Effect of Implant Abutment Modification on the Extrusion of Excess Cement at the Crown-Abutment Margin for Cement-Retained Implant Restorations

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Purpose: *To compare the effect of implant abutment modification on the amount of cement extruded at the crown-abutment margin and to evaluate the vertical discrepancy after cementation.* ***Materials and Methods:*** *Access openings of titanium abutments were modified with an opening (open) and placement of two vent holes 3 mm from the occlusal edge and 180 degrees apart (internal vent). Access openings were filled with resin material (closed) and used as controls. Each abutment was secured to an implant analog. Eugenol-free zinc oxide cement (TempBond NE) was selected to cement the cast crowns (n = 9) onto test abutments. The amount of cement extruded out of the margin was calculated, and vertical seating discrepancies were determined with a linear transducer device before and after cementation. Differences among groups were analyzed statistically.* ***Results:*** *The mean amount of extruded cement ranged from 36% to 90% of the total cement placed within the crowns. The order, from least to greatest amount of excess cement extrusion at the margins, was internal vent, open, and closed; significant differences were observed between test groups. The net vertical discrepancies of tested specimens ranged from –7 μm to +6 μm (mean, 0 μm). No statistically significant differences in vertical discrepancy were found between the groups.* ***Conclusions:*** *Venting the hollow abutment resulted in the least amount of cement extrusion when compared to closing off the screw access channel or leaving it open. Within the limitations of this study, it may be concluded that the use of two, 0.75-mm radius vent holes placed 3 mm apical to the occlusal area of the abutment and 180 degrees apart will limit the amount of cement extruded into the gingival sulcus of implant-retained crowns.* Int J Oral Maxillofac Implants 2011;26:1241–1246

Key words: *cementation, cement retention, customized abutment, implant restorations, seating discrepancy, temporary cement*

Fixed implant restorations are usually retained by screws or cement.[1,2] From the 1980s to the early 1990s there was a strong preference for screw-retained restorations, which subsequently changed with the introduction of the Swiss Bonefit implant, later called the ITI implant (Straumann). At about the same time, the transition from screw to cement retention was also promoted with the introduction of the CeraOne component by Nobelpharma (now Nobel Biocare).[3] The advantages of cement-retained implant crowns include improved esthetics, control of occlusion, decreased cost and time[4]; also, in general, cementation of fixed implant restorations more closely follows the procedures routinely performed on natural teeth.[3,4] However, cement-retained implant restorations are not without their issues. In a 3-year prospective multicenter study comparing the health of the soft tissues surrounding cemented and screw-retained implant restorations, it was reported that the tissues responded more favorably in the latter cases.[5]

Multiple case reports have cited excess cement as a major cause of peri-implantitis,[6,7] and a recent cohort study indicated that 80% of peri-implant disease was a direct result of bacterial colonization of extruded cement.[8] The study also indicated that the time for the peri-implant disease to become clinically evident ranged from 4 months to almost 9.3 years.

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Cementation procedures on implant restorations to minimize the extrusion of excess cement include modified cementing techniques to limit the total amount of cement used,[9,10] as well as crown venting procedures.[11] With tooth-supported crowns, the effect of venting is useful for seating crowns.[12] With implant-supported crowns, it is important to control the extrusion of excess cement at the crown-abutment margin. The size and position of a crown vent hole have been evaluated and related to the percentage weight of cement extruded at the crown-abutment margin and vent hole for cement-retained implant crowns.[13]

The effect of venting the occlusal surface of crowns was investigated almost half a century ago by Jorgensen and Petersen, who demonstrated improved seating between a crown and a simulated prepared tooth when measured as vertical displacement.[14] Further studies related to crown seating have also demonstrated the use of vertical displacement on tooth forms.[15,16] Cementation pressures relative to seating capability, as well as other factors that would affect the rate at which the excess cement is forced out of the space between a prepared tooth and a crown, have also been documented.[17]

When planning cemented implant restorations, consideration of the abutment type includes materials and configuration. Stock abutments supplied by manufacturers require little or no modification. Others, fabricated by a laboratory, are customized, ie, patient-specific abutments. Abutments commonly used with implant cementation procedures may also be classified as solid, with no internal cavity, or hollow, where the screw is accessed through a lumen within the center of the abutment. The screw access channel in the hollow or open abutment is commonly completely occluded prior to cementing the crown[18]; ie, it is covered with materials such as cotton wool, polytetrafluoroethylene, wax, and/or composite.[18,19] The need to completely occlude the abutment prior to cementation has been evaluated[20] but not with respect to the amount of cement that may be contained within it. When a crown that seats fully onto an abutment is cemented, an inverse relationship exists between the amount retained and that extruded at the abutment-crown margin for a given amount of cement.

It has been hypothesized that an open/hollow abutment may provide an internal reservoir for cement. The flow of cement into the space provided may be further affected by auxiliary venting in the form of two round holes 180 degrees apart placed in the axial walls of the abutment. Therefore, this study sought to compare the effect on seating discrepancy, measured as vertical displacement of the restoration, of cementing a closed abutment (CA), an open abutment (OA), and an internal vent abutment (IVA). The null hypothesis was that the differences in cement reservoir space within abutments OA, IVA, and CA would have no effect on the amount of cement extruded at the margin of an implant crown-abutment assembly. Secondarily, it was hypothesized that there would be no differences in the vertical displacement of crowns cemented onto IVA, OA, and CA abutments.

MATERIALS AND METHODS

Twenty-seven Straight RC Anatomic Abutments and analogs for bone-level implants (Straumann USA) were selected for evaluation. This number was determined from a previous pilot study. The abutments were tightened to 35 Ncm with a torque wrench onto individual analogs. To facilitate crown coping fabrication, the abutment screw access channel was partially filled with a 3-cm-long piece of polytetrafluoroethylene tape, commonly known as plumber's tape (Oatey), packed over the screw head.[19] The remainder of the screw access chamber was filled with resin material (Triad, Dentsply International) that was contoured to conform to the occlusal aspect of the abutment and light-cured. Each of the abutment-analog complexes was numbered. A thin layer of wax lubricant (DVA Separator, Dental Ventures of America) was painted onto the abutments to act as a separator. The copings were fabricated by waxing directly to the metal abutment, as recommended by the manufacturer, and were standardized by placing each abutment into a custom jig and injecting wax around it. Twenty-seven wax copings were made and inspected for uniformity. Following investing (Microstar HS, Jensen Dental) and casting in high noble porcelain bonding alloy (JP1, Jensen Dental), the cast copings were adjusted under 20× magnification to assist in adaptation to their corresponding abutments. The same technician fabricated all copings and verified the clinical acceptability of margins. The implant copings were numbered individually to conform to the number of the abutment analog that they were fabricated on. The 27 copings were then randomly assigned to one of three groups: *(1)* the control group (CA), in which the entire screw access channel was filled with the resin material; *(2)* the OA group, which had the original open screw access channel, but the PTFE tape was left over the screw head to simulate what would be done in clinical practice to allow access to the screw head; and *(3)* the IVA group, which was similar to the OA group but featured the addition of two, 0.75-mm radius holes[13] placed 3 mm apical to the occlusal edge of the abutment, 180 degrees apart, to represent the mesial and distal proximal surfaces (Fig 1).

To assist in orientation and reduce errors caused by rotation of the coping on the abutment, four 5-mm-long vertical marks (midfacial, lingual, and each

Fig 1 *(Above)* Abutment modifications. *(Left to right*) Closed abutment, open abutment, and internal vent abutment.

Fig 2 *(Center)* Cemented coping-abutment-analog complex under a 5-kg load, with extruded excess cement shown.

Fig 3 *(Right)* The cleaned CAAC after removal of excess extruded cement.

proximal surface) were placed on the outer surface of each coping and on the corresponding position on the abutment apical to the margin. To measure seating discrepancy, the vertical height of the coping/abutment/analog complex (CAAC) was measured using a linear transducer device (Model GT2, Keyence) capable of accuracy to within 0.5 μm. A custom jig was made to facilitate all measurements. After all the precementation vertical measurements were made and recorded, the CAACs were weighed (Santorius analytic balance model GD 503). TempBond NE cement (Kerr USA) was selected and mixed according to the manufacturer's instructions and loaded into a 1.2-mL syringe with a fine tip (Ultradent Products). The mixed cement was placed into the intaglio surface until the coping was approximately 75% filled. Before the cement-containing coping was seated onto the abutment analog, the weight was recorded (preseating weight).

The cement-containing coping was then seated onto the appropriate abutment, initially held with finger pressure, then placed into a spring compression device. This process was completed well within the cement's working time. The seated unit was loaded with 5 kg of force[14] and allowed to set for 10 minutes (Fig 2). Excess cement was grossly removed from the cemented CAAC and refined with the use of a chemical solvent (Orange Solvent, EPR Industries). After being cleaned and air dried, the CAAC was weighed and recorded (cleaned cementation weight) (Fig 3). The weight of cement retained within the cemented CAAC was calculated by subtracting the cleaned cementation weight from the preseating weight. The total amount of cement loaded into the coping was calculated as the preseating weight minus the unfilled CAAC weight. The percentage of cement extruded during cementation was calculated using the preseating, cleaned cementation, and CAAC weights.

To evaluate the vertical discrepancy, the vertical height of the CAAC was measured before and after cementation with the custom measuring jig. Due to a skewed distribution of the data, a logit transformation of the percentages was done. A one-way analysis of variance was used to determine differences within groups, and the Tukey Highly Significant Difference test (at $\alpha = .05$) was used to compute the differences between groups.

RESULTS

The vertical displacement for all but one specimen of the preseated and cleaned cementation CAAC measurements ranged between –7 and +6 μm, with a mean of 0 μm. No statistical differences were noted within or between the three groups ($P > .05$). One specimen, after cementation, was 79 μm higher than the precementation recording. The coping of this CAAC had failed to seat correctly and was considered operator error. When this specimen was examined, a distinct cement luting line was visible at the crown-abutment junction. This could not be detected on any other sample.

The amount of cement extruded from the cemented CAAC margins varied with the type of abutment modification. The CA group extruded a mean of 90% of the total cement placed within the crown out of the system (range, 66% to 97%). (The 66% belonged to the single specimen that failed to completely seat, as described earlier.) The OA group extruded a mean of 54%

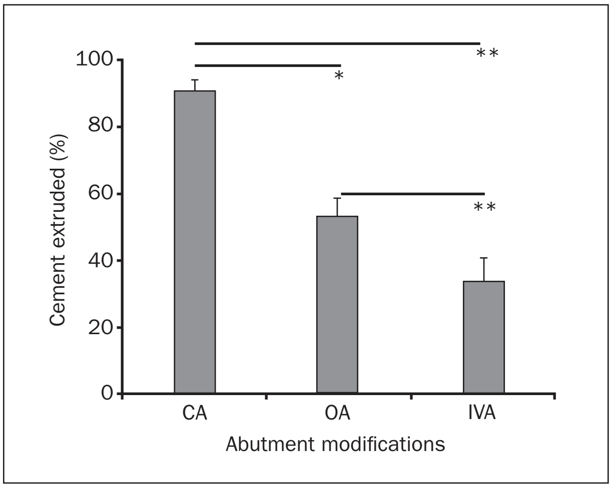

Fig 4 Percentage of cement extruded from the CAAC complex. CA = closed abutment; OA = open abutment; IVA = internal vent abutment. Bars represent standard deviations. *Statistically significant (*P* < .05); **statistically significant at *P* < .01.

Table 1 Summary of One-Way Analysis of Variance Using Log Transformation of Percentages

Score	SS	df	MS	F	*P*
Treatment (between groups)	39.72	2	19.86	78.86	< .0001
Error	6.30	25	0.25		

SS = sum of squares; df = degrees of freedom; MS = mean square.

of the total cement out of the CAAC (range, 48% to 62%). The IVA group extruded a mean of 36% (range, 26% to 46%) of the total cement out of the CAAC (Fig 4). There were differences between the mean percentages of extruded cement among the test groups ($P < .0001$) (Table 1).

DISCUSSION

When a crown is being seated, there is a finite and limited space for the cement to fill. Venting as a means of improving the fit between a crown and an abutment has been documented using an external vent.[21] However, venting of the crown may alter the structural integrity of the restoration and presents difficulties with respect to repair as well as determining the most appropriate location of a vent hole or holes.[13] This study was designed to evaluate the use of an internal abutment space as a means of decreasing the extrusion of excess cement and improving the seating capability of a crown coping. The CA specimen had no ability to allow for cement flow within the abutment, as the screw access channel was occluded. If the crown failed to fully seat on the abutment, the CAAC would hold more cement by virtue of the raised crown coping, which increases the volume of space available. This occurred in one specimen, which was raised by 79 µm. This was also reflected in the percent of cement extruded in this specimen, calculated at 66% of the total amount of cement placed within the crown. This compares to the 97% that was extruded when the crown seated more completely in another CA specimen.

The amount of cement placed within the crown prior to seating is at the operator's discretion[12,13,20–22]; there are no set standards, and they include lining specific sites,[22] half filling the crown,[12] and using a crown-fill technique.[20] Here, the decision was made to fill 75% of the coping to simulate a worst-case scenario and duplicate conditions that may occur in clinical practice. The copings were loaded with cement and weighed prior to seating the units together to reduce errors that may occur as a result of cement being removed by contact with the operator, which may happen as the units are seated together.

The shape of the abutments used in the present study is similar to a flat-top cone with a lingual bevel and an undulated margin. For simplification and to calculate the volume of cement available between the coping and the abutment, this shape can be considered to approximate that of a flat-top cone, the volume (v) of which may be calculated with the formula $v = h\pi(r_1^2 + r_1r_2 + r_2^2)/3$, where h indicates vertical height, r_1 is the base radius, and r_2 is the top radius (Fig 5).

The space provided for cement is dependent on multiple factors, including investment, wax, and metal dimensional changes as a result of the fabrication procedures. No die spacer was used, per the manufacturer's instructions. For the purpose of calculations and demonstrating the effects seen, a uniform luting cement space of 50 µm was assumed. The present calculations suggest that a CA with such a luting space between it and the intaglio of the crown would require a volume of 6 mm^3 of cement. The screw access chamber has an additional available volume of approximately 25 mm^3. When two vent holes are provided,

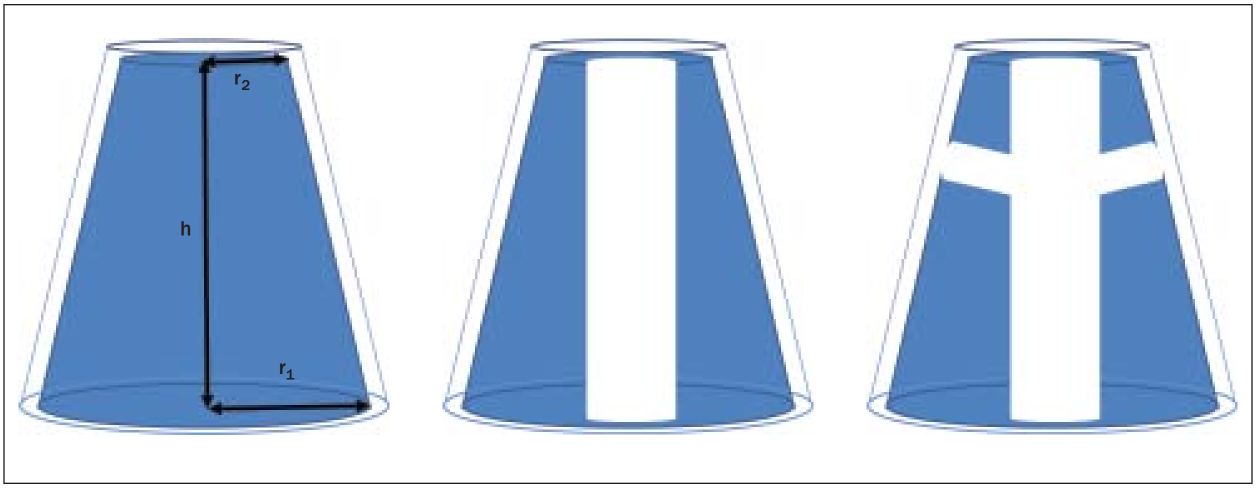

Fig 5 Diagrams of the created abutments (*left to right*: CA, OA, IVA). Space available for cement is indicated in white. h = height; r_1 = bottom radius; r_2 = top radius.

each with a radius of 0.75 mm, the volume increases by another 1 mm^3. The calculations showed that the total volume of the intaglio of the crown coping, if filled, was 133 mm^3, and at 75% filled, the cement volume was 99.8 mm^3.

There were significant differences between each group tested that could not be accounted for purely by the volume changes made by modification to the abutments. The OA group had a maximum cement extrusion of 62%, with a mean value of 54%, compared to the IVA group, which had a maximum cement extrusion of 46% and a mean of 36%. This is an interesting observation given that the volume increase to retain cement within the system differed by only 1 mm^3, or 3%, with the internal volumes of the OA and IVA calculated at 31 mm^3 and 32 mm^3, respectively. It is assumed that cement flow was affected by the inclusion of the two vents. It is possible that the vents allowed air trapped within the system to escape more readily, or that the cement on the axial walls may have been pushed into the internal aspect of the access screw channel, further filling it.

No modifications for anti-rotation were made to the RC Abutment, which is controlled to some degree by its shape occlusally, where a lingual bevel exists. Some rotation would alter the vertical height of the CAAC as the margin of the RC Abutment undulates, being more apically placed on the facial aspect. It is likely that this rotation effect, combined with the load of 5 kg, may have resulted in the negative vertical displacement recorded as the coping was seated on the abutment. Overall, the vertical displacements were not statistically significantly different between groups.

Clinically, excess cement has been cited as a probable cause of peri-implantitis; it is considered that the cement acts as a seeding layer onto which bacteria can colonize.[8] If this theory is correct, then the clinical goal must be to limit the amount of cement that is pushed into the peri-implant tissues on seating. Some clinicians suggest that the restoration be loaded with cement, seated, and maintained under occlusal loading until the cement has set. This would imply that any excess that exists under the soft tissues has hardened and must then be removed. However, detection of the cement may be difficult if it is located subgingivally. Radiographic detection of the cement has also been shown to be dependent upon type, with some luting cements having poor radiographic properties.[23] Removal of set cement has been shown to be problematic, and it is considered unlikely that some cement types can be removed completely.[24]

The amount of cement needed to cause disease has yet to be established, but it would seem reasonable that reducing the volume extruded to a minimum is advantageous. Adaptation of the abutment in the manner described—with the two internal abutment vent holes—fulfills the requirement of a reduction in excess cement that would be extruded out of the marginal interface between crown and abutment and into the peri-implant soft tissues. The percentage reductions, from 90% for CA to 54% for OA and 36% for IVA, were statistically significantly different between all three groups ($P < .05$), and there were no statistically significant differences in seating discrepancy before and after cementation ($P > .05$).

Understanding the maximum volume of cement required for individual abutment systems would provide useful information to the clinician, who could then allow appropriate amounts of cement to be dispensed into the intaglio of the restoration. This would further limit the extrusion of cement into vulnerable sites and improve cleanup.

The fabrication of implant abutments with some form of internal venting may be considered advantageous by implant manufacturers and laboratories alike and can be used with both custom and hollow as-manufactured abutments as a means to contain the cement, thus reducing excess. The number, size, and exact location of any venting holes requires further investigation, as does the suitability of placing holes within materials such as zirconia, as this may alter physical properties such as strength. Limitations of this in vitro study included the absence of simulated soft tissue effects; it is possible that the peri-implant tissues may alter the amount of excess cement that is extruded. Cementation was also carried out in a dry environment; the fluid of the gingival sulcus may alter the consistency of the cement and the excess cement that is extruded. The amount of cement placed within the crown was large; it is anticipated that limiting the initial volume and selective placement of the cement within the crown would affect the amount extruded. The only cement studied was a eugenol-free zinc oxide cement. It is possible that other cements may behave differently as a result of flow capabilities and viscoelastic effects. Finally, the number and position of the internal vents may also affect cement flow, a variable that also requires further investigation.

CONCLUSIONS

Within the limitations of this in vitro study, the null hypothesis was partly accepted. The amount of excess cement extruded at the abutment-crown margin was greatest for the closed abutment, followed by the open abutment and the internal vent abutment; each one was statistically significantly different ($P < .05$). However, vertical displacement was not affected by abutment modifications ($P > .05$). The internal vent abutment is a modification that leaves the abutment screw access open and places two vent holes (mesial and distal) into the abutment; it provides an apparent benefit by reducing the excess cement that is extruded through the margin of implant restorations.

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