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The Effect of CAD/CAM Crown Material and Cement Type on Retention to Implant Abutments

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Abstract

Purpose: To evaluate the pullout resistance of CAD/CAM implant-supported crowns cemented with provisional and definitive cements on Ti-base implant abutments.
Materials and Methods: Sixty crowns were milled for use in Ti-base implant abutments and divided (n = 15/group) according to material, as follows: (a) [Pr] Temporary acrylic resin; (b) [Co-Cr] Cobalt-Chromium alloy; (c) [Zr] polycrystalline zirconia; and (d) [Ti] titanium. The cementation was performed with RelyX Temp NE (RxT) cement or RelyX U200 self-etching resin cement, under a 50 N (5 kg) load for 10 minutes. Twenty-four hours after cementation, the crowns were subjected to the pullout test in a universal test machine, at a 1.0 mm/min crosshead speed. The tests were performed first without cement to evaluate frictional resistance (Baseline), then with provisional cement (RelyX Temp NE without cement again (Baseline After RxT), and finally with resin cement (U200). The results were analyzed by ANOVA and Tukey test ($p < 0.05$).
Results: Data evaluation as a function of cement type demonstrated the superiority of resin-based cements relative to provisional and baseline groups ($p < 0.01$). While Co-Cr crowns presented the highest pullout strength values, Pr showed the lowest values (data collapsed over cement) ($p < 0.001$). Retentiveness data as a function of both factors demonstrated similar pullout resistance between groups without cement ($p < 0.001$), except Zr baseline. Also, Co-Cr presented higher pullout strength compared to other materials.
Conclusions: Self-adhesive resin cement exhibited superior retention compared to temporary cement, regardless of crown material. Co-Cr and titanium presented higher levels of retention to Ti-base abutment after being cemented.

Dental implants are a treatment modality with high success rates, although biological and technical complications are expected in the mid- and long-term.[1-3] Typically, two-piece implants can be either screw- or cement-retained on standard or customized abutments. Advantages and disadvantages of both prosthesis retention systems have been addressed in several studies.[3-11] The advantages of using cement-retained restorations are primarily esthetics, passive fit of the crown, reduced laboratory technique sensitivity, and the potentially improved load distribution during function. Nonetheless, a major disadvantage of cement retention lies in the difficulty of removing excess cement in the gingival sulcus that could lead to peri-implant soft tissue inflammation.[9,12,13] Cemented prostheses are also indicated to correct implant improper positioning and for improved control of occlusion, for instance, in narrow implants.[14] On the other hand, the advantages of screw-retained restorations include retrievability, which prevents the need for complex procedures during prosthesis removal for maintenance, evaluation of oral hygiene and peri-implant probing, repairs, or abutment screw tightening.[7] Some indications for screw retention include inadequate interocclusal space (minimum 4 mm height) and the necessity of soft tissue conditioning and individualization of emergence profile during provisionalization.[9] Among the prosthetic complications reported for implant-supported restorations, abutment screw loosening is the most common and is more frequently observed in screw-retained than in cement-retained single crowns.[15]

Implant abutment selection is important, as it supports the prosthesis framework and controls the emergence profile for esthetics and biological interaction.[16] For improved performance, it is important that abutments present the best fit at the implant junction for decreased micromotion and bacterial contamination.[17] Within this context, companies offer prefabricated abutments that vary in design between systems and in general are fabricated for applications where customization is limited. Opportunities for customization include the widely used universal casting long abutment (UCLA) and more recently blocks for milling either the entire abutment including the implant-abutment connection at CAD/CAM dental systems (mostly feasible for nonconical connections) or for milling only the coronal portion since the implant-abutment connection is milled by the manufacturer. Although commonly used, UCLA abutments may present compromised fit after casting and porcelain veneer firing cycles, since an oxidized layer is created at the fitting interface.[18]

In this scenario, recently introduced abutments, such as Ti-base, have been designed to be CAD/CAM friendly and to allow rapid fabrication of prostheses with maximal fit. In essence, Ti-base abutments are prefabricated abutments with a hybrid concept of cemented and screwed fixation in the same prostheses where the implant-abutment connection is used with the precision as delivered from the manufacturer, in contrast to UCLA abutments. Ti-base abutments may be indicated in two different clinical situations: (1) well positioned implants that can receive bilayered or monolithic crowns or (2) in instances where implant positioning is not adequate, a custom core may be milled and cemented to correct angulation and a crown then cemented and, in this case, it becomes unretrievable.[16] The main advantage of Ti-base abutments is that the abutment-crown assembly may be retrieved, as in UCLA abutments and any screw-retained system, since they are cemented outside of the mouth, and excess cement removed, overcoming potential cementation-induced peri-implantitis,[19] for subsequent fixation with screws. Moreover, most common CAD/CAM systems currently present an increasing library database for rapid fabrication of prostheses onto Ti-base abutments.

The use of a digital workflow for prosthesis fabrication onto Ti-base abutments presents a few challenges that warrant further investigation. The milling strategies between different prosthesis materials vary and may produce discrepancies in cementation space, which eventually influences final crown retention.[20] Moreover, either metallic or ceramic crowns demand individual cementation protocols for which there is no consensus.[21] Zirconia, for instance, is a highly polycrystalline material that should be subjected to specific surface treatments that have been debated[22] with advantages reported for some protocols such as tribochemical silica-coating relative to others.[23] Clinically, debonding of porcelain-fused-to-zirconia crowns and fixed dental prostheses[24] has been reported as an issue negatively affecting survival rates, thus encouraging continued research.

Figure 1 CAD design simulating different crown materials with the pull handle for the pullout test.

Crowns milled for Ti-base abutments may present a close internal fit to allow initial frictional retention. The presence of frictional retention allows clinicians to perform occlusal and proximal adjustments prior to final cementation. This step is hindered when crowns milled of any material present a loose fit. Although bonding between titanium abutments and several restorative materials has been reported, a protocol for Ti-base cementation for varied crown materials and cementation media has not been established. Therefore, this study sought to evaluate the pullout resistance of milled provisional resin, zirconia, titanium, and Co-Cr crown materials cemented onto Ti-base abutments. The postulated null hypotheses were that: (I) cement type would not influence pullout retention values, (II) the absence of cement would not influence pullout retention values, and (III) crown material would not influence pullout retention values.

Materials and methods

A total of 60 maxillary central incisor crowns with identical anatomy were fabricated in CAD software, from a single .stl file (Ceramill Mind; Amann Girrbach, Curitiba, Brazil) (n = 15/group). A handle was designed by means of separate CAD software (SolidWorks, Boston, MA) to provide the attachment for pullout testing in a universal testing machine, which consisted of a projection along the incisal edge of the crowns with a round perforation of 2 mm (Fig 1).

The crowns were milled in the following materials: (a) [Pr] temporary acrylic resin (VIPI, Pirassununga, Brazil); (b) [Co-Cr] Cobalt-Chromium alloy; (c) [Zr] polycrystalline zirconia; and (d) [Ti] titanium. Ti-base abutments and their respective external hexagon analogs (S.I.N. Sistema de implantes, São Paulo, Brazil) were embedded in acrylic resin (Jet; Clássico Artigos Odontológicos, São Paulo, Brazil). To standardize the long axis alignment and achieve parallelism between the acrylic base and the analog/Ti-base, Ti-base abutments were digitally torqued to the implants and fixed in a surveyor (Delineador B2; Bio-Art, São Carlos, Brazil). This procedure certified that the analog/Ti-base would be on the same axis of insertion during pullout testing. To reduce distortion during acrylic resin polymerization, space was provided for the maximum amount of acrylic resin to be poured, allowing the implant to be free of contact. After polymerization, sufficient acrylic resin was poured to cover the implant up to the collar surface.

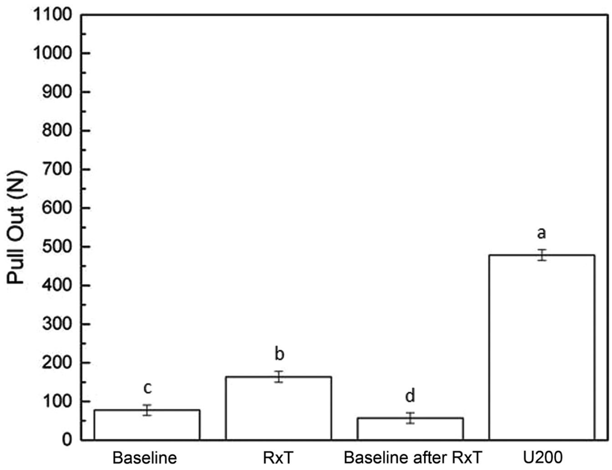

Figure 2 Pullout retention values as a function of mean and 95% confidence interval. U200 group evidenced higher pullout strength compared to other groups. Different letters indicate significant difference between groups ($p < 0.001$).

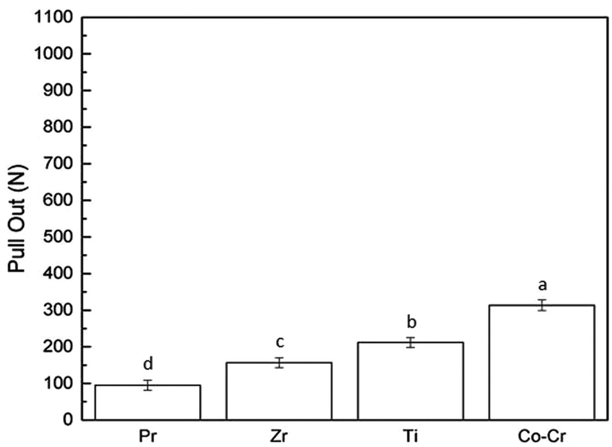

Figure 3 Pullout retention values as a function of mean and 95% confidence interval. All crowns materials were significantly different. Different letters indicate significant difference between groups ($p < 0.001$).

Two cement types were selected: (I) Temporary cement (RelyX Temp NE 3M ESPE Oral Care, St. Paul, MN) and (II) self-adhesive resin cement (RelyX U200). Prior to cementation, Ti-base abutments were torqued as per manufacturer's recommendations (32 N.cm).

To standardize the amount of cement to be mixed, a digital scale was used for each crown. A device with a weight of 5 kg was used during crown cementation for the first 10 minutes. The following groups were created for each crown material:

(1) [Baseline]: crown pullout without cement for evaluation of the frictional retention after crown milling;
(2) [RxT]: crown pullout with provisional cement - RelyX Temp NE;
(3) [Baseline after RxT]: crown pullout without cement for evaluation of the frictional retention after testing with temporary cement - RelyX Temp NE;

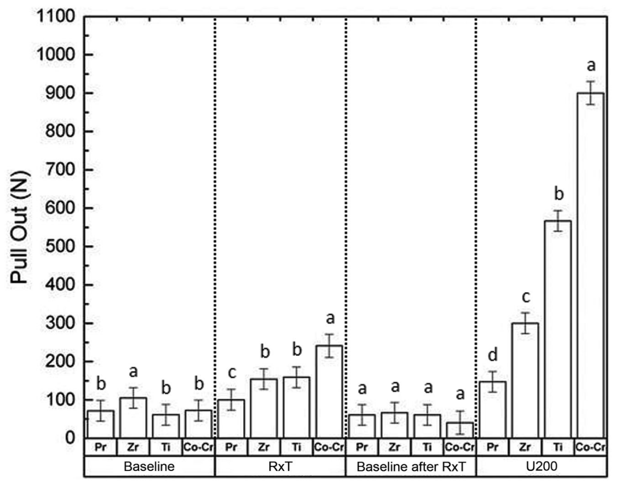

Figure 4 Pullout retention values as a function of mean and 95% confidence interval. For U200 and RelyX Temp NE, Co-Cr evidenced higher pullout strength compared to other materials. Groups without cement demonstrated similarity regarding to pullout strength data for all crown materials, except Zr baseline. Different letters indicate significant difference between groups ($p < 0.001$).

(4) [U200]: crown pullout with self-adhesive resin cement - RelyX U200.

The pullout test was performed by means of a universal testing machine (Kratos Equipamentos Industriais Ltda., São Paulo, Brazil) at a crosshead speed of 1.0 mm/min until crown displacement. The results were recorded in the equipment's proprietary software.

Statistical analysis

Data were statistically evaluated through two-way ANOVA with fixed factors of the materials (temporary resin, Co-Cr, zirconia, and titanium) and cement type (provisional and self-adhesive resin cement) following post-hoc comparisons by Tukey test. Data are presented as a function of mean values with the corresponding 95% confidence intervals. All analyses were accomplished using SPSS software (SPSS 23; IBM Corp., Armonk, NY).

Results

Results from the two-way ANOVA are shown in Figure 2. When comparing the pullout strength values as a function of cement, the U200 group presented higher pullout strength compared to other groups. The use of temporary cement increased pullout strength values relative to groups without cement. Additionally, removing temporary cement decreased pullout strength compared to baseline ($p < 0.001$) (data collapsed over crown material).

All crown materials were significantly different, when data were collapsed over cement. While Co-Cr crowns presented the highest pullout strength values, Pr presented the lowest ($p < 0.001$) (Fig 3). Evaluation of pullout data as a function of cement and crown material showed that for both cements, U200 and RxT, Co-Cr presented significantly higher pullout strength compared to other materials. Nonetheless, groups without cement demonstrated similarity regarding pullout strength data for all crown materials, except Zr baseline ($p < 0.001$) (Fig 4).

Discussion

This study evaluated the pullout resistance of CAD/CAM implant-supported crowns cemented with provisional and self-adhesive resin cements on Ti-base implant abutments. While a variety of conventional and adhesive cements warrant future investigation, the main focus in this study was to verify pullout retention gain with one temporary and one permanent self-adhesive resin cement in several crown materials when an existing frictional retention was present between crowns and abutments. In addition, it was possible to compare initial frictional retention levels with those collected after pulling out the crowns cemented with RxT and cleaned for retesting without any cement. The results of the current study demonstrated that the use and type of cement and crown material influenced the retentiveness level of CAD/CAM implant-supported crowns, rejecting the postulated null hypotheses.

The rationale behind the use of Ti-base abutments relies mainly on the ease of milling a variety of available CAD/CAM materials. Although such abutments seem an interesting hybrid concept of cemented and screwed fixation in the same prostheses with increasing use,[8] information on the influence of the effect of crown materials and cement types on retention is scarce.

For clinical application, both implant prosthesis retention systems, cemented or screwed, present well-documented advantages and disadvantages.[3-7,10,12] Despite the biomechanical superiority of cement-retained prostheses shown in a long-term clinical study,[11] the use of screw-retained prostheses is preferred by the majority of clinicians due to their retrievability.[7] In addition, the difficulty of removing excess cement is considered the major problem of cement retention,[13] which may increase the risk of inflammation, eventually causing marginal bone loss.[8] Accordingly, the main advantages of hybrid prostheses is to aggregate the advantages of both systems, as previously mentioned.[19]

It has been found that the final prosthesis retention depends on, among other factors, the type of cement used, convergence angle, abutment height, crown material composition, surface texture, and initial frictional retention.[25-27] Previous studies have evaluated the pullout retention values for metal abutments with different cements and demonstrated that the cement type influences the retentiveness level of the prosthesis.[27,28] Additionally, some authors suggested that provisional cements could be adequate for conventional cement-retained, implant-supported crowns,[29,30] which is supported by our findings. The results of the current study demonstrated that resin-based cement presented significantly higher pullout strength compared to the provisional cement group, and also compared to groups without cement (data collapsed over crown material). It was interesting to note that the use of temporary cement significantly increased pullout retention values relative to groups without cement. Additionally, removing temporary cement decreased pullout strength compared to baseline (data collapsed over crown material). It can be inferred that the initial frictional retention was altered by residual cement in the Ti-base grooves or a possible crown/abutment deformation during the pullout test, thus causing the statistical differences among groups without cement. Whereas our study simulated a possible clinical scenario of crown try-in and its temporary cementation prior to final bonding, it has been previously reported that specimen reuse may be the source of changes in the abutment/crowns surfaces during cleaning potentially altering the mechanical interlocking.[31] However, different behavior was observed when data were evaluated as a function of both factors, with groups without cement demonstrating similar pullout resistance for all crown materials, except for Zr Baseline. This finding is reassuring for clinicians, since the benefit of the use of provisional cements is that they allow retrieval of a restoration without damaging the abutment/crown assembly.[27] Notwithstanding, there is no consensus about the minimum pullout value that provides long-term retentiveness to an implant-supported rehabilitation.

Over the last decade, a digital workflow for prosthesis fabrication has been increasingly encouraged. The use of CAD/CAM has allowed the high-precision machining of prefabricated blocks of several restorative materials.[32] The results showed that, depending on the crown material (temporary acrylic resin, zirconia, Co-Cr, or titanium), differences in crown pullout resistance may occur even when similar milling parameters are used (data are collapsed over cement). Additionally, Co-Cr crowns presented the highest pullout strength values, and Pr presented the lowest. These findings can be explained by the different mechanical properties (e.g., modulus of elasticity) and various surface textures of metal alloy, zirconia, Ti, and acrylic resin. These surface textures may influence the level of retentiveness of the crown, as previously highlighted. Such observations are in contrast with previous findings that did not show differences in the level of retentiveness of metal-alloy and zirconia copings when set onto Ti abutments fixed with permanent or provisional cements.[27]

The standardization of milling parameters is important to ensure an adequate fit between the abutment and its crown and consequently the stability and longevity of the implant/abutment/crown complex.[33] In this study, all Ti-base crowns were milled by the same operator and CAD/CAM system, using similar milling parameters; however, given the variety of available luting agents, crown materials, abutment designs, and milling parameters, continued effort is needed to create a protocol for cementation of Ti-base implant abutments.

Conclusions

Within the limitations of this in vitro study, the following conclusions were made based on the results:

(1) Both crown material and cement type influenced the pullout resistance of CAD/CAM implant-supported crowns on Ti-base implant abutments.
(2) Self-adhesive resin cement exhibited superior behavior when compared to temporary cement and groups without cement, regardless of crown material.

(3) Co-Cr and Ti presented higher levels of retention to Ti-base abutment, in the final cementation.

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References

1. Pjetursson BE, Thoma D, Jung R, et al: A systematic review of the survival and complication rates of implant-supported fixed dental prostheses (FDPs) after a mean observation period of at least 5 years. Clin Oral Implants Res 2012;23:22-38
2. Schwarz S, Schroder C, Corcodel N, et al: Retrospective comparison of semipermanent and permanent cementation of implant-supported single crowns and FDPs with regard to the incidence of survival and complications. Clin Implant Dent Relat Res 2012;14:e151-158
3. Hebel KS, Gajjar RC: Cement-retained versus screw-retained implant restorations: achieving optimal occlusion and esthetics in implant dentistry. J Prosthet Dent 1997;77:28-35
4. Pjetursson BE, Tan K, Lang NP, et al: A systematic review of the survival and complication rates of fixed partial dentures (FPDs) after an observation period of at least 5 years. Clin Oral Implants Res 2004;15:667-676
5. Goodacre CJ, Kan JY, Rungcharassaeng K: Clinical complications of osseointegrated implants. J Prosthet Dent 1999;81:537-552
6. Lee A, Okayasu K, Wang HL: Screw- versus cement-retained implant restorations: current concepts. Implant Dent 2010;19:8-15
7. Michalakis KX, Hirayama H, Garefis PD: Cement-retained versus screw-retained implant restorations: a critical review. Int J Oral Maxillofac Implants 2003;18:719-728
8. Wittneben J-G, Millen C, Brägger U: Clinical performance of screw-versus cement-retained fixed implant-supported reconstructions—a systematic review. Int J Oral Maxillofac Implants 2014;29:84-98
9. Wittneben JG, Joda T, Weber HP, et al: Screw retained vs. cement retained implant-supported fixed dental prosthesis. Periodontol 2000 2017;73:141-151
10. Chee W, Jivraj S: Screw versus cemented implant supported restorations. Br Dent J 2006;201:501-507
11. Nissan J, Narobai D, Gross O, et al:. Long-term outcome of cemented versus screw-retained implant-supported partial restorations. Int J Oral Maxillofac Implants 2011;26:1102-1107
12. Pauletto N, Lahiffe BJ, Walton JN: Complications associated with excess cement around crowns on osseointegrated implants: a clinical report. Int J Oral Maxillofac Implants 1999;14:865-868
13. Linkevicius T, Vindasiute E, Puisys A, et al: The influence of the cementation margin position on the amount of undetected cement. A prospective clinical study. Clin Oral Implants Res 2013;24:71-76
14. Wismeijer D, Bragger U, Evans C, et al: Consensus statements and recommended clinical procedures regarding restorative materials and techniques for implant dentistry. Int J Oral Maxillofac Implants 2014;29 Suppl:137-140
15. Sailer I, Muhlemann S, Zwahlen M, et al: Cemented and screw-retained implant reconstructions: a systematic review of the survival and complication rates. Clin Oral Implants Res 2012;23:163-201
16. Kurbad A, Kurbad S: CAD/CAM-based implant abutments. Int J Comput Dent 2013;16:125-141
17. Steinebrunner L, Wolfart S, Bossmann K, et al: In vitro evaluation of bacterial leakage along the implant-abutment interface of different implant systems. Int J Oral Maxillofac Implants 2005;20:875-881
18. Byrne D, Houston F, Cleary R, et al: The fit of cast and premachined implant abutments. J Prosthet Dent 1998;80:184-192
19. Staubli N, Walter C, Schmidt JC, et al: Excess cement and the risk of peri-implant disease—a systematic review. Clin Oral Implants Res 2017;28:1278-1290
20. Patzelt SB, Spies BC, Kohal RJ: CAD/CAM-fabricated implant-supported restorations: a systematic review. Clin Oral Implants Res 2015;26:77-85
21. Gracis S, Thompson VP, Ferencz JL, et al: A new classification system for all-ceramic and ceramic-like restorative materials. Int J Prosthodont 2015;28:227-235
22. Qeblawi DM, Munoz CA, Brewer JD, et al: The effect of zirconia surface treatment on flexural strength and shear bond strength to a resin cement. J Prosthet Dent 2010;103:210-220
23. Tzanakakis EG, Tzoutzas IG, Koidis PT: Is there a potential for durable adhesion to zirconia restorations? A systematic review. J Prosthet Dent 2016;115:9-19
24. Sailer I, Makarov NA, Thoma DS, et al: All-ceramic or metal-ceramic tooth-supported fixed dental prostheses (FDPs)? A systematic review of the survival and complication rates. Part I: Single crowns (SCs). Dent Mater 2015;31:603-623
25. Bernal G, Okamura M, Munoz CA: The effects of abutment taper, length and cement type on resistance to dislodgement of cement-retained, implant-supported restorations. J Prosthodont 2003;12:111-115
26. Covey DA, Kent DK, St Germain HA, et al:. Effects of abutment size and luting cement type on the uniaxial retention force of implant-supported crowns. J Prosthet Dent 2000;83:344-348
27. Schiessl C, Schaefer L, Winter C, et al: Factors determining the retentiveness of luting agents used with metal- and ceramic-based implant components. Clin Oral Investig 2013;17:1179-1190
28. Garg P, Pujari ML, Prithviraj DR, et al: Retentiveness of various luting agents used with implant supported-prosthesis: an in vitro study. J Oral Implantol 2014;40:649-654
29. Kim Y, Yamashita J, Shotwell JL, et al: The comparison of provisional luting agents and abutment surface roughness on the retention of provisional implant-supported crowns. J Prosthet Dent 2006;95:450-455
30. Worni A, Gholami H, Marchand L, et al: Retrievability of implant-supported crowns when using three different cements: a controlled clinical trial. Int J Prosthodont 2015;28:22-29
31. Carnaggio TV, Conrad R, Engelmeier RL, et al: Retention of CAD/CAM all-ceramic crowns on prefabricated implant abutments: an in vitro comparative study of luting agents and abutment surface area. J Prosthodont 2012;21:523-528
32. Contrepois M, Soenen A, Bartala M, et al: Marginal adaptation of ceramic crowns: a systematic review. J Prosthet Dent 2013;110:447-454
33. Zhang J, Zhang R, Ren G, et al: A method for using solid modeling CAD software to create an implant library for the fabrication of a custom abutment. J Prosthet Dent 2017;117:209-213