Cementation Protocol for Bonding Zirconia Crowns to Titanium Base CAD/CAM Abutments

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Purpose: To establish the most effective cementation protocol for bonding zirconia crowns to Ti-Base CAD/CAM abutments in terms of abutment height, cement type, and surface pretreatment. Materials and Methods: Zirconia crowns were designed to fit abutments of 2.5-mm (short) and 4.0-mm (tall) height. The retention of conventional resin cement with a universal adhesive (RelyX Ultimate, 3M ESPE) was compared to self-adhesive resin cement (RelyX U200, 3M ESPE) following different surface pretreatments (n = 10/group): (1) no treatment (NT); (2) Ti-Base abutment surface blasting with alumina particles (SB); (3) zirconia crown tribochemical surface blasting with silica-coated alumina particles (TBS); and (4) a combination of SB + TBS. Pull-out testing was performed in a universal testing machine. Data were statistically evaluated using a linear mixed model following least significant difference post hoc test. Results: Pull-out data as a function of Ti-Base height demonstrated higher retention for tall compared to short abutments (P < .001). Ultimate outperformed U200 cement (data collapsed over height and pretreatment) (P < .001). Analysis of pretreatment depicted higher retention for SB + TBS, followed by SB, TBS, and NT (P < .04). The interaction between Ti-Base height and cement type highlighted the superior adhesive strength of Ultimate compared to U200 for both heights (P < .001). Irrespective of type of pretreatment, surface pretreatment improved the retention for U200 cement and short Ti-Base (P < .03 compared to NT). In contrast, higher retention was demonstrated for SB + TBS, followed by SB, TBS, and NT, for Ultimate cement combined with tall Ti-Base (P < .02) (data collapsed over height and cement, respectively). Conclusion: There was a direct relationship among Ti-Base height, micromechanical and/or chemical pretreatment, and conventional adhesive bonding in improving the retention of zirconia crowns.


With the advent of osseointegration, restoring missing teeth with implant-supported prostheses has become an increasingly used treatment modality, with high implant survival rates reported in long-term follow-up studies (> 95% over 10 years).1–4 The standard of care in single implant–supported rehabilitation comprises the use of prefabricated metallic abutments in conjunction with metal-ceramic or all-ceramic crowns.4–7 Yttria-stabilized tetragonal zirconia polycrystal (Y-TZP) systems have gained attention for use as a restorative material in a wide range of clinical scenarios due to their high biocompatibility and mechanical properties that result from compressive stresses generated by the phase-transformation toughening mechanism, hindering crack propagation (Σ: 900 to 1,200 MPa/KIC: 6-9 MPa m1/2).5–13 The calculated survival rates for implant-supported single crowns has ranged from 97% for metal-ceramic and between 90% and 96% for Y-TZP crowns after observation periods of 5 and 10 years, respectively.1,3,4,6,7 Although survival rate is one of the most...
critical aspects for determining the suitability of a restorative system, the complication rate gives more complete information on its clinical performance. Hence, biologic and technical complications are frequently reported for implant-supported reconstructions, especially for Y-TZP–based crowns. An estimated 5-year rate of biologic and technical complications depicted approximately 5% to 7% for soft tissue complications, 3% to 8% for abutment/screw loosening, about 5% for retention loss, and 2% to 9% for veneer fracture. Consequently, current research in implant-supported reconstructions has been focused on the development/improvement of prosthesis components to provide retrievable systems with more favorable biomechanical performance and longevity.

The combination of intraoral scanning with computer-aided design/computer-assisted manufacturing (CAD/CAM) has challenged traditional techniques and enabled an innovative workflow in oral rehabilitation involving the use of abutments that have their geometries saved in CAD/CAM software libraries, known as titanium base (Ti-Base) abutments. Such abutments combine the benefits of prefabricated and customized abutments in a hybrid fixation mode (screwed and cemented) on the same prosthesis. Essentially, computerized technology allows digital scanning at the implant level for onscreen design of customized monolithic or layered restorations of any given material—including Y-TZP—that will be fabricated with rapid prototyping procedures, milling, or 3D printing and then cemented chairside and screwed on the implant.

Advantages of a fully or partially digital workflow (intraoral scanning or conventional impression and cast scanning, respectively) consist of reducing production costs (not including purchase costs) and improving time efficiency, as there is a reduction of approximately 50% in the mean work time (laboratory and clinical steps) compared to the conventional pathway. Moreover, Ti-Base abutment advantages include its retrievability, highly precise implant-abutment fit (delivered by the manufacturer, thus following regulatory standards), potentially improved integrity of the implant interface relative to Y-TZP abutments, and emergence profile customization, with the superstructure maintaining soft tissue and anatomical contour. With this design, bonding can be performed under controlled laboratory conditions (dry environment and optimized polymerization), allowing for excess cement removal prior to prosthesis installation. This feature is advantageous for enhancing bonding durability and reducing inflammatory effects due to cement remnants in the peri-implant tissue that may eventually induce marginal bone loss.

Nonetheless, loss of retention is one of the most frequent technical complications associated with cement-retained systems (up to 5% over 5 years). Several factors have been associated with implant-supported prosthesis retention, including abutment taper degree, height, and texture; superstructure fit; cement type; and surface pretreatment. Although Ti-Base abutments are currently available on the market, there is limited information concerning luting protocols and their effect on prosthesis retention. Classically, luting materials for indirect restorations have been classified as temporary or permanent cement, including zinc phosphate, glass-ionomer, and resin cements. Studies from the present author group have presented a ranked order considering the bonding behavior of various types of cement to Ti-Base abutments, which serves as a preliminary clinical guide. Irrespective of crown material, resin cement exhibited superior retention compared to temporary and glass-ionomer cement, with no conclusive outcome concerning resin cement type. Likewise, metallic outperformed Y-TZP superstructures for both temporary and permanent cements.

Although superstructure material influenced the retention of implant-supported crowns, current esthetic demand has stimulated the widespread indication for Y-TZP restorative systems. Given its quasichemical inertness, which is a significant limitation of the highly crystalline content, and the absence of the glass phase, adequate Y-TZP bonding has been clinically challenging. Hence, different surface pretreatments have been proposed to improve the effectiveness and durability of resin cement bonding to Y-TZP. While some of these methods physically facilitate bonding through grit-blasting the substrate and/or Y-TZP with alumina particles (airborne-particle abrasion), others are based on physicochemical activation of the ceramic surfaces using silica-coated alumina particles followed by silanization (tribochemical silica coating) or on chemical activation of resin cement systems containing functional monomers. A previous systematic review and meta-analysis concluded that bond effectiveness is maximized when airborne-particle abrasion, tribochemical silica coating, or chemical etching with 10-methacryloyloxydecyl dihydrogen phosphate (MDP) monomer are performed on a Y-TZP surface, with the resin bonding presenting more aging-resistant properties. Likewise, there is strong clinical evidence of successful long-term bonding to zirconia ceramics following different physicochemical surface pretreatments.

Previous investigations of the retentive strength of Ti-Bases bonded to zirconia abutments or crowns using self-adhesive resin cement and surface airborne-particle abrasion have indicated more reliable bonding when the bonding surface was abraded, whereas the synergistic effect among Ti-Base height, resin cement type, and tribochemical coating still needs to be addressed. Therefore, this study sought to evaluate the effect of Ti-Base height, resin cement type, and surface pretreatment on Y-TZP and/or Ti-Base abutment on the pull-out...
retention of Y-TZP implant-supported crowns. The pos-
tulated null hypotheses were that: (1) Ti-Base abutment
height would not influence pull-out retention values;
(2) cement type would not influence pull-out retention
values; and (3) surface pretreatment would not influence
pull-out retention values.

MATERIALS AND METHODS

Sample Preparation
Yttria-stabilized tetragonal zirconia polycrystal (Y-TZP)
(Ceramill Zolid, Amann Girrbach) disks were used to
fabricate hybrid retention crowns to fit CAD/CAM Ti-
Base abutments. A total of 160 crowns with identical
external geometries were designed in CAD software
(Ceramill Mind, Amann Girrbach) to fit two different
Ti-Base (Novo Colosso, Emfils) abutment heights (n = 
80/abutment height): (1) 2.5 mm (short) and (2) 4 mm
(tall). At the buccal and lingual cusps of the crowns,
projections beyond the occlusal surface were designed
with a round perforation of 2 mm to attach stainless
steel wires for pull-out testing. Such projections were
designed at the cusps to allow occlusal access for abut-
ment screw torquing. The screw-access hole was sealed
with polytetrafluoroethylene (PTFE) tape and temporary
composite resin (BIOLIC, Biodinâmica). In addition, an
internal space of 50 mm for cementation was planned,
starting 0.5 mm from the margin. The Ti-Base abut-
ments presented an internal conical connection to fit
their implant counterpart geometry.

Ti-Base abutments and their corresponding implants
were embedded in acrylic resin (Jet, Artigos Odontológi-
cos Clássico). For standardized long-axis alignment, Ti-
Base abutments digitally torqued to the implants were
fixed in a surveyor (Delineador B2, Bio-Art), and acrylic
resin was poured in 25-mm–diameter polyvinyl chloride
(PVC) tubes with their long axis aligned to the tube
long axis to simulate the bone level of the implant for
the tests. This procedure was performed to standardize
implant and Ti-Base abutment vertical orientation for
pull-out testing. The acrylic base held the samples in
the same position once they were fixed to the universal
testing machine (Kratos KE) (Fig 1).

Two resin-based cement types were evaluated: (1)
self-adhesive resin cement (RelyX U200, 3M ESPE) and
(2) resin cement (RelyX Ultimate, 3M ESPE) with uni-
versal adhesive for treatment of titanium and Y-TZP
substrates (Scotchbond Universal, 3M ESPE). Different
surface pretreatments for Ti-Base abutment and/or Y-
TZP crown were evaluated for both abutment heights
(n = 10/group): (1) no treatment (NT); (2) Ti-Base abut-
ment blasting with alumina particles of 45 µm at 2 bar
for 15 seconds at a 5-mm step-over distance (surface
blasting [SB]); (3) Y-TZP crown blasting with silica-coated
aluminum particles of 30 µm at 2 bar for 15 seconds
at a 5-mm step-over distance (Rocatec Soft, 3M ESPE)
(tribochemical silica coating [TBS]); and (4) SB on the
abutment + TBS on the crown. Prior to cementation, Ti-
Base abutments were torqued per manufacturer recom-
endations (32 Ncm). To standardize cementation, after
cement mixing and crown insertion on the abutment,
a weight of 5 kg was used for 10 minutes until cement
curing. Excess cement was removed from the abutment
margin, and an LED light was initially applied on each
surface for 20 seconds (VALO Cordless, Ultradent). The
assembly was stored in a moist environment at 37°C for
24 hours before testing.

Pull-out Retention Testing
A stainless steel wire of approximately 1.8 mm was in-
serted through both occlusal projections of each crown
d and fixed in a device positioned directly below the load
 cell (Fig 1). Pull-out testing was performed in a univer-
sal testing machine (Kratos KE) at a crosshead speed of
1 mm/minute until crown displacement and load drop.
The force (N) was recorded for statistical analysis.

Statistical Analyses
Preliminary data analysis showed indistinguishable vari-
ances in the study of the dependent variable (Levene
test, all P > .25). Pull-out retention data were statistically
evaluated using linear mixed models with fixed factors
of Ti-Base abutment height (short and tall), resin cement
type (U200 and Ultimate), and surface pretreatment (NT,
SB, TBS, and SB + TBS). Post hoc comparisons were car-
ried out using Fisher least square difference test. Analy-
yses of the power of the statistical tests demonstrated a
minimum observed power of 94%. Data are presented
as a function of mean values with the corresponding
95% confidence interval (CI). All analyses were per-
duced using SPSS version 23 (IBM).
RESULTS

The statistical summary for pull-out retention data as a function of study factors and their interactions is depicted in Figs 2 to 4. When data were collapsed over cement type and surface pretreatment, tall Ti-Base abutment (250 ± 14 N) demonstrated higher retention than the short Ti-Base abutment (214 ± 14 N) \( (P < .001) \) (Fig 2a). Conventional resin cement associated with Ultimate (270 ± 14 N) showed significantly higher pull-out values relative to U200 (194 ± 14 N) (data collapsed over Ti-Base height and surface pretreatment; \( P < .001 \)) (Fig 2b). Data analyzed as a function of surface pretreatment exposed a synergistic effect in increasing the retention when both the Ti-Base abutment and Y-TZP crown were blasted, since significantly higher pull-out values were demonstrated for SB + TBS (293 ± 20 N), followed by SB (252 ± 20 N), TBS (225 ± 19 N), and NT (157 ± 19 N), with all pairwise comparisons significantly different (all \( P < .04 \)) (Fig 2c).

Evaluation of pull-out data as a function of Ti-Base abutment height and cement type showed a superior performance of conventional resin cement associated with universal adhesive (Ultimate: 241 ± 20 and 299 ± 20 N for short and tall abutments, respectively) in comparison to self-adhesive resin cement (U200: 186 ± 20 and 201 ± 20 N for short and tall abutments, respectively), irrespective of Ti-Base abutment height (\( P < .001 \)). While there was a similar force to dislodgment for tall and short abutments for U200 cement (\( P = .30 \)), a statistically significant difference was observed for tall compared to short abutments when Ultimate cement means were compared (\( P < .001 \)) (Fig 3a).

Data collapsed over cement type indicated significant effects of SB (224 ± 27 N), TBS (220 ± 27 N), and SB + TBS (243 ± 29 N) compared to NT (167 ± 27 N) on short abutments (\( P < .008 \)). Nonetheless, no significant difference between any surface pretreatment method was noted (all \( P > .261 \)). In contrast, tall Ti-Base abutment data supported the combined effect of increasing retention values when both the Ti-Base abutment and Y-TZP crown (SB + TBS; 342 ± 29 N) were blasted, followed by SB (280 ± 31 N), TBS (231 ± 27 N), and NT (148 ± 27 N), with all pairwise comparisons significantly different (\( P < .02 \)). While there was a similar force to dislodgment between tall and short abutments for NT and TBS
pretreatment ($P = .34$), a statistically significant difference was observed between tall and short abutments for the SB and SB + TBS pretreatments ($P < .01$) (Fig 3b).

Pull-out data as a function of cement type and surface pretreatment demonstrated a significant effect of SB irrespective of method (SB: 194 ± 29 N; TBS: 233 ± 27 N; SB + TBS: 201 ± 29 N) compared to NT (149 ± 27 N) when U200 cement data were analyzed ($P < .03$). Nonetheless, no significant difference between any surface pretreatment was demonstrated ($P > .07$). Concerning Ultimate cement data, the SB + TBS group (385 ± 29 N) showed higher pull-out values for blasting both Ti-Base abutment and crown surfaces ($P < .001$). SB (311 ± 29 N) and TBS (218 ± 27 N) pretreatments exhibited intermediate values ($P < .001$), with both methods significantly more retentive than NT (166 ± 27 N) ($P < .01$). While there was a similar force to dislodgment between U200 and Ultimate cements for NT and TBS pretreatment ($P = .39$), a statistically significant difference was observed between Ultimate and U200 cements for SB and SB + TBS pretreatment ($P < .001$) (Fig 3c).

Moreover, the statistical description of pull-out retention data as a function of all factors—Ti-Base abutment height, resin cement type, and surface pretreatment—highlighted the direct relationship between Ti-Base abutment height and a positive influence of adhesive bond strength and surface pretreatment, irrespective of abutment (SB) and/or crown (TBS and/or SB + TBS) pretreatment, on increasing the force to dislodgment of Y-TZP crowns (Fig 4).

**DISCUSSION**

Implant-supported prosthesis retention was previously shown to be influenced by abutment taper degree, height, and texture; superstructure fit; cement type; and surface pretreatment.27–33 Hence, a crown pull-out test was proposed in the current study to evaluate the effect of abutment height, resin cement type, and surface pretreatment on the force to dislodgment of highly crystalline ceramic restorations (Y-TZP) cemented on Ti-Base abutments. Despite there being no scientific consensus
on what constitutes a minimum pull-out retention value that would assure longevity to an implant-supported rehabilitation, current and previous data provide a scenario of bonding behavior that can guide clinicians through a wide spectrum of possibilities when cementing Y-TZP crowns to Ti-Base abutments.\textsuperscript{16,17} Overall, the results demonstrated a direct relationship among Ti-Base height, adhesive luting with conventional resin cement associated with self-etch adhesive (presenting 10-methacryloyloxydecyl dihydrogen phosphate [MDP] in the composition), and micromechanical and/or chemical pretreatment, especially the synergism succeeding Ti-Base SB and Y-TZP TBS (SB + TBS group) in improving the retention of zirconia crowns.

The introduction of computerized technology in dentistry has ensured a unique digital workflow in the field of oral rehabilitation through the use of abutments that have their geometries stored in CAD/CAM systems—ie, the Ti-Base abutment, which supports reproducible, structured processes and reduces human resources.\textsuperscript{15–21} Hybrid abutments combine the benefits of prefabricated and customized abutments, including a highly precise implant-abutment fit, absence of ceramic material (mostly Y-TZP) inside the implant connection, the reproduction of a tailored emergence profile, and a bonding procedure under controlled laboratory conditions that increases bonding durability and decreases the soft tissue reaction triggered by cement remnants.\textsuperscript{16,17,22,24–26} Nonetheless, an important aspect influencing the biomechanical performance of implant-supported rehabilitations is the retention mode of the superstructure to the implant—which is hybrid in the Ti-Base concept—aggregating the features of both systems.\textsuperscript{5} While screw-retained restorations are especially known for their retrievability, cement-retained advantages include passive fit of the crown, clinical and laboratory operability, the possibility of implant alignment correction, and potentially improved functional load distribution.\textsuperscript{25,42–45}

Loss of retention (up to 5% in 5 years) is a drawback of all cemented systems,\textsuperscript{3–6} and the scientific literature addressing the influence of cementation protocol on Y-TZP crown retention to Ti-Base abutments is scarce.\textsuperscript{15–17} Initially, the macrodesign, abutment taper degree, and cone height were found to affect the retention of implant-supported rehabilitation.\textsuperscript{29,31} In the present study, the force to dislodgment for 4.0-mm (tall) and 2.5-mm (short) Ti-Base abutments was compared. Data as a function of Ti-Base height have corroborated previous findings, since significantly higher retention was shown when the tall Ti-Base abutment was compared to the short Ti-Base abutment. Hence, the first postulated null hypothesis that Ti-Base abutment height would not influence pull-out retention values was rejected. Other investigations have pointed out that the higher the parallellism and/or height-to-width ratio of the abutment axial walls, the higher the performance on uniaxial pull-out tests, with a 1.5-mm–height increase in the axial wall of standard abutments showing twice the retention values.\textsuperscript{29,31} Nonetheless, short Ti-Bases are clinically important to rehabilitate clinical scenarios of limited interarch space,\textsuperscript{32} which supports the need for future investigations to clarify a minimum height that would still result in adequate frictional retention of Ti-Base abutments for esthetically and biomechanically favorable hybrid prostheses.
Bonding to silica-free nonetchable ceramics remains a challenge to the dental community.\textsuperscript{34,35} Previous studies have generated a ranked order of force to dislodgement for Ti-Base abutments cemented to a Y-TZP superstructure in which resin cement has shown the significantly highest pull-out values (~200 to 400 N), followed by glass-ionomer and provisional cement, which both showed similar retention (< 100 N).\textsuperscript{16,17} Thus, the current study compared the influence of resin cement type (conventional resin cement associated with self-etch adhesive vs self-adhesive resin cement) on the pull-out retention of Ti-Base abutments connected to Y-TZP crowns. Data as a function of resin cement type demonstrated higher retention for Ultimate (270 N) than U200 (194 N) cement. The retention values are corroborated by previous data, and this significant difference supports the rejection of the second null hypothesis. Despite a similar composition, in previous bond strength investigations, methacrylate monomers (containing phosphoric acid groups [MDP] in the cement and adhesive content for U200 and Ultimate, respectively) have also demonstrated more favorable adhesion when Y-TZP was cemented to conventional resin cement compared to self-adhesive cement, especially after artificial aging.\textsuperscript{17,35,46} In U200, acidic monomers have already shown to negatively affect the cement degree of conversion through chemical interactions with the amine initiator (U200: 26% to 68%; Ultimate: 61% to 84%), and a high degree of conversion is critical for improving resin cement mechanical properties.\textsuperscript{47,48}

The interaction between Ti-Base height and cement type has highlighted the superior adhesive strength of Ultimate compared to U200, irrespective of abutment height. While tall Ti-Base exhibited significantly higher retention than short Ti-Base for Ultimate cement, no significant difference between Ti-Base heights was observed for U200 cement. Hence, there was a direct relationship between the macromechanical retention and the higher bond strength properties of the conventional resin cement, which may lie in the higher surface area available for bonding effectiveness.\textsuperscript{33} In contrast, the absence of a significant difference between short and tall Ti-Base cemented with U200 (which were both significantly lower than both Ti-Base heights cemented with Ultimate) may be associated with the weaker bond strength of self-adhesive cements related to conventional resin cements.\textsuperscript{17,33,35,46}

Furthermore, the limited adhesive potential of Y-TZP superstructures and resin-based cement has been well-defined; however, the bond strength is suggested to be improved with the use of micromechanical and/or chemical surface treatments that involve blasting the substrate and/or Y-TZP surface with alumina particles or TBS with silica-coated alumina particles followed by silanization, as well as functional monomers (such as MDP) in the cement system composition.\textsuperscript{34–37} Hence, this study compared the influence of Ti-Base substrate SB, Y-TZP TBS, and the association of both surface pretreatments (SB + TBS) in comparison to NT on increasing Y-TZP crown retention to Ti-Base abutments. Data as a function of surface pretreatment have suggested a ranked order among the proposed methods, in which increased retention was observed for SB + TBS, followed by SB, TBS, and then NT. Thus, the third postulated null hypothesis that surface pretreatment would not influence pull-out retention values was also rejected. SB increased surface roughness, likely increasing micromechanical interlocking through the higher surface area available for bonding,\textsuperscript{34,35,37} and TBS aggregated the chemically reactive effect rendered by the silica-coated surface and silane coupling agent to the resin cement.\textsuperscript{34,35} Moreover, both SB and TBS particle sizes were similar, 30 to 45 µm, which has previously shown a positive effect on improving adhesion, as well as no detrimental influence on the zirconia strength by inducing defects on the material surface.\textsuperscript{38,49}

Evaluating the interactions among the study factors has indicated that surface pretreatment improved the retention for U200 cement and short Ti-Base abutment, irrespective of type (NT < SB = TBS = SB + TBS). In contrast, retention was maximized for Ultimate cement and tall Ti-Base when both surfaces were pretreated (SB + TBS), followed by SB, TBS, and NT. For NT and TBS pretreatments, similar retention was shown between Ultimate and U200 cement and tall and short Ti-Bases; however, for SB and SB + TBS pretreatments, a significant difference was noted between Ultimate and U200 cement and tall and short Ti-Bases. Altogether, the results emphasize the importance of the macro- and microlevel frictional resistance, as well as the bond strength properties of the resin cement, in a hierarchical fashion.\textsuperscript{29,31,33–37,46} Grit-blasting surface techniques (SB + TBS) and conventional resin cements showed maximized effects when tall Ti-Base abutments were evaluated, and the association of methods can be clinically important for providing strong and durable bonds.\textsuperscript{34–37}

The adhesive failure as a consequence of the tensile test marks the increased adhesive bonding when physicochemical coating was performed, since a higher amount of cement remnants were concentrated at the bonding surfaces, especially on the Ti-Base surface. Grit-blasting metallic surfaces with alumina particles (SB) is one of the most effective methods of improving retention, as it physically removes debris, increases the bonding area, and forms an oxide layer on the metal surface that yields a physicochemical surface modification, enhancing wettability and adhesion.\textsuperscript{34,50} Despite TBS, the zirconia surface significantly increased the retention compared to NT through the micromechanical adhesion and the additional chemical adhesion produced by
silanization of the silica-coated alumina particles. Previous studies have also shown reduced bond strength compared to SB due to impaired MDP efficacy as a consequence of the surface silica coverage, as well as of the weak silica attachment to the hard zirconia surface.

Concerning the methodology, the most common laboratory tests to assess the adhesive properties of a luting agent are bond strength tests, such as shear, tensile, microtensile, and push-out tests. While the main advantage of bond strength tests, if properly designed and evaluated, is the reproducibility of results, this concern consists of the nonsimulation of a clinically relevant situation. Although crown pull-out retention test does not accurately reproduce all oral conditions that can cause crown dislodgment when fixed on an implant abutment, it supports the evaluation of individual variables, including abutment geometry, surface pretreatments, and luting cements, on the retention levels of a restorative system.

Furthermore, previous studies have shown a detrimental effect of artificial aging on resin bond strength. Nonetheless, a systematic review and meta-analysis on resin bonding effectiveness has shown decreased bond strength when zirconia received no micromechanical pretreatment (approximately 50% reduction), whereas hardly any effect of aging was observed following the physicochemical pretreatment of the surface, which still requires further investigation. In fact, the current study reports initial bonding data ranking the highest immediate bonding scores for different Ti-Base heights, resin cement types, and surface pretreatments, which will guide subsequent studies in which not only long-term artificial aging, but especially fatigue, can be added to effectively simulate the humid and stressful oral function. Moreover, future clinical trials to verify these findings are warranted.

CONCLUSIONS

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

- Ti-Base abutment height influenced the pull-out resistance of CAD/CAM implant-supported zirconia crowns, where tall abutments presented higher retention forces than short ones.
- Conventional resin cements associated with self-etch adhesive exhibited higher retention than self-adhesive cements.
- Ti-Base surface blasting and zirconia tribochemical silica coating (SB + TBS) increased the retention of zirconia crowns, followed by Ti-Base surface blasting (SB) or tribochemical silica coating (TBS), respectively, compared to NT.
- In a hierarchical fashion, the results demonstrated a direct relationship between the Ti-Base height, micromechanical and/or chemical pretreatment (SB + TBS), and adhesive luting with conventional resin cement associated with self-etch adhesive in maximizing the retention of zirconia crowns.

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REFERENCES

The Incidence of Root Canal Therapy After Full-Coverage Restorations: A 10-Year Retrospective Study

The process of restoring a tooth with a crown leaves many opportunities for pulpal irritation. The objective of this study was to identify and analyze the factors that contribute to the incidence of nonsurgical root canal therapy (NS-RCT) after delivery of single-unit full-coverge restorations. Insurance claims from 88,409 crown placements in the Delta Dental of Wisconsin insurance database were analyzed from the years 2008 to 2017. The Cox regression model was used to analyze the effect of the predictor variables on survival of the tooth. Untoward events were defined as NS-RCT, tooth extraction, retreatment of root canal, or apicectomy, as defined by the Code on Dental Procedures and Nomenclature. Of 88,409 crowns placed, 8.97% were complete metal, 41.40% were all-ceramic, and 49.64% were porcelain-fused-to-metal (PFM). The probability of survival for all teeth with crowns placed was 90.41% after 9 years. NS-RCT was the most common untoward event. PFM crowns exhibited a higher rate of untoward events than complete metal crowns and a lower rate than all-ceramic crowns. Crowns placed in individuals 50 years of age and younger had higher rates of untoward events than those placed in individuals 51 years and older. The risk of endodontic treatment after the placement of crowns is low. This risk increases with the placement of all-ceramic or PFM crowns and as the age of the patient decreases.


Literature Abstract