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Original Article

Effect of Implant Abutment Acid Etching on the Retention of Crowns Luted with Different Cements: An *In Vitro* Comparative Evaluation

R. Ajay, V. Rakshagan[1], M. Kamatchi[2], A. SelvaBalaji[3], Jambai Sampath Kumar Sivakumar[4], M. Senthil Kumar[5]

Department of Prosthodontics and Crown and Bridge, Vivekanandha Dental College for Women, Tiruchengode, Tamil Nadu, [1]Department of Prosthodontics and Implant Dentistry, Saveetha Dental College and Hospital, Saveetha University, Chennai, Tamil Nadu, [2]Department of Pedodontics and Preventive Dentistry, Vivekanandha Dental College for Women, Tiruchengode, Tamil Nadu, [3]Department of Pedodontics and Preventive Dentistry, Indira Gandhi Institute of Dental Sciences, Pillayarkuppam, Pudhucherry, [4]Department of Conservative Dentistry and Endodontics, Vivekanandha Dental College for Women, Tiruchengode, Tamil Nadu, [5]Department of Conservative dentistry and Endodontics, Madha Dental College and Hospital, Chennai, Tamil Nadu, India

ABSTRACT

Background: Air abrasion of the implant abutment surface improves the bond strength of luting agents. However, the effect of acid etching and combination of air abrasion and acid etching on the bond strength of various luting agents under masticatory load is yet to be documented. **Purpose:** The purpose of this study was to evaluate the effect of implant abutment surface modifications on the tensile bond strength (TBS) of cast metal copings (CMCs) luted with different luting agents, subjected to cyclic fatigue loads. **Materials and Methods:** A total of 150 Ni-Cr CMCs were made on commercially pure titanium (Cp-Ti) laboratory analogues. The samples were categorized into three groups based on surface modifications and five subgroups for luting agents. The CMCs were cemented to the respective surface-modified groups, stored in distilled water at 37°C for 24 hours, and then subjected to load cycling, followed by tensile loading. One-way analysis of variance (ANOVA) was used to compare the mean bond strength between luting agents. **Results:** Self-adhesive resin cement showed the highest TBS followed by resin-modified glass ionomer cement, zinc polycarboxylate, and zinc phosphate cement. Non-eugenol temporary cement showed least TBS values on all modified abutment surfaces. **Conclusion:** Air abrasion + acid etching (HY) provided the greatest TBS followed by acid-etched (AE) surface only. Air-abraded (AA) surface yielded the least TBS for luting agents.

KEYWORDS: *Acid etching, cement retention, surface-modified abutments, tensile bond strength*

INTRODUCTION

The common modes of retention of the implant prosthesis (crowns and bridges) are derived from the cements used to lute them. Progressive loading, passive casting, axial loading, accessibility, and so forth are some of the advantages of cement-retained prosthesis (CRP) and at the same time are limitations of screw-retained prosthesis.[1]

From the implant literature, it can be inferred that abutment surface modifications improved the bond strength of the luting agents. The predominant variables of modifications are abutment taper, screw

Address for correspondence: Dr. Ajay R., Department of Prosthodontics and Crown & Bridge, Vivekanandha Dental College for Women, Elayampalayam, Tiruchengode, Namakkal 637205, Tamil Nadu, India.
E-mail: jrangclassiq@gmail.com

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How to cite this article: Ajay R, Rakshagan V, Kamatchi M, SelvaBalaji A, Sivakumar JS, SenthilKumar M. Effect of implant abutment acid etching on the retention of crowns luted with different cements: An *in vitro* comparative evaluation. J Pharm Bioall Sci 2019;11:S360-4.

Access this article online

Quick Response Code:

Website: www.jpbsonline.org

DOI: 10.4103/jpbs.JPBS_35_19

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access channel engagement, height, number of axial walls, platform, and roughness of abutment surface. Engaging the screw channel offsets the retention loss of luted crowns with a taper up to 22°.[2-4]

Altering the surface morphology of the titanium abutment was an effective way to improve cement retention. There are numerous methods to achieve the same. These abutment surface modification methods can be broadly classified into two categories: (1) mechanical methods that include sandblasting,[5-8] roughening with diamond rotary,[9] and circumferential grooving,[10,11] and(2) chemical method that includes etching the abutment surface with 48% H_2SO_4 at constant temperature of 60°C for an hour.[12]

The bond strength of $Zn_2(PO_4)_3$ cement on acid-etched abutment was greater than sandblasted abutment.[12] However, the bond strength of other luting agents with etched abutments is not described yet in the literature. The aim of this study was to evaluate and compare the retention of cast metal coping (CMC) luted with various cements on sandblasted and acid-etched abutments under cyclic fatigue loads.

Materials and Methods

A total of 150 commercially pure titanium (Cp-Ti), single piece laboratory analogues (Nobel Biocare India Pvt. Ltd., Mumbai) were used. These analogues were 5.5 mm in height and 4.3 mm in diameter. All the analogues were mounted in auto-polymerizing acrylic resin using surveyor.

CMCs were fabricated from preformed snappy abutment caps (Nobel Biocare India). These preformed caps were adapted over the analogues and waxed.[13] An occlusal platform of 7-mm diameter and 1.2-mm thickness was attached on the top of each preformed caps and 1-mm-diameter dimple of 0.5 mm depth was created 3 mm away from the long axis with No. 2 round bur as a site for off-axial cyclic loading. To apply tensile load, a circular ring provision was attached at the center of the occlusal platform.[12]

Beryllium-free nickel-chromium alloy (Wiron® 99; Lincoln; BEGO USA Inc.) was used to cast the pattern. The fitting surface was carefully inspected for nodules or fins and removed to ensure the fit of CMC on the analogues. This was followed by air abrasion of the intaglio surface of CMC with 50 µm Al_2O_3. Disclosing media was used to verify the fit of CMC. The stability of CMC was assessed by applying lateral finger pressure and by looking for any rocking movements.[14]

Table 1 shows the sample distribution under categorized groups and subgroups. The samples (N = 150) were categorized into the following three major groups based on the type of abutment surface modification: Group I, air abrasion (AA); Group II, acid etching (AE), and Group III, hybrid (HY)—combining both AA and AE. Based on the type of cement used to lute CMC, there were five subgroups (n = 10 under each subgroup): Subgroup I, $Zn_2(PO_4)_3$ cement (Elite Cement 100; GC Corporation; Tokyo, Japan); Subgroup II, zinc polycarboxylate (ZnCOO−) cement (Harvard Dental International GmbH, Germany); Subgroup III, non-eugenol temporary (NET) cement (TempBond NE; Kerr Corp, Orange, CA); Subgroup IV, resin-modified glass ionomer (RMGI) cement (3M RelyX Luting 2 Cement; 3M ESPE; St Paul, USA) and Subgroup V, self-adhesive resin (SAR) cement (3M RelyX U200; 3M ESPE).

AA group samples were air-abraded with 50 µm Al_2O_3 at 1 bar pressure of compressed air from a constant distance of 10 mm for 5 seconds. AE group samples were etched with 48% H_2SO_4 at a temperature of 60°C for 1 hour, which was then followed by ultrasonic cleaning in $NaHCO_3$ bath to remove any acid residues. HY group samples were air-abraded and then etched following the above-mentioned procedures. The screw access channels of the analogues were filled with addition silicone putty. The CMCs were steam-cleansed and luted to the respective surface-modified groups with the cements following manufacturers' instructions with a constant axial hydraulic load of 5 kg.[5] Excess cement was removed with Hollenback carver and the seating of CMC was assessed visually. CMCs luted on the surface-modified analogues (groups) with the luting agents (subgroups) were stored in distilled water at 37°C for 24 hours.

The CMCs were subjected to load cycling (5000 cycles to simulate 1 year of average mastication with 5 kg load at 80 cycles/min)[12] at the dimple created on occlusal platform. This was followed by uniaxial tensile load test using servo controlled universal testing machine (Model UNITEK-94100; FIE, Department of Manufacturing

Table 1: Sample distribution (N = 150)

Subgroups	Groups		
	I: AA (n = 50)	II: AE (n = 50)	III: HY0 (n = 50)
I. $Zn_2(PO_4)_3$	10	10	10
II. $ZnCOO^-$	10	10	10
III. NET	10	10	10
IV. RMGI	10	10	10
V. SAR	10	10	10

AA = air-abraded, AE = acid-etched, HY = air abrasion + acid etching, NET = non-eugenol temporary, RMGI = resin-modified glass ionomer, SAR = self-adhesive resin

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Engineering, Annamalai University, Chidambaram, India), traveling at a cross-sectional speed of 5 mm/min until the CMCs were detached from the samples. Tensile bond strength (TBS) was measured in newton for each subgroup.

The obtained data were analyzed using SPSS, version 18.0 (SPSS, Chicago, IL). Shapiro–Wilks test was used to assess normality of the data. Based on the distribution, one-way analysis of variance (ANOVA) with post hoc Tukey's honestly significant difference test was used to compare the mean bond strength between luting agents. The obtained data were considered to be statistically significant when *P* value was less than 0.05.

Results

The mean and standard deviation of the TBS of the luting agents are presented in Table 2. SAR showed the highest TBS values on all the three modified abutment surfaces (AA: 524.87 ± 1.796; AE: 561.44 ± 0.786; and HY: 556.84 ± 2.113). AE and HY surface treatments increased the retentive values of the luting agents significantly except for SAR, where AE had better retentive values than HY. However, this difference was statistically insignificant. The retentive values of RMGI on all three surface-modified abutments (AA: 275.83 ± 1.240; AE: 397.52 ± 1.805; and HY: 400.38 ± 1.438) followed SAR. AA and AE surface treatments showed higher TBS for $ZnCOO^-$ (AA: 253.34 ± 1.644; AE: 310.05 ± 1.626) than $Zn_2(PO_4)_3$ (AA: 244.03 ± 2.312; AE: 302.82 ± 2.501). On the other hand, in HY surface treatment, TBS of $Zn_2(PO_4)_3$ (386.00 ± 1.822) was slightly higher than the $ZnCOO^-$ (379.58 ± 1.998). However, these changes in the TBS yielded statistically significant difference. The weakest TBS values were obtained for NET. The TBS of NET in HY was 146.78 ± 2.773. Moreover, there was no significant difference (*P* = 0.288) on the TBS of NET on AA and AE (142.23 ± 1.338 and 143.65 ± 1.839). The effect of AA, AE, and HY on TBS of the luting agents are shown pictographically in Figures 1–3.

Table 2: Mean and standard deviation of the TBS [N] of cements on surface-modified abutments

Subgroups	Groups	Mean ± standard deviation	Difference*
$Zn_2(PO_4)_3$	AA	244.03 ± 2.312	–
	AE	302.82 ± 2.501	–
	HY	386.00 ± 1.822	–
$ZnCOO^-$	AA	253.34 ± 1.644	–
	AE	310.05 ± 1.626	–
	HY	379.58 ± 1.998	–
NET	AA	142.23 ± 1.338	a
	AE	143.65 ± 1.839	a
	HY	146.78 ± 2.773	–
RMGI	AA	275.83 ± 1.240	–
	AE	397.52 ± 1.805	–
	HY	400.38 ± 1.438	–
SAR	AA	524.87 ± 1.796	–
	AE	561.44 ± 0.786	–
	HY	556.84 ± 2.113	–

AA = air-abraded, AE = acid-etched, HY = air abrasion + acid etching, NET = non-eugenol temporary, RMGI = resin-modified glass ionomer, SAR = self-adhesive resin, TBS = tensile bond strength

*Values having the letter "a" were not significantly different for post hoc Tukey's test (*P* = 0.288)

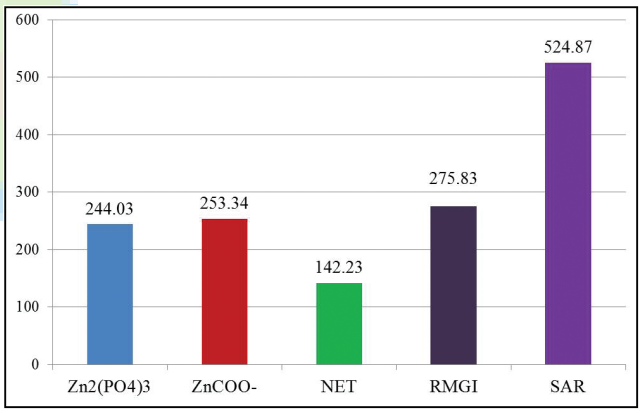


Figure 1: Effect of air-abrasion (AA) on the tensile bond strength (TBS) of luting agents

Discussion

CRP is commonly used in implant dentistry. This approach has closest resemblance to conventional fixed prosthodontic procedures.[15] Superior occlusion, cost-effectiveness, less complex laboratory procedures, ease of component usage, and less chairside time are the additional benefits.[16] Studies have already proven that the retentive quality of luting agents was improved by abutment surface modification by AA[17,18] compared to unmodified abutment and diamond roughened surfaces.[9] In the previous study,[12] it was proven that AE, the abutment surface, paved for greater TBS than AA modified surface. Also, cycling loading affected the TBS of the luting agent. AA, the abutment surface with 50 μm Al_2O_3, lead to the creation of microscale retention associated with microcavities for cement retention.[19] Hence, in this study, AA surface-modified abutments were used as control and cyclic loading was performed for the luted CMC on the surface-modified abutments.

Another method of achieving surface roughness on the abutment surface is by AE. AE improved the retention of the CMC than AA. Acid etching the abutment surface with 48% H_2SO_4 at 60°C for 60 minutes was

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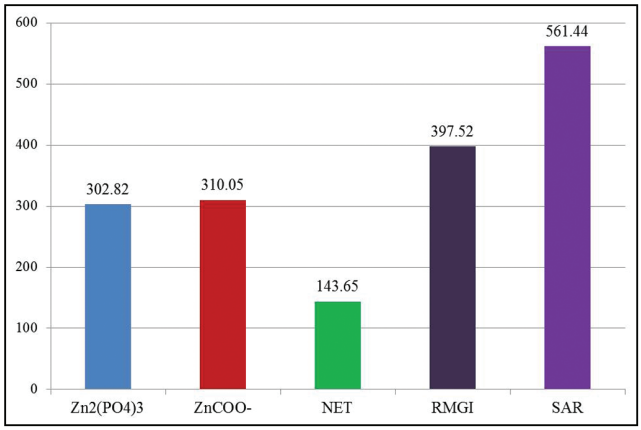


Figure 2: Effect of acid-etching (AE) on the tensile bond strength (TBS) of luting agents

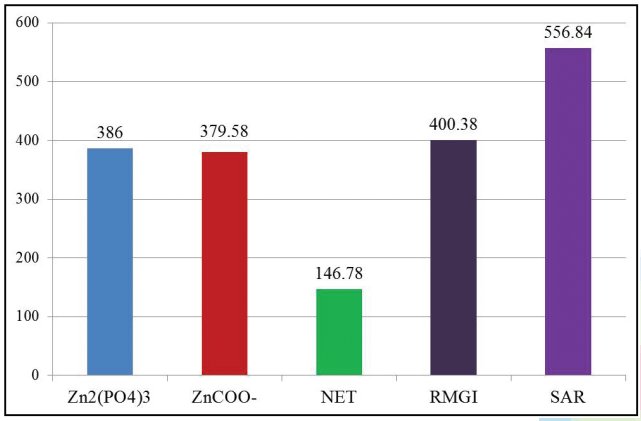


Figure 3: Effect of air abrasion + acid etching (HY) on the tensile bond strength (TBS) of luting agents

performed. This improved the TBS of all luting agents, which was significantly higher than that of AA group except NET. In scanning electron microscope analysis, it was observed that acid etching the abutment surface contributed to increased surface undercuts than air-abraded abutments. The reason would be higher arithmetic mean roughness (Ra) for AE abutments than AA abutments.[19] Increase in the undercuts and nanocavities on AE abutment surfaces increased the micro- and nanoretention, which in turn contributed to high TBS of luting agents in this study.

Another plausible explanation for decreased TBS in AA group is that after air abrasion, some Al_2O_3 particles probably remained embedded on the surface of the abutments, which concealed the micromechanical retention. However, in AE group, acid etching yielded several advantages to the abutment surface by increasing micro-and nanoscale mechanical interlocking, increasing effective bonding surface area, and decreasing contaminants from the surface.[19] The technique for acid etching base metal alloys was first elucidated by Tanaka *et al.*[20] for resin-bonded fixed partial denture to improve the bond strength of resin cements to base metal alloys.

For all the luting agents except SAR, HY surface-modified abutments yielded greater TBS than the AA and AE groups. This may be attributed to a synergistic effect between AA and AE, which would have created both micro- and nanosurface roughness, respectively. Acid etching the air-abraded surface removed the remnants of Al_2O_3 and other surface contaminants, thus increasing the TBS of the luting agents.[19]

Among the luting agents, SAR had the greatest TBS when compared to other cements. The highest retention values for SAR among other luting agents are attributed to methacrylated phosphoric esters, which can react chemically with the chromium oxide on the intaglio surface of CMC and with titanium dioxide on the abutment surface. The strong bonding between the CMC and the surface-modified abutment is created by micro-/nanomechanical retention enhanced by HY surface treatment and the oxide layer on the metallic surfaces.[21]

The TBS of $ZnCOO^-$ was significantly greater than $Zn_2(PO_4)_3$ and NET. This may be attributed to the adhesive properties of $ZnCOO^-$. While setting, $ZnCOO^-$ can adhere to tooth structure by calcium ion chelation[22] and to metal surfaces by metallic ion chelation.[23-25] Therefore, $ZnCOO^-$ chemically bonds to the surface-modified implant by adhesion and thus possess significantly higher retention than $Zn_2(PO_4)_3$ and NET. $Zn_2(PO_4)_3$ provides CMC retention by micromechanical interlocking between the casting and the abutment surface irregularities.[26] Because there is lack of chemical adhesion, $Zn_2(PO_4)_3$ possess significantly lesser TBS than $ZnCOO^-$. RMGI adhere to prepared dentinal and metallic surfaces in the same way as does $ZnCOO^-$. However, the curing process may last 24 hours or more.[27]

As a limitation, the type of cement failure is not evaluated and accounted in this *in vitro* study. This study used oral environment simulations that were not able to reproduce all oral conditions appropriately. Further, future researches regarding the TBS of CRP shall investigate luting agents with various implant systems under validated, standardized *in vitro* conditions. Development of new-generation luting agents exclusively for the field of implant prosthetics may be warranted.

Conclusion

Within the limitations of the study, the following conclusions can be deduced:

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1. AE and HY abutment surface modifications had greater retention of the CMC than AA group.
2. HY modification yielded superior retention of the CMC than the other two methods of modifications.
3. HY modification can be considered as a superior technique to increase the retention of any luting agent under masticatory loads.
4. SAR showed the highest retentive values when compared with other luting agents used in this study.
5. NET possessed the least retentive values.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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