INFLUENCE OF SCREW ACCESS CHANNEL ON THE COMPRESSIVE STRENGTH OF LITHIUM DISILICATE AND ZIRCONIA IMPLANT-SUPPORTED CROWNS

INFLUÊNCIA DO CANAL DE ACESSO DO PARAFUSO SOBRE A FORÇA COMPRESSIVA DE COROAS IMPLANTOSSUPORTADAS EM ZIRCÔNIA E DISSILICADO DE LÍTIO

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Uniterms:

Compressive Strength;
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ABSTRACT

Purpose: The purpose of this study was to evaluate the influence of a screw access channel (SAC) on the compressive strength of implant-supported crowns manufactured with screw-retained or cement-retained abutments using either yttria-stabilized zirconia (YSZ) or lithium disilicate (LS2) infrastructures. Materials and method: Forty specimens composed of external hexagonal implant analogs with a 4.1mm platform, prefabricated titanium abutments for cement-retained prostheses, and infrastructures for full crowns were fabricated. The specimens were divided into four groups (n = 10) based on the ceramic system and presence of SAC as follows: G1= YSZ crown without SAC (control); G2 = YSZ with SAC; G3 = LS2 crown without SAC (control); G4 = LS2 crown with SAC. All crowns were cemented, and the screw access holes in the crowns of the experimental groups were restored using a composite. The specimens were subjected to compression tests using a universal load-testing machine (EMIC DL 2000) at a speed of 0.5 mm/min. Statistical analysis was performed using one-way ANOVA, followed by Tukey's test (α= 0.05). Results: Significant differences were observed between the groups ($p<0.001$); The YSZ control group (G1= 3372 ± 571 N) exhibited higher compressive strength than the corresponding experimental group (G2= 1675 ± 293 N), LS2 control group (G3=1931 ± 430 N), and LS2 experimental group (G4= 1447 ± 449 N). However, there were no differences between the compressive strengths of G2, G3, and G4 ($p\geq$ 0.10). Conclusion: The fabrication of cement-retained implant restorations with SAC does not clinically compromise the fatigue failure of LS2 crowns. In addition, among the types of crowns tested, the YSZ crowns without SAC exhibited significantly higher fatigue failure.

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RESUMO

Objetivo: A avaliar a influência de um canal de acesso do parafuso (CAP) sobre a resistência à compressão de coroas implantossuportadas fabricadas com abutments parafusados ou cimentados usando zircônia estabilizada com ítria (YSZ) ou estruturas de dissilicato de lítio infraestruturas (LS2). Materiais e Método: Quarenta espécimes compostos por análogos de implantes de conexão hexagonal externa e uma plataforma de 4,1 mm, pilares pré-fabricados de titânio para próteses cimentadas e infraestruturas para coroas totais foram confeccionados. Os corpos-de-prova foram divididos em quatro grupos (n = 10) com base no sistema cerâmico e presença de CAP da seguinte forma: G1 = YSZ coroa sem CAP (controle); G2 = YSZ com CAP; G3 = coroa LS2 sem CAP (controle); G4 = coroa LS2 com CAP. Todas as coroas foram cimentadas, e os orifícios de acesso dos parafusos nas coroas dos grupos experimentais foram restaurados com um compósito fotopolimerizável. Os corpos-de-prova foram submetidos a testes de compressão em máquina universal de teste de carga (EMIC DL 2000) a uma velocidade de 0,5 mm / min. A análise estatística foi realizada usando ANOVA de uma via, seguida do teste de Tukey (α = 0,05). Resultados: Diferenças significativas foram observadas entre os grupos (p <0,001); O grupo controle YSZ (G1 = 3372 ± 571 N) exibiu maior resistência à compressão do que o grupo experimental correspondente (G2 = 1675 ± 293 N), grupo controle LS2 (G3 = 1931 ± 430 N) e grupo experimental LS2 (G4 = 1447 ± 449 N). Entretanto, não houve diferenças entre as resistências à compressão de G2, G3 e G4 (p≥ 0,10). Conclusão: A fabricação de restaurações de implantes cimentadas e com CAP não compromete clinicamente a falha por fadiga das coroas LS2. Além disso, entre os tipos de coroas testadas, as coroas YSZ sem CAP exibiram falha por fadiga significativamente maior.

INTRODUCTION

The design of dental implants has been significantly improved over the years and a wide range of implant systems with different types of connections between the prosthetics and implants are commercially available. For a successful rehabilitative treatment using dental implants, it is important to consider the patient expectations, financial cost, manufacturing simplicity, prosthesis retention, occlusion, passivity, esthetics, stress distribution, and prosthesis reversibility and maintenance.[1-3] In addition, before surgery, an implant-supported prosthesis retention system must be selected during the planning stage to determine the most appropriate implant position. Furthermore, biomechanical principles and the desired esthetic outcome should be considered; [1] however, the retention system to be used should be selected on an individual basis.

Implant-supported prostheses can be retained by either cementing them over the implant or attaching the prosthesis to the implant with a screw. Several studies have investigated the advantages and disadvantages of the screw- and cement-retained implant-supported prostheses.[4-8] Screw-retained prostheses are preferred in cases with reduced intermaxillary space and have been considered the best implant-supported prosthesis retention system by some authors because they offer the advantages of retrievability and greater practicality.[4,9,10] In contrast, cement-retained prostheses have been recommended primarily for the treatment of partial edentulism and could be the best choice when the esthetic outcome is essential and in cases of wrongly placed implants.[11,12]

The main advantages of screw-retained prostheses are their retrievability and ease of restoration maintenance, which enables the easy removal of the prostheses for repair in the event of ceramic fractures or the fracture or loosening of screws, thus enabling easy oral hygiene assessment and the improvement of the peri-implant tissue health.[11,12] The main disadvantage of a cement-retained prosthesis is the risk of retained residual cement, which can result in peri-implantitis.[5] Nevertheless, cement-retained prosthesis offers several advantages such as better occlusion, esthetic outcomes, and prosthesis setting.[15,16] For posterior teeth, the implants should be placed on the central fossa of the teeth to produce an axial force. The occlusal contact provided by cement-retained prostheses is more stable owing to the lack of a screw access channel (SAC), which occupies a considerable part of the occlusal table. In contrast, in screw-retained prostheses, contact generally occurs in the SAC, thus affecting the efficiency of the channel sealing material, which are usually resinous composites. In addition, the SAC is considered esthetically unsatisfactory, especially in the lower premolars and molars areas.[6,15]

Nevertheless, some factors limit the further application of cement-retained prostheses such as difficulties with retrievability and with the removal of excess cement.[16,17] To overcome the limitations of cement-retained prostheses, various techniques have been introduced for improving the retrievability or for registering the position of the SAC.[18] For example, the use of interim cement for definitive restorations has been proposed as an effective method to enhance the retrievability of cement-retained prostheses.[13,16] However, the removal of these cement may be difficult,[13] which may lead to the damage of the prostheses, the internal surfaces of implants, and the abutment screw.[10] Consequently, some authors have suggested the photographic marking of the SAC point or the marking of the access point with a differently colored ceramic to enable the drilling of the SAC through the ceramic.[19,20] However, this strategy could lead to damage to the abutment screw and the placed crown.[21] In contrast, some studies have suggested the fabrication of cement-retained crowns with SAC, similar to those found in screw-retained prostheses.[10,22] Consequently, after cementing the crown on the abutment, the screw can be easily accessed through the access channel, and the restoration can be removed without any damage or impairment of its retention on the abutment.

The materials used for implant-supported crowns are similar to those used in tooth-supported overdentures. Metal-free ceramic crowns cemented on prefabricated titanium abutments are considered a good choice owing to their esthetic appeal and biocompatibility. However, the influence of the SAC on the resistance of metal-free crowns is debatable and is yet to be properly investigated. Hence, the present study aimed to assess the compressive strength of lithium disilicate and yttria-stabilized zirconia infrastructures cemented on titanium abutments with and without SAC. The null hypothesis to be tested was that the SAC preparation would not influence the compressive strength of these crowns.

MATERIALS AND METHOD

Forty specimens were fabricated and divided into four experimental groups (n=10). First, implant analogs (code 09004; Bionnovation, São Paulo, Brazil) fixed in self-curing acrylic resin (Biocryl; Scheu-Dental GmbH, Iserlohn, Germany) were introduced into a PVC tube with a height of 3 cm and diameter of 2 cm using a delineator until polymerization was complete. Subsequently, the titanium abutments for the cement-retained prostheses with a collar height of 2 mm (TIPREP code 06009; Bionnovation, São Paulo-Brazil) were screwed onto the implant analogs by applying a torque of 30 N/cm.

Forty infrastructures were fabricated (20 lithium disilicate (LS2; e.max IVOCLAR, Liechtenstein) and 20 yttria-stabilized zirconia (YSZ; CAD/CAM CERAMILL, Amann Girrbach, Austria), and used as the cement-retained implant-supported prostheses (Figures 1 and 2).

The LS2 and YSZ groups were further subdivided into two groups, namely, conventional infrastructures (G1 and G3) and infrastructures with access holes (G2 and G4). In each main group, one of the subgroups was the control group, and the other was the experimental group (Table 1).

Table 1. Specimen grouping.

Group	N	Material	Screw access channel
G1 - Control	10	Yttria-stabilized zirconia (YSZ)	Without
G2 - Experimental	10	Yttria-stabilized zirconia (YSZ)	With
G3 - Control	10	Lithium disilicate (LS2)	Without
G4 - Experimental	10	Lithium disilicate (LS2)	With

Figure 1. YSZ test specimens of cement-retained implant-supported prostheses.

Figure 2. G1 (above) - YSZ without a screw access channel (Control); G2 (below) - YSZ with a screw access channel.

The YSZ infrastructures (G1 and G2) were blasted with aluminum oxide (Optiblast Microblaster; Syosset, New York, USA), silanized with an alloy primer (Kuraray - Japan), cemented (RelyX U200; 3M ESPE, São Paulo, Brazil), and cured using an LED Curing Light (VALO; Ultradent Products, Inc., South Jordan, Utah, USA). Before cementation with RelyX® U200, the LS2 infrastructures (G3 and G4) were blasted, treated with 8% hydrofluoric acid, and silanized with a ceramic primer (RelyX® Ceramic primer; 3M ESPE, São Paulo, Brazil).

In groups G2 and G4, the screw access was restored using composite (Filtek Z350 XT and Filtek™ Supreme XT Universal Restorative Supreme; 3M ESPE, São Paulo, Brazil).

Twenty-four hours after cementation, the specimens were subjected to vertical compression stress using a universal testing machine (Emic DL 2000, São José dos Pinhais, Paraná, Brazil) at a speed of 0.5 mm/min (Figure 3).

The maximum compressive strength of each specimen was measured and recorded in Newton (N). A priori power analysis and sample size calculations were performed based on existing data from similar in vitro studies (G*Power software - Franz Faul, Christian-Albrechts-Universität Kiel, Kiel, Germany).[10,22] Statistical analysis of the data was performed using SPSS (version 25.0, SPSS Inc. Chicago, IL, USA). The Shapiro-Wilk test exhibited normality of distribution ($p \leq 0.20$), whereas the Levene test revealed the equality of variance ($p=0.53$). Thus, the data were analyzed using one-way analysis of variance (ANOVA) with the level of significance set at $\alpha = 0.05$, and Tukey's post hoc pairwise multiple comparisons were performed to determine if the differences among the four implant-abutment designs were statistically significant.

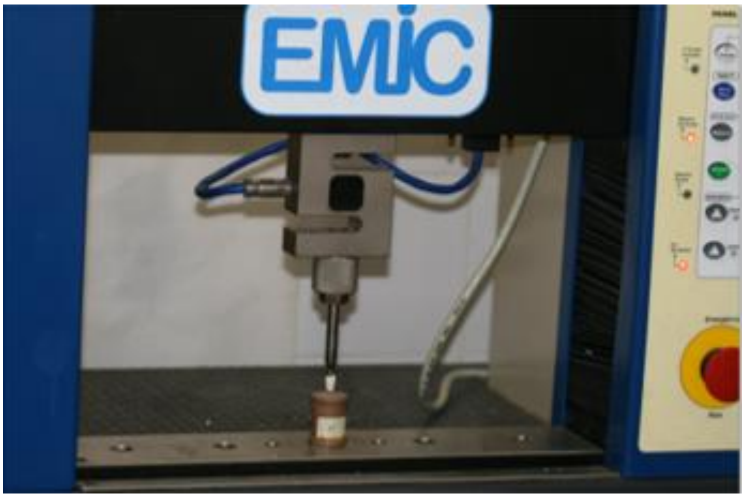

Figure 3. Universal testing machine; the test specimen is placed into the position required to perform the vertical compression resistance test.

RESULTS

A summary of the statistically analyzed results (N) of the in vitro testing of the compressive strength of the control and experimental groups is shown in Table 2 and Figure 4. The cement-retained groups (G1=3372± 571, and G3= 1931± 430) exhibited the largest mean compressive strength, whereas the screw-retained groups (G2= 1675± 293, and G3= 1447 ± 449) exhibited lower compressive strength values.

The one-way ANOVA results indicated that there was a significant difference in the mean compressive strength among the groups ($p<0.001$) (Table 3). In addition, the pairwise comparisons of the groups revealed that there were significant differences between G1 and the other groups ($p<0,001$), whereas G2, G3, and G4 exhibited similar mean values ($p\geq0.10$; Table 4).

Table 2. Mean and Standard Deviation (SD) values of compressive strength of all groups.

Group	CS ± SD, N	95% Confidence interval		Minimum	Maximum
		Lower bound	Upper bound		
G1	3372 ± 571	2964	3781	2183	4118
G2	1675 ± 293	1466	1885	1359	2207
G3	1931 ± 430	1624	2239	1328	2676
G4	1447 ± 449	1102	1792	773	2166

SAC - screw access hole; LS2 - Lithium disilicate; YSZ - Yttria-stabilized zirconia; CS – Compressive strength; SD – standard deviation; N - Newtons; G1 – YSZ crown without SAC (control); G2 – YSZ with SAC; G3 – LS2 crown without SAC (control); G4 – LS2 crown with SAC

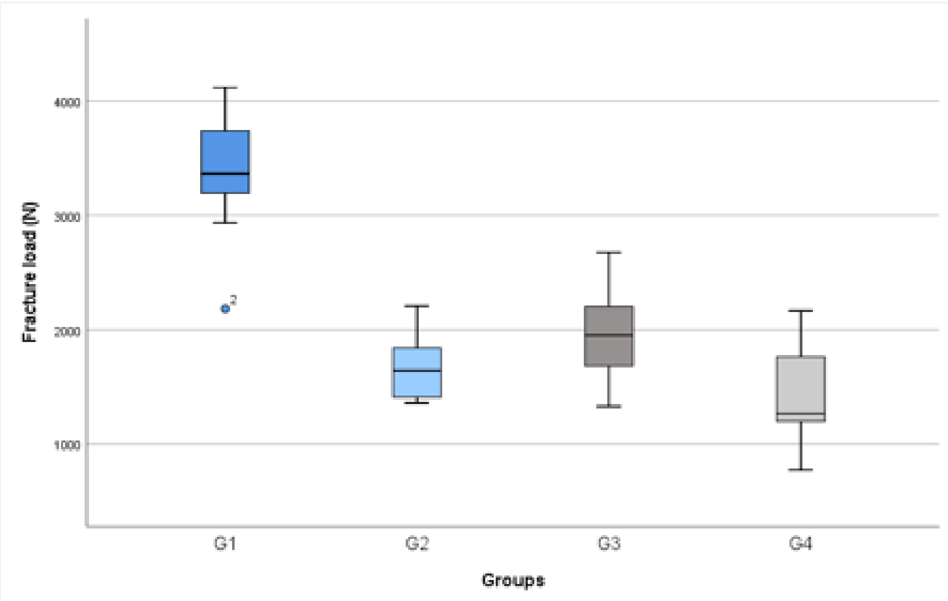

Figure 4. Box-plot diagram comprising the compressive strength (N), means, and standard deviation of the 4 groups of the implant-supported crowns studied: G1 – YSZ crown without SAC (control); G2 – YSZ with SAC; G3 – LS2 crown without SAC (control); G4 – LS2 crown with SAC.

Table 3. Tabular results of one-way analysis of variance for all groups.

Sources of variation	Sum of Squares	*df*	Mean square	F	P*
Between groups	220.78	3	735.96	36.90	<0.001
Within groups	698.00	35	199.42		
Total	290.58	38			

df, degrees of freedom; *Anova analysis
Different lower-case letters in the same column indicate significant differences (P<.05)

Table 4. Post-hoc-test for experimental and control groups.

Tukey's multiple comparisons tests	Mean difference	q	P-value	95% CI of difference
G1 vs G2	1696	199.71	<0.001	1157 – 2235
G1 vs G3	1440	199.71	<0.001	902 – 1979
G1 vs G4	1925	205.18	<0.001	1371 – 2478
G2 vs G3	- 256	199.71	0.581	-794 – 283
G2 vs G4	228	205.18	0.685	-325 – 781
G3 vs G4	484	205.18	0.104	-69 – 1037

q = Weighted/adjusted P-value used as output from Tukey's multiple comparisons test; CI = confidence interval.
G1 – YSZ crown without SAC (control); G2 – YSZ with SAC; G3 – LS2 crown without SAC (control); G4 – LS2 crown with SAC

DISCUSSION

In this study, the compressive strength of YSZ- and LS2-based crowns was evaluated. The test results revealed that the G1 group exhibited the highest compressive strength among all tested groups; however, there were no differences among the G2, G3, and G4 groups. Hence, the null hypothesis that the SAC preparation would not influence the compressive strength of these crowns was partially refuted.

The current analysis revealed that the preparation of SACs in implant-supported crowns decreased the compressive strength values, especially in the YSZ infrastructures, which is consistent with the reports of previous studies.[2,23,24] A recent in-vitro analysis revealed that there were significant differences between the compressive strength of cement-retained zirconia crowns (2239 ± 543 N) and screw-retained zirconia crowns (without aging= 932 ± 309 N; before aging= 817 ± 282 N; p<0.001), indicating that the absence of SAC improved the ceramic stability.[2] Another study evaluated the effect of two SAC preparation techniques on the fracture load of cement-screw-retained implant-supported zirconia-based crowns. The results revealed that the mean fracture load value of the control samples (without SAC, 888.3 ± 228.9 N; p<0.001) was significantly higher, whereas the values of the crowns with SACs prepared using the CAD/CAM technique (610.4 ± 125 N) or manually (496 ± 104.1 N) were similar (p= 0.44) (Mokhtarpour et al. 2016). In addition, another study demonstrated that the presence of a surrounding zirconia wall around the SAC (3878.06 ± 880.95 N) increased the mean fracture resistance value of the crown; however, it was significantly lower than that of the control sample (without SAC, 5794.85 ± 1158.87 N; p <0.001) (Saboury et al. 2018). Some researchers have reported that the preparation of SAC during the restoration can disrupt the structural integrity of the ceramic around the opening and at the cusp tip, resulting in ceramic fracture.[9,14,15] In addition, variations in the diameter and location of the SAC may affect the fracture strength of the restorations.[25] Furthermore, factors such as cement systems, bonding procedures, and occlusion contribute to the success of implant-supported prostheses, and all these variables should be considered.[14,23]

In contrast, the results of this study revealed that there were no significant differences between the compressive strength of the G3 and G4 groups; neither was there a significant difference between these groups and the G2 group. Similarly, a previous study demonstrated that SACs had no significant effect on the compressive strength of monolithic zirconia (with SAC= 2047.8 ±83.2 N; without SAC= 2028.7 ±104.5 N), monolithic lithium disilicate (with SAC= 605.4 ±37.9 N; without SAC= 615.3 ±76.6 N), or veneered zirconia (with SAC= 411 ±34.4 N; without SAC= 461.2 ±72.7 N) ceramic crowns.[22] In addition, the results of this study are consistent with those of a previous study,[10,26] which reported that SAC had no significant effect on the integrity of restorations. Nevertheless, clinicians should be aware of the risk of screw loosening, regardless of the modality of the prosthesis connection used, particularly, in the case of unitary or small partial prostheses. Porcelain repairs owing to the fracture of the porcelain or to adjust their color, and occlusal adjustment after the placement of prostheses are common. However, the possibility of the removal of excess cement after cementation reduces the risk of peri-implantitis in cement-retained prostheses and should be given high priority.

The diversity of the results reported by different researchers could be attributed to the differences in the methodology and specimen materials. This is because the ceramic systems and loading conditions affect the stress distribution, hence the fracture behavior of crowns varies with material and methodology. However, considering that the mean masticatory force in the posterior region is 220 N,[27] and may increase to 1,181 N with parafunctional habits,[28] the ability of the restorations in this study to resist the masticatory force in the mouth was evaluated. The results revealed that all restorations were able to resist the usual masticatory loads in the mouth. Thus, the reduction in resistance detected may not have any significant effect on the efficacy of the restorations used in this study, as the levels of strength involved in mastication are significantly lower than those observed in this study. This observation holds even though the observed values were significantly lower than those exhibited by crowns without access holes (in cement-retained prostheses), as reported in a previous clinical study[29] on masticatory efficiency and bite force. In the previous study, the mean maximum bite force values in dentulous patients were 350 ± 54 N on the right side and 388 ± 80 N on the left molar areas.

To date, few studies have analyzed the properties of cement-retained implant-supported prostheses with screw access holes and their clinical applicability. Nevertheless, these devices have been used by prosthesis laboratories for the fabrication of CAD/CAM crowns. These laboratories do not employ the titanium abutments provided by the original manufacturers, but instead, use generic ones, thus impairing the adaptation of the abutments to implants, known as ‘links’ or ‘T-bases.’ Moreover, the use of YSZ and LS2 crowns cemented on titanium abutments as cement-retained prostheses (e.g., Tiprep® (Bionnovation Biomedical, Brazil)) or universal stumps with mounting screws can be considered as a viable option, as they are inexpensive, adaptable, and highly biocompatible. However, calcinable components used for the melting of alternative alloys such as Ni-Cr or Co-Cr, which enable corrosion, should be avoided. In addition, the direct coupling of YSZ and/or LS2 to implants is deleterious to hexagonal external connections, as these hexagons are crushed in this form of coupling. Moreover, direct coupling is unviable in internal connections; hence, the use of abutments or the cementation of the infrastructure (whether YSZ or LS2) onto the porcelain is preferable.

The findings of this study will increase the confidence in the use of ceramic, retrievable crowns that are cemented to a titanium abutment before the abutment screw tightening. In addition, this study used a consolidated method for the compressive stress analysis.[22] Although the crowns studied were only subjected to one cycle of the compressive load until fracture, whereas in a clinical setting, the crowns may undergo fracture following fatigue processes and the formation of small cracks,[30] previous in-vitro analyses have revealed that aging does not affect the failure load of implant-supported crowns.[2]

Nevertheless, further studies are necessary under the conditions mentioned above. If the results of the current study can be supported by further successful clinical research, SAC preparation will be deemed a useful method to fabricate cement-screw-retained implant-supported LS2- and zirconia-based restorations. In addition, clinical assessments should be performed to investigate the behavior of these materials in various patient categories (with or without parafunction).

CONCLUSION

Based on the scope and results of the present study, the following conclusions were drawn:

1. The fabrication of a screw access hole did not affect the resistance of LS2 infrastructures cemented on titanium abutments.
2. The resistance of the YSZ infrastructures without screw access holes was superior to those of other assessed infrastructures.
3. The resistance exhibited by the YSZ infrastructures with screw access holes was similar to that of lithium disilicate infrastructures with or without access holes and was significantly higher than the resistance required to withstand masticatory forces.

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