheses.

Further studies are required to determine whether the result of the current *in vitro* experiment would be repeated in clinical situation.

References

Agar, J.R., Cameron, S.M., Hughbanks, J.C. & Parker, M.H. (1997) Cement removal from restorations luted to titanium abutments with simulated subgingival margins. *Journal of Prosthetic Dentistry* **78**: 43–47.

Aleksejuniene, J., Scheie, A.A. & Holst, D. (2006) Inter-individual variation in the plaque formation rate of young individuals. *International Journal of Dental Hygiene* **4**: 35–40.

Andersson, B., Odman, P., Lindvall, A.M. & Branemark, P.I. (1998) Cemented single crowns on osseointegrated implants after 5 years: results from a prospective study on CeraOne. *International Journal of Prosthodontics* **11**: 212–218.

Andersson, B., Odman, P., Lindvall, A.M. & Lithner, B. (1995) Single-tooth restorations supported by osseointegrated implants: results and experiences from a prospective study after 2 to 3 years. *The International Journal of Oral & Maxillofacial Implants* **10**: 702–711.

Assenza, B., Artese, L., Scarano, A., Rubini, C., Perrotti, V., Piattelli, M., Thams, U., San, R.F., Piccirilli, M. & Piattelli, A. (2006) Screw vs cement-implant-retained restorations: an experimental study in the beagle. Part 2. Immunohistochemical evaluation of the peri-implant tissues. *Journal of Oral Implantology* **32**: 1–7.

Belser, U., Buser, D. & Higginbottom, F. (2004a) Consensus statements and recommended clinical procedures regarding esthetics in implant dentistry. *The International Journal of Oral & Maxillofacial Implants* **19** (Suppl.): 73–74.

Belser, U.C., Buser, D., Hess, D., Schmid, B., Bernard, J.P. & Lang, N.P. (1998) Aesthetic implant restorations in partially edentulous patients – a critical appraisal. *Periodontology 2000* **17**: 132–150.

Belser, U.C., Mericske-Stern, R., Bernard, J.P. & Taylor, T.D. (2000) Prosthetic management of the partially dentate patient with fixed implant restorations. *Clinical Oral Implants Research* **11** (Suppl.): 126–145.

Belser, U.C., Schmid, B., Higginbottom, F. & Buser, D. (2004b) Outcome analysis of implant restorations located in the anterior maxilla: a review of the recent literature. *The International Journal of Oral & Maxillofacial Implants* **19** (Suppl.): 30–42.

Blanes, R.J., Bernard, J.P., Blanes, Z.M. & Belser, U.C. (2007) A 10-year prospective study of ITI dental implants placed in the posterior region. II: influence of the crown-to-implant ratio and different prosthetic treatment modalities on crestal bone loss. *Clinical Oral Implants Research* **18**: 707–714.

Chee, W., Felton, D.A., Johnson, P.F. & Sullivan, D.Y. (1999) Cemented versus screw-retained implant prostheses: which is better? *The International Journal of Oral & Maxillofacial Implants* **14**: 137–141.

Christensen, G.J. (1966) Marginal fit of gold inlay castings. *Journal of Prosthetic Dentistry* **16**: 297–305.

Dumbrigue, H.B., Abanomi, A.A. & Cheng, L.L. (2002) Techniques to minimize excess luting agent in cement-retained implant restorations. *Journal of Prosthetic Dentistry* **87**: 112–114.

Gapski, R., Neugeboren, N., Pomeranz, A.Z. & Reissner, M.W. (2008) Endosseous implant failure influenced by crown cementation: a clinical case report. *The International Journal of Oral & Maxillofacial Implants* **23**: 943–946.

Giannopoulou, C., Bernard, J.P., Buser, D., Carrel, A. & Belser, U.C. (2003) Effect of intracrevicular restoration margins on peri-implant health: clinical, biochemical, and microbiologic findings around esthetic implants up to 9 years. *The International Journal of Oral & Maxillofacial Implants* **18**: 173–181.

Higginbottom, F., Belser, U., Jones, J.D. & Keith, S.E. (2004) Prosthetic management of implants in the esthetic zone. *The International Journal of Oral & Maxillofacial Implants* **19** (Suppl.): 62–72.

Ishikiriama, A., Oliveira Jde, F., Vieira, D.F. & Mondelli, J. (1981) Influence of some factors on the fit of cemented crowns. *Journal of Prosthetic Dentistry* **45**: 400–404.

Jung, R.E., Pjetursson, B.E., Glauser, R., Zembic, A., Zwahlen, M. & Lang, N.P. (2008) A systematic review of the 5-year survival and complication rates of implant-supported single crowns. *Clinical Oral Implants Research* **19**: 119–130.

Keller, W., Bragger, U. & Mombelli, A. (1998) Peri-implant microflora of implants with cemented and screw retained suprastructures. *Clinical Oral Implants Research* **9**: 209–217.

Michalakis, K.X., Hirayama, H. & Garefis, P.D. (2003) Cement-retained versus screw-retained implant restorations: a critical review. *The International Journal of Oral & Maxillofacial Implants* **18**: 719–728.

Nedir, R., Bischof, M., Szmukler-Moncler, S., Belser, U.C. & Samson, J. (2006) Prosthetic complications with dental implants: from an up-to-8-year experience in private practice. *The International Journal of Oral & Maxillofacial Implants* **21**: 919–928.

Patel, D., Invest, J.C., Tredwin, C.J., Setchell, D.J. & Moles, D.R. (2009) An analysis of the effect of a vent hole on excess cement expressed at the crown-abutment margin for cement-retained implant crowns. *Journal of Prosthodontics* **18**: 54–59.

Pauletto, N., Lahiffe, B.J. & Walton, J.N. (1999) Complications associated with excess cement around crowns on osseointegrated implants: a clinical report. *The International Journal of Oral & Maxillofacial Implants* **14**: 865–868.

Schedle, A., Franz, A., Rausch-Fan, X., Spittler, A., Lucas, T., Samorapoompichit, P., Sperr, W. & Boltz-Nitulescu, G. (1998) Cytotoxic effects of dental composites, adhesive substances, compomers and cements. *Dental Materials* **14**: 429–440.

Tan, B., Gillam, D.G., Mordan, N.J. & Galgut, P.N. (2004) A preliminary investigation into the ultrastructure of dental calculus and associated bacteria. *Journal of Clinical Periodontology* **31**: 364–369.

Wadhwani, Ch. & Pineryo, A. (2009) Technique for controlling the cement for an implant crown. *Journal of Prosthetic Dentistry* **107**: 57–58.

White, D.J. (1997) Dental calculus: recent insights into occurrence, formation, prevention, removal and oral health effects of supragingival and subgingival deposits. *European Journal of Oral Sciences* **105**: 508–522.

Wilson, G.W. (2009) The positive relationship between excess cement and peri-implant disease: a prospective clinical endoscopic study. *Journal of Periodontology* **80**: 1388–1392.

© 2011 John Wiley & Sons A/S