Effects of abutment taper on the uniaxial retention force of cement retained implant restorations

Efeito da conicidade do pilar na resistência de união de coroas cimentadas sobre implantes

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ABSTRACT

Aim: The purpose of this study was to evaluate the bond strength of metallic crowns cemented to straight and angled customizable abutments with zinc phosphate. Material and Method: Thirty-nine external hex analogs and abutments were divided in group S: customizable straight abutment (n = 10), group A17 with 17° angled abutment (n = 10) and group A30 with 30° angled abutment (n = 10) all cemented with zinc phosphate. The metal copings were cemented onto their corresponding metal dies according manufacture guidelines. Data from the all groups were compared with a 1-way ANOVA (α=.05) and Tukey's test. SEM evaluation were performed (n = 3) aiming to investigate microscopic features of the abutment-cement-crown interfaces. Results: The mean force (SD) required to dislodge the crowns in the S, A17 and A30 groups was 357.26 (62.21) N; 251.50 (20.13) N and 276.70 (17.96) N respectively. The Tukey test ($p < 0.05$) revealed a significant statistically differences between the groups ($p = .002$) and the 17° angled abutment and 30° angled abutment group were statistically similar to each other and different from the group of straight abutments. Zinc phosphate showed an inhomogeneous cement line in SEM analysis. Conclusions: Within the limitations of this study, it can be conclude that the available surface area and convergence of the abutments axial walls of the straight abutments positively influenced bond strength in metallic crowns cemented with zinc phosphate.

KEYWORDS: Implant-supported dental prosthesis; Dental implant-abutment connection; Tensile strength; Zinc phosphate cement.

INTRODUCTION

Prosthetic reconstruction with implants can involve screw-retained or cement-retained restorations. The greatest advantage of screw-retained prostheses is reversibility. Cement-retained restoration offers the ability to improve occlusal contacts, improved aesthetic conditions from the elimination of the screw access hole, and further passivity of the framework, which can improve stress distribution. In general, both have shown continuous evolution, and the survival rates of implant restorations are steadily growing[1-3].

There is still no consensus that one retention method is superior to another, and the use of a given system depends on the dentist's preference and the limitations of each specific case. Specifically, cement-retained restorations offer the potential for complete passivity resulting from high frictional retention. Another advantage is that retention increases by up to three times when compared to conventional fixed prostheses. Besides the fact that abutments present generally larger surface areas than naturally prepared teeth, this superiority in retention is also linked to the convergence of the abutment axial walls as preset by the manufacturer, ranging from around 6° to 10°[2].

In general, the contact surface between the inner walls of the restoration and the external area of the abutments determines the degree of frictional retention. There is a direct relationship between surface area, parallelism of axial walls, and frictional retention of the restoration[4-6]. These principles are equally valid and applicable to conventional bridges and implant-supported cemented prostheses. Thus, factors such as the height and width of the prosthetic component, the type of cement, and the cementing technique may influence the tensile strength of cemented prosthetic pieces[4, 7, 8].

In clinical situations where the bone condition complicates the placement of implants— which can lead to a greater number of variables to be observed in prosthetic rehabilitation—coupled with the wear often necessary to customize the component to the clinical situation, angled and customizable abutments figure as an alternate solution. These abutments have a large screw hole in one of the axial walls for decreasing the surface area and changing the inclination of the axial walls preset by the manufacturer[7].

Given the small number of studies addressing the relative retentiveness of several definitive and temporary dental cements with metal surfaces[9], there is justification for an investigation of the correlation between the different angles of the axial walls of metal abutments, the different surface areas available for bonding, and the use of conventional or resin cements. This may provide relevant information for the choice of dental cement considering the particularities of each clinical situation. It might also provide important strategic information to the industry about the possible need for surface treatment performed in the production line, aiming to better the clinical performance of angled components.

MATERIAL AND METHODS

Specimen description and confection procedures

Thirty-nine regular hex analogs and abutments (Neodent, Curitiba, PR, Brazil) were used in this study. The analogs were obtained from a single lot of commercially available stock and randomly divided into three groups (n = 10) according to the abutment type. Three different types of abutments with different heights, occlusal convergence angles, and surface areas were used as provided by the manufacturer. Straight customizable abutments, 17° customizable angled abutments, and 30° customizable angled abutments were used in association with permanent zinc phosphate cement (SS White, Rio de Janeiro, Brazil). Thus, the groups were divided into group S: straight abutments (n = 10); A17 group: 17° customizable angled abutments (n = 10); and A30 group: 30° customizable angled abutments (n = 10). In addition, three representative samples from each group (n = 3) were necessary to analyze the microstructural characteristics of the interface created between abutment, cement, and crown by scanning electron microscopy (SEM).

For inclusion of the analogs in optimal positions, three devices of aluminum were made to allow the correct positioning of the analogs prior to inclusion on polystyrene resin (Aerojet, São Paulo, Brazil). The device consisted of aluminum bars with dimensions of 12.5 cm x 2.5 cm x 1.0 cm, with five holes of the same width and a previous angulation analog according to group (i.e., one bar was made with straight holes, a second bar with 17° angled holes, and a third bar with 30° pre-angled holes).

The analogs were placed in the devices' holes and stabilized by long screws screwed through the aluminum bar. Then PVC cylinders 20 mm in diameter and 20 mm high were positioned centrally over the aluminum bar, and polystyrene resin was then poured inside the cylinders. After the resin curing time, the cylinders were removed from the PVC, and the long screws were removed as well.

The abutments were tightened to the analogs with 32 N·cm. Thirty-nine wax copings with occlusal wax rings were formed directly over the abutments. The wax rings were added to the occlusal portion of the waxed coping for retentive testing.

After the waxed crowns were numerically identified according to their analogs, all wax patterns were sprued, invested in a phosphate-bonded investment (Micro Fine, Talladium, Brazil), and cast in NiCr alloy (Fit Cast, Talladium, Brazil; 25% Cr, 10% Mo, and 60.75% Ni) according to the manufacturer's guidelines. After casting, the blocks were immediately cooled in water. Then the blocks were manually fractured, and all metal was removed and obtained. After deflasking and ultrasonic cleaning, the internal aspects of the castings were visually inspected, and surface irregularities were removed with a small, round tungsten carbide bur. Residual investment materials were removed using an ultrasonic cleaner with a mild detergent and sandblasted using 50-µm aluminum oxide particles.

The torque of the abutments was checked, and the access holes of the straight and angled abutments were completely sealed with a dense elastomeric material with care to not impede the passive fit of the crowns (Optosil P Comfort, Heraeus Kulzer, Hanau, Germany; Fig. 1).

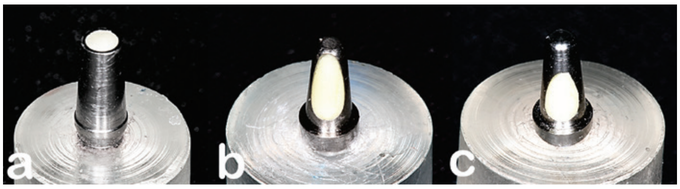

Figure 1 - Screw access holes sealed with silicone. A: straight abutment, B: 17° abutment, C: 30° abutment.

The samples were subjected to cementing with zinc phosphate cement. Following the group division, the cement manipulation was carried out according to the manufacturer's recommendation. After the handling time, the cement was applied to the crown's axial walls. Then each restoration was seated immediately with finger pressure, and a 10 kg static vertical load was applied with a loading device. After setting, the excess cement was removed with an explorer, and the samples were stored in water in a dark environment at room temperature (24ºC ± 2ºC).

Tensile bond strength (TBS) test

Each specimen was positioned in a mechanical testing machine (DL 2000, EMIC, São José dos Pinhais, PR, Brazil) using an apparatus fabricated specifically to ensure the application of isolated axial forces (Fig. 2). Using a 100 kg load cell at a crosshead speed of 0.5 mm/minute, the tensile test was performed, and the tensile bond strength (TBS) data was recorded in newtons (N).

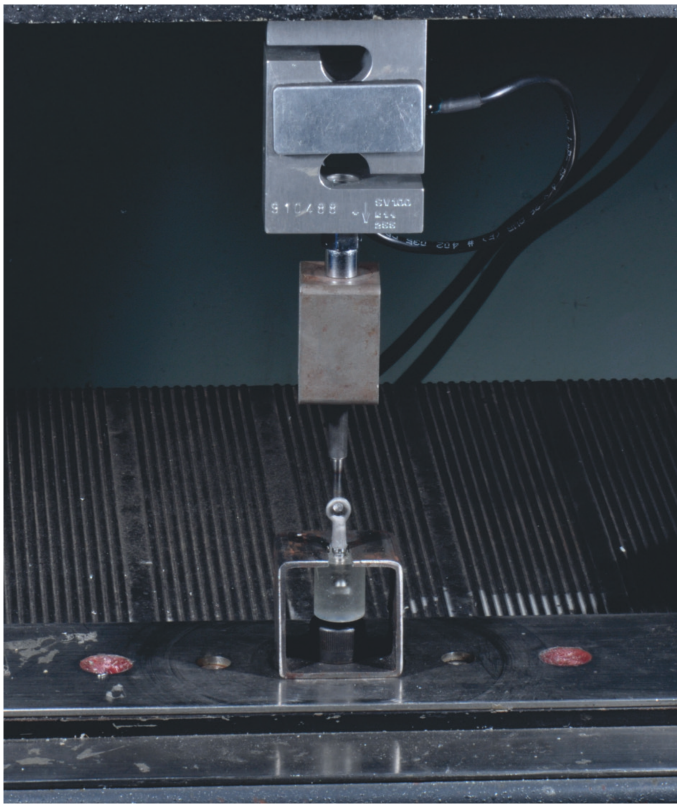

Figure 2 - Apparatus fabricated specifically to ensure the application of vertical forces.

SPSS software (SPSS 18.0, SPSS Inc., Chicago, IL, USA) was used for all statistical analyses. Differences in TBS values between the groups were compared by one-way analysis of variance (ANOVA), followed by a Tukey test with significance levels set at $P < .05$.

Failure mode analysis

Each tested specimen was classified according to the predominant remaining structure on the abutment surface following the described failure mode: adhesive failure (no cement remnant on the abutment surface—mode 1) or mixed failure (cement remnants on the abutment and fit surfaces of the crown—mode 2). The results of the failure mode classification within each substrate were subjected to percentile distribution.

SEM analysis

To observe the morphology at the bonding interfaces, three additional specimens were obtained for each group (n = 3)[10]. The specimens were completely embedded in epoxy resin and longitudinally cross-sectioned (Isomet, Buehler Ltd, Lake Bluff, IL, USA) to expose the crown-cement-abutment internal fitting interface (Fig. 3). The specimens were then wet-polished with 600-, 1,200-, and 2,000-grit SiC paper. The cross-section profiles were examined by scanning electron microscopy (SEM, Phenom G2 PRO, Phenom World BV, Eindhoven, Netherlands), focusing on the depth of the cement's penetration; micromechanical entanglement; and the integrity, homogeneity, and continuity along the bonding interface. Ten images were obtained from each sample, and a representative image was chosen considering similarities and repetitive patterns.

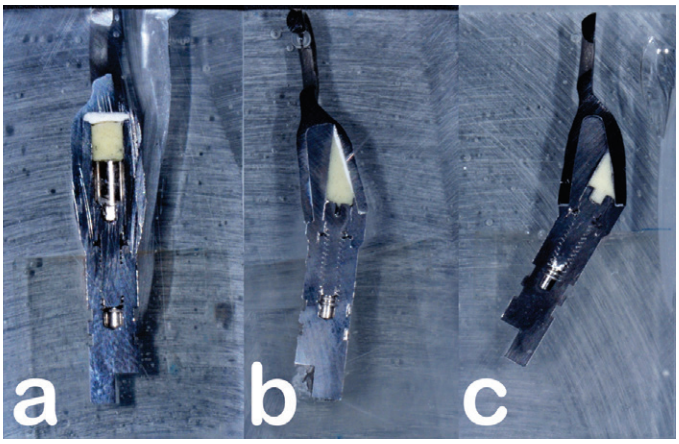

Figure 3 - Specimens longitudinally cross-sectioned to analyze the crown-cement-abutment internal fitting interface. A: straight abutment, B: 17° abutment, C: 30° abutment.

RESULTS

Tensile bond strength test

The Tukey test ($p < .05$) revealed significant statistical differences between the groups ($p = .002$), and the 17° angled abutment and 30° angled abutment groups were statistically similar to each other and different from the group of straight abutments (Table 1).

Failure mode analysis

In failure mode analysis, two types of failures were observed: adhesive failure and mixed failure (adhesive and cohesive).

Table 2 - Failure modes distribution for all groups [% (n out of 10)].

Group	Failure Mode	
	Adhesive	Mixed
S	100(10)	0(0)
A17	70(7)	30(3)
A30	70(7)	30(3)

Samples of groups A17F and A30F showed different amounts of two types of failure modes, and the group of straight abutments demonstrated only adhesive failures. High values of TBS were associated with adhesive failures. Table 2 lists the percentage distribution of failure modes between the groups.

Table 1 - Mean ± SD - bond strength of tested groups (N)

Group	Mean ± SD	
S	357.26 ± 62.21	A
A17	251.50 ± 20.13	B
A30	276.70 ± 17.96	B

*Different letters show significant statistic differences among the groups - Tukey Test (p<,05).

SEM evaluation

SEM micrographs of zinc phosphate interfaces are shown in Figure 4. The analyzed specimens showed full completion of the irregularities on the NiCr crown side. Unfilled voids and empty spaces were sometimes detected. Discontinuation along the bonding interface was also detected and was more frequent and extensive on the Ti abutment side. Internal cracks (arrows) in the cement are shown in Figure 4D.

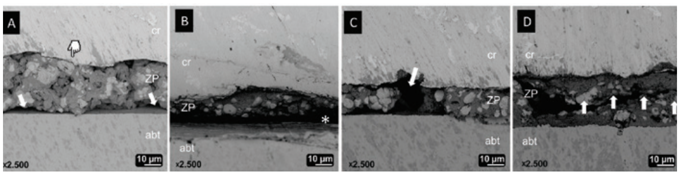

Figure 4 - cr: NiCr crown; abt: Ti abutment; ZP: zinc phosphate. SEM micrographs of zinc phosphate interfaces are shown in A, B, C, and D. A: full completion of the irregularities on the NiCr crown side (pointer); unfilled voids and empty spaces were sometimes detected (arrows). B: Discontinuation along the bonding interface (asterisk) was also detected and was more frequent and extensive on the Ti abutment side; C: empty spaces at the interface (arrow); D: Internal cracks (arrows) in cement.

DISCUSSION

The present study demonstrates that the surface area, the angulation of the axial walls, and the characteristics of the cement are factors that influence the tensile strength of metal crowns cemented on customizable abutments.

The results show statistically significant differences between groups. The groups A17 and A30 were statistically similar and differed from the group of straight abutments. In group A17, the abutments have reduced surface area but the same taper of axial walls as the abutments of the A30 group; both have inferior characteristics of the surface area, height, and angle of the axial walls when compared to the straight abutment. This shows that the surface area and the taper of the straight abutments were significant for the result[10, 11].

Zinc phosphate cement is the oldest and most popular dental cement, and its formulation remains similar to that introduced more than a century ago[12]. Even today, the zinc phosphate is used to cement crowns due to low cost, easy workability, and good mechanical properties; however, it is a cement with critical solubility in the oral environment[13]. Zinc phosphate cement adheres by means of mechanical retention on dentin surface irregularities, and the restorative material does not promote adhesion between the tooth and the casting, but rather a mechanical interlocking[14-17].

The failures observed in this study, after the tests were analyzed macroscopically, were mostly adhesive in nature. The failure mode was only adhesive to the group of the straight abutments, and for the angled abutment groups (A17 and A30), mixed failures occurred but with a predominance of adhesive failures. This observation accords with some studies[18] that have reported that failures occurring in the body of the zinc phosphate cement are generally adhesive in nature since it has low bonding strength to structures. Zinc phosphate cement presents a critical manipulation technique and still has low tensile strength; this determines the importance of preparation geometry in reducing the development of tensile destructive stresses along cement interface, resulting in restoration retention loss. Perhaps for this reason, the angled abutments showed some cohesive failures[17, 19]. The predominance of adhesive failures for the zinc phosphate can also be explained by the characteristics of the groups since they do not receive any type of surface treatment—such as sandblasting—remaining smooth and unaltered.

In this study, the abutment surface remained unchanged. The authors decided to test the bond strength on a smooth titanium surface as provided by the manufacturer, aiming to prevent any influence of a physical modification of the surface. Treatments such as sandblasting, or abrasion, are responsible for a considerable increase in bond strength[20], which could override the results investigated in this study.

It is essential, however, that further studies be conducted—within the parameters already evaluated here—with the aim of determining the critical point of wear that the cement can be used; studies should also analyze the behavior of the bonding strength in the face of thermal and mechanical loading.

Within the limitations of this in-vitro study, and based on the literature, it can be concluded that the available surface area and the convergence of the axial walls of the straight abutments positively influenced the highest bond strength found.

ACKNOWLEDGMENTS

This study was supported by CAPES/Brazil. Authors are grateful to Dr. E.W. Kitajima, Dr. F.A.O. Tanaka and R.B. Salaroli (NAP/MEPA-ESALQ/USP, Brazil) for SEM equipment support and to NEODENT (Curitiba, PR, Brazil) that provided all implant materials.

REFERENCES

01. Adell R, Eriksson B, Lekholm U, Branemark PI, Jemt T. Long-term follow-up study of osseointegrated implants in the treatment of totally edentulous jaws. Int J Oral Maxillofac Implants. 1990; 5: 347-59.

02. 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.

03. Michalakis KX, Hirayama H, Garefis PD. Cement-retained versus screw-retained implant restorations: a critical review. Int J Oral Maxillofac Implants. 2003; 18: 719-28.

04. Covey DA, Kent DK, St Germain HA, Jr., Koka S. Effects of abutment size and luting cement type on the uniaxial retention force of implant-supported crowns. J Prosthet Dent. 2000; 83: 344-8.

05. Heintze SD. Crown pull-off test (crown retention test) to evaluate the bonding effectiveness of luting agents. Dent Mater. 2010; 26: 193-206.

06. Kaufman EG, Coelho DH, Colin L. Factors influencing the retention of cemented gold castings. J Prosthet Dent. 1961; 11: 487-502.

07. Kent DK, Koka S, Banks SB, Beatty MW. Factors influencing retention of a CeraOne gold cylinder. Implant Dent. 1996; 5: 96-9.

08.

09. Schneider R, de Goes MF, Henriques GE, Chan DC. Tensile bond strength of dual curing resin-based cements to commercially pure titanium. Dent Mater. 2007; 23 : 81-7.

10. Taylor TD, Agar JR, Vogiatzi T. Implant prosthodontics: current perspective and future directions. Int J Oral Maxillofac Implants. 2000; 15: 66-75.

11. Naves LZ, Santana FR, Castro CG, Valdivia AD, Da Mota AS, Estrela C, Correr-Sobrinho L, Soares CJ. Surface treatment of glass fiber and carbon fiber posts: SEM characterization. Microsc Res Tech. 2011; 74: 1088-92.

12. 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; 12:111-5.

13. Ames WB. A new oxiphosphate for crown setting. Dent Cosmos. 1892; 34: 392-3.

14. Gorodovsky S, Zidan O. Retentive strength, desintegration and marginal quality of luting cements. J Prosthet Dent. 1992; 68: 269-74.

15. Arcoria CJ, Kelly GT, Icenhower TJ, Wagner MJ. Microleakage in amalgam restorations following burnishing, polishing, and time-varied thermocycling. Gen Dent. 1992; 40: 421-4.

16. Diaz-Arnold AM, Vargas MA, Haselton DR. Current status of luting agents for fixed prosthodontics. J Prosthet Dent. 1999; 81:135-41.

17. Ernst CP, Wenzl N, Stender E, Willershausen B. Retentive strengths of cast gold crowns using glass ionomer, compomer, or resin cement. J Prosthet Dent. 1998; 79:472-6.

18. Hill EE. Dental cements for definitive luting: a review and practical clinical considerations. Dent Clin North Am. 2007; 51:643-58, vi.

19. Øilo G, Norway H. Luting cements: a review and comparison. Int Dent J. 1991; 41:81-8.

20. Haddad MF, Rocha EP, Assuncao WG. Cementation of prosthetic restorations: from conventional cementation to dental bonding concept. J Craniofac Surg. 2011; 22:952-8.

21. de Campos TN, Adachi LK, Miashiro K, Yoshida H, Shinkai RS, Neto PT, Frigerio ML. Effect of surface topography of implant abutments on retention of cemented single-tooth crowns. Int J Periodontics Restorative Dent. 2010; 30:409-13.

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