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Influence of filling materials on the fracture resistance of resin composite used for sealing screw access hole

Influência dos materiais de preenchimento na resistência a fratura das resinas compostas utilizadas para selamento do orifício de acesso ao parafuso

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Resumo

Introdução: As próteses parafusadas possuem orifício de acesso ao parafuso (SAH), os quais são selados com resina composta. Sua perda ou desgaste está entre as complicações mais comuns em próteses sobre implantes, associadas a fratura da lâmina cerâmica. **Objetivo**: Assim, é importante avaliar a influência dos materiais de selamento na resistência à fratura de resina composta aplicada ao SAH no selamento de prótese sobre implantes parafusadas. **Material e método**: As amostras foram produzidas utilizando pilares UCLA em liga metálica de NiCr com posterior aplicação de cerâmica. Após asperização e condicionamento da superfície cerâmica, foram aplicados silano e adesivo dentinário, antes da selagem dos condutos com as resinas compostas Z100 e P60. Foram avaliados nove grupos (n = 10): selamento com Z-100 (ZNC) e P-60 (PNC) sem selamento do SAH; selamento com Z100 (ZCP) e P-60 (PCP) com algodão absorvente; Z100 (ZPT) e P60 (PPT) com politetrafluoroetileno; Z100 (ZGP) e P60 (PGP) com guta-percha e coroa de cerâmica cimentada (ICS). Após o teste de resistência à fratura, os dados foram analisados usando ANOVA de dois fatores e testes Tukey HSD (p<0,05). O tipo de fratura foi avaliado por microscópio eletrônico de varredura. **Resultado**: Independentemente do material obturador, os maiores valores médios de resistência à fratura foram observados no selamento com P60 (p=0,002). Quando combinados com resinas compostas por um material de selamento, os resultados obtidos foram: ZGP: 805,5N/ PGP: 929,5N<ZPT: 1079,1N/ PPT: 1149,5N=ZNC 1183,1N/ PNC: 1350,6N <ZCP: 1403,6N / PCP: 1641,3N <ICS: 2645,0N. **Conclusão**: O uso de P60 com algodão exibiu a maior resistência à fratura.

Descritores: Compósito de resina; implante dentário; resistência flexural; reabilitação oral.

Abstract

Introduction: Screw-retained restorations have a screw access hole (SAH) sealed with resin composite aiming at safe-guarding the aesthetic features of the ceramic veneer. The loss or wear of the resin composite applied in sealing the SAH is among the most common complications in implant prosthodontics, as the fracture of ceramic veneer. **Objective:** Evaluate the influence of sealant materials on the fracture resistance of resin composite applied in sealing screw access hole in screwed (SAH) implants. **Material and method:** The samples were produced from UCLA abutments in metallic NiCr alloy with subsequent application of ceramic. After asperisation and conditioning ceramic surface, was applied silane and dentin adhesive, before sealing the conduits with resin composites Z100 and P60. Nine groups (n=10) were evaluated: sealing with Z-100 (ZNC) and P-60 (PNC) without obturation of SAH; sealing with Z100 (ZCP) and P-60 (PCP) with absorbent cotton; Z100 (ZPT) and P60 (PPT) with polytetrafluoroethylene; Z100 (ZGP) and P60 (PGP) with gutta-percha and a cemented ceramic crown (ICS). After the fracture resistance test, the data were analyzed using two-way ANOVA and Tukey HSD tests (p<.05). **Result:** The fracture mode was evaluated by scanning electron microscope. Irrespective of the filling material, the highest mean values of fracture resistance were observed in the sealing with P60 (p=.002). When combined with resins composed of a sealing material, the results obtained were: ZGP: 805.5N/ PGP: 929.5N<ZPT: 1079.1N/ PPT: 1149.5N=ZNC 1183.1N/ PNC: 1350.6N<ZCP: 1403.6N/ PCP: 1641.3N<ICS: 2645.0N. **Conclusion:** The use of P60 with cotton wool exhibited the highest fracture resistance.

Descriptors: Composite resins; dental implant; flexural resistance; mouth rehabilitation.

INTRODUCTION

Generally, implant prosthodontics can be retained by cement or screw, and the choice of the retention mechanism is largely influenced by personal attitudes[1,2]. Remarkably, screw-retained prostheses are found to possess a highly relevant property: a greater degree of retrievability[1,3-5]. Screw-retained restorations have a screw access hole (SAH) that allows access to the fastening screw[6-8]. Indeed, although the placement of the SAH is dependent upon the implant position[5], the opposing occlusion and the prosthetic components[5], it is, nonetheless, preferable that it is centered within the occlusal surface, thus causing lesser disruption of the occlusal anatomy[9].

The SAH is sealed with resin composite aiming at safe-guarding the aesthetic features of the ceramic veneer[1-3,7,8]. Aside the aesthetic factors, the sealing of the SAH with resin composite is also regarded essentially important in the sense that it helps to prevent microleakages along the components of the implant system and the presence of malodor[7]. As has been widely acknowledged in the literature, brittle materials, such as adhesive resin composite, are susceptible to catastrophic failure[3], and composite fracture is considered one of the main reasons for the clinical failure of resin composite[10].

The loss or wear of the resin composite applied in sealing the SAH is among the most common complications in implant prosthodontics[11]. Adhesive restorations are required to be durable and functional, considering that the SAH has an average diameter of between 2.5 to 3 mm[5,11], which corresponds to 50-60% of the occlusal table[1,4,11]. In the molar region, the chewing forces are seen to be stronger and may lead to a greater likelihood of fracture of the resin composite stemming from wear and tear of the material caused by the increase in stress observed in the region[10]. However, even if the occlusal contacts have been directed to other areas of the occlusal surface to avoid contact with the SAH[12], there is an indirect contact through food particles that remain in the area during the chewing process. The trapped food particles can cause wear of the resin surface[13].

Another mechanical complication for implant-supported prostheses is the fracture of ceramic veneer[3,4,14], which occurs mainly with screw-retained implant restorations owing to the presence of the SAH[3,4,11,14]. Interestingly, the use of a sealing material, such as the resin composite, may be a solution when it comes to stabilizing the occlusal surface of prostheses with this type of retention[2,3].

A filling material has to be condensed into the channel under the resin used to seal the SAH; this material should be easily removable so as to facilitate access without damage to the fixation screw when needed[15]. The filling of the SAH helps to ensure the success of the implant restoration. To address this issue, a wide range of filling materials have been proposed in the literature which include the following: elastomeric impression material[7], soft composite[16], cotton pellets[4,7], foam pellets[3], gutta-percha[7,16], auto-polymerizing acrylic resin[15], wax[16], polytetrafluoroethylene (PTFE) tape[15,17], and a combination of materials such as cotton/ soft composite[16]. Until the present moment, there is a deficiency in the literature, in the sense that, there are no studies that have been devoted toward investigating which type of the aforementioned materials exhibits the most favorable properties for clinical use.

Considering the importance of the screw access hole to the implant-retained restorations and the need to standardize the procedure involving the sealing of the SAH, the present in vitro study was aimed at assessing the influence of different filling materials on the fracture resistance of two resin composites used for sealing the screw access hole. The null hypothesis is that there is no difference between the types of closure materials in terms of fracture resistance of the resin composites used in sealing the SAH of the screwed implants.

MATERIAL AND METHOD

An experimental study of laboratory type (in vitro) was developed using an implant replica of an external hexagon implant with a diameter of 5.0 mm (3i Implant Innovations) was fixed with a lateral setscrew inside a custom-made metal matrix. An UCLA plastic abutment (3i Implant Innovations) was bolted over the implant analogue. A cylindrical metal matrix with non-stick surface and sectioned in half, with same length of 12.3 mm and a diameter of 10.0 mm, was put around the UCLA. The abutment was embedded with an auto-polymerizing acrylic resin (DuraLay; Reliance Dental MFG).

The total sample size was 90 specimens, divided into 9 groups, each group containing 10 specimens according to the resin composite applied in sealing the SAH and the materials used for filling the SAH. The groups were divided as follows: ZNC- sealing with Z100 (3M ESPE) and without filling of the SAH (negative control, Z100); PNC- sealing with P60 (3M ESPE) and without filling of the SAH (negative control, P60); ZCP- sealing with Z100 and filling with absorbent cotton pellet (Soft Cotton; Ind. Com. Imp. e Exp. LTDA); PCP- sealing with P60 and filling with absorbent cotton pellet; ZPT sealing with Z100 and filling with polytetrafluorethylene tape-PTFE (Isotape; TDV); PPT- sealing with P60 and filling with PTFE; ZGP- sealing with Z100 and filling with gutta-percha (Guta-Percha Bastão, Dentsply Ind. E Com. Ltda); PGP- sealing with P60 and filling with gutta-percha; ICS- intact ceramic surface (positive control), simulating a cement-retained metal-ceramic crown. The two resin composites used in this work are indicated for the posterior teeth[18].

The specimens of the ICS group were made using a cylindrical metal matrix with non-stick surface totally filled with auto-polymerizing acrylic resin. After the polymerization of the resin, the metal rod was removed. The specimen was subsequently unscrewed and the two halves of the matrix were separated.

Before casting the specimens, two procedures were carried out: firstly, the specimens of ZNC and PNC groups had the stop screw removed with cylindrical carbide burs at low speed. This was done to allow the introduction of a non-stick metal rod inside the screw channel in order to standardize the weight of the resin composites used to seal the SAH in ZNC and PNC groups, since the specimens of these groups were prepared without filling of the SAH.

The methodology used in this work was based on the study developed by Pereira et al.[19] which involves the casting of all the specimens in Ni-Cr metal alloy (VeraBond II; AALBA Dent. Inc.) according to the standard casting and finishing recommended by the manufacturer's instruction. The next step involved the application of ceramic (Noritake Super Porcelain EX-3; Noritake Kizai Co, Ltd) with a final thickness of 2.0 mm which is in compliance with the manufacturer`s recommendation A non-stick metal rod was inserted into the SAH before the ceramic application aiming at keeping the SAH unclosed.

Prior to carrying out the sealing, the ceramic surface of the SAH, in all specimens, was air-abraded, with aluminum oxide of 50 μm (Bio-Art Equipamentos Odontológicos Ltda) at 35 psi for 20 seconds, etched with 10% hydrofluoric acid (Condicionador de porcelanas; Dentsply Ind. E Com. Ltda) for 2 minutes. The ceramic surface was then washed with water spray and dried. Thereafter, the filling of the SAH was performed for the groups, namely, ZCP, PCP, ZPT, PPT, ZGP and PGP. A periodontal probe (Sonda Willians; Golgran Ind. e Com. de Instrumental Odontológico LTDA) was employed with the aim of standardizing the amount of filling inside the channel, and, as such, limit the amount of resin composite in the hole.

After filling the channel, a silane coupling agent (Silano; Dentsply Ind. E Com. Ltda) was applied. Subsequently, a single coat of bonding agent (Scotchbond Multi Uso Plus; 3M ESPE) was applied after one minute followed by polymerization using a visible light unit (Curing Ligth XL3000; 3M ESPE) with a light-source intensity of at least 400 mW/cm^2 for 20 seconds. Finally, the resin composite (Z100 or P60) was applied in sealing the SAH in 3 portions, where each portion was subjected to polymerization for 40 seconds by a visible light unit (Curing Light XL3000; 3M ESPE) with a light-source intensity of at least 400mW/cm^2 at a distance of 10.0mm from the ceramic surface. In the ZNC and PNC groups, as the experiment did not involve filling of the channel, a metal matrix (10.0 mm of diameter of the cylindrical base and vertical rod with 12.3 mm of length) was employed aiming at standardizing the thickness of the resin composite - around 2.0 mm.

All samples were stored in distilled water for 24 hours at a constant temperature of 37°C[20]. They were, subsequently, subjected to thermocycling for 20 hours over 1000 cycles and for 30 seconds each under temperatures of 5°C and 55°C[20]. Thermocycling makes the results clinically more relevant. This can be attributed to the fact that during this process, there may be an accumulation of damages to the restorations[4], as a result of the stress from the sealing material which bears a resemblance to the chewing process, thus leading to a reduction of the shear strength[21]. A hardened steel bur with a rounded tip of 1.0 mm diameter was used to apply a vertical static compressive load in the center of the sealing resin or the ceramic surface (ICS group) with the aim of simulating a cusp contact. The fracture resistance testing was performed using a universal testing machine (EMIC DL2000) with a 10KN load cell at 0.5 mm/min cross-head speed[5,19,20], until the fracture of the composite sealing resin was obtained. During the test, the specimen was held in position with the aid of horizontal screws in a stainless steel matrix.

All data were registered in Newton (N) and analyzed using two-way ANOVA and Tukey Honestly Significant Difference (HSD) test for multiple comparisons with confidence interval of 95% and statistical significance of $p < 0.05$. The mode of failure of the specimens was evaluated by a scanning electron microscope (SEM) (JSM – 6610LV; JEOL USA Inc.) and was classified as follows: adhesive (failure at the ceramic-resin composite interface), cohesive (fracture within the ceramic or within the resin composite), or a combination of the two failures (areas of cohesive and adhesive failure). The software used was Statistical Package for the Social Sciences (SPSS for Windows, version 21.0) with the significance level set at 5%.

RESULT

The summary of two-way ANOVA (Table 1) is presented along with the p-values of the Levene and Shapiro-Wilk tests relative to the homogeneity of variance and normality of experimental errors, respectively. Irrespective of the filling material, P60 resin showed the highest mean fracture resistance values (p=.002). Among the filling materials investigated here, the worst results were found when gutta-percha was applied while absorbent cotton presented the best results for both resin composites (Table 2).

Table 1. Summary of two-way ANOVA and p-values of the Levene and Shapiro-Wilk

Source of variantion	Sum of squares	Degrees of freedom (df)	Mean Square	F ratio	Significance
Resin composite	449311.7	1	449311.8	10.6	0.002*
Filling Material	4522317.1	3	1507439.0	35.7	0.000*
Interaction	75087.6	3	25029.2	0.5	0.621
Error	3412882.9	81	42134.4		

p-value of Shapiro-Wilk test = 0.879. p-value of Levene test = 0.126. * significant at 5%.

Table 2. Mean load at fracture in Newton (N) and Standard Deviation (SD)

Filling Material	Z100		*	P60		*
	Mean (N)	(SD)		Mean (N)	(SD)	
Without filling	1183.1	(146.2)	b	1350.6	(240.1)	B
Cotton pelltes	1403.6	(220.6)	c	1641.3	(269.3)	C
Polytetrafluorethylene tape	1079.1	(132.6)	b	1149.5	(148.1)	B
Gutta–percha	805.5	(139.1)	a	929.5	(214.6)	A
Positive Control	2645.0	(272.2)	d	2645.0	(272.2)	D

*Tukey HSD test for multiple comparisons with a confidence interval of 95%; groups (for each resin) with same letter are not significantly different.

Concerning the mode of failure in the ZNC and PNC groups, most of the specimens were affected by a combination of failures (Figure 1), followed by cohesive failure. In the ZCP, PCP, ZPT and PPT groups, there was prevalence of cohesive failure (Figure 2a and Figure 2b) followed by combination of failure. In the ZGP and PGP groups, all specimens were affected by a combination of failures. None of the specimens exhibited only adhesive failure.

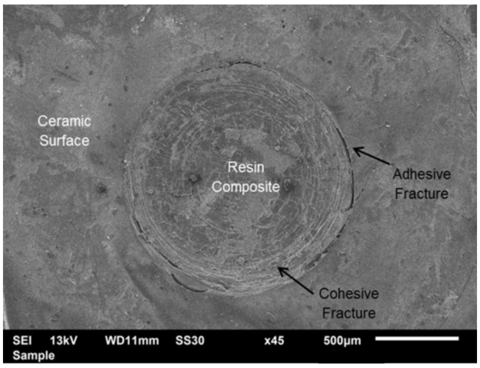

Figure 1. Combination of failures (adhesive and cohesive) in specimens of PNC group.

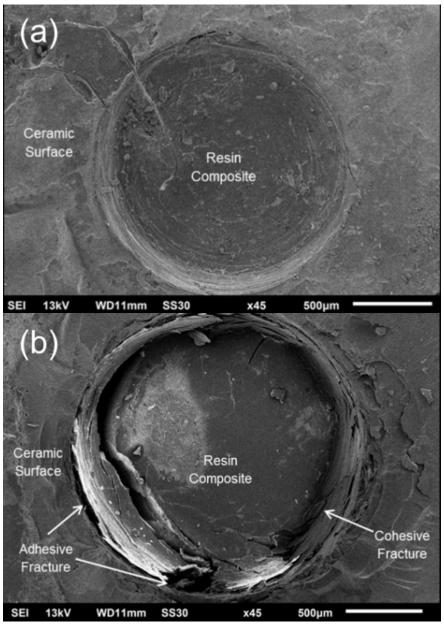

Figure 2. Cohesive failures of the resin composite in specimen. **Figure 2a.** Cohesive failures of PCP group. **Figure 2b.** Cohesive failures of ZPT group.

Another interesting observation that deserves mentioning is that the bulk of resin composite sank into the channel of the SAH in the cohesive failures, leading to circles of microfractures; this finding was more evident in the groups sealed with Z-100 compared to P-60. Adhesive failures in the ZGP and PGP groups were found to be more catastrophic than in the other groups.

DISCUSSION

The results obtained in this study showed that the highest average values of fracture resistance in the resin composites tested were found in the group sealed with absorbent cotton, followed by the group with PTFE tape and, finally, the gutta-percha group. The absorbent cotton is found to allow a better condensation and, consequently, a greater support to the composite sealing resin, though its removal from the OAP appears to be difficult[15]. With regard to the PTFE, although it is easily manipulated, it fails to present a final and effective condensation due to its elasticity and this tends to influence the fracture resistance of the OAP sealing material[15]. It is also worth mentioning that, contrary to the behavior observed in the PTFE, cotton may be associated with odors and greater infiltration of microorganisms[7,15]. Therefore, these results contribute toward rejecting the hypothesis established in the study.

The connection system between prostheses and implants must be considered a paramount factor if one is to achieve a long-term success in dental operations[6,8]. According to Karl et al.[2], the decision about which retention mechanism is optimal should be based on the stability and morphology of the occlusal table. But the presence of the SAH can interfere with the occlusion of implant prosthodontics[1,4,11,22], leading to unstable occlusal contacts[1,6], and compromising the ability to generate vertical or axial loading. Moreover, the number of ceramic fractures in screw-retained prostheses is found to be higher than observed in cement-retained ones. This can be attributed to the fact that the SAH can weaken the occlusal ceramic surface[4,5,14,23]. However, the retrievability of the screw-retained prostheses is essentially an important advantage of this class of dental prostheses[1,4,6,8]. The relevance of this property becomes evident mainly when it is necessary to replace or save restorations and implants[1,9]. Moreover, it is necessary to perform an adequate sealing of the SAH when one takes into account the influence of the SAH on the function and esthetics of the screw-retained prostheses and, in some cases, on the impossibility of distribution of the occlusal contacts around the SAH.

Some authors have pointed out the inexistence of established guidelines for the sealing of the SAH[2,4,23]. According to Moráguez, Belser[15], some requirements, such as ease of manipulation, influence the choice of material to be employed. The authors argue that although there is hardly any consistent scientific support, the main function of these materials is to protect the head of the screw during the removal of the composite sealing resin[15]. However, the fact that these materials are placed in a position below the composite sealing resin, they could have a functional role of providing support to the resin composite, apart from exercising an influence over the fracture resistance during occlusal stress. This may explain the reason why the cotton pellets exhibited the best results, followed by the PTFE tape and gutta-percha, sequentially.

All the filling materials were repeatedly condensed after the treatment of the ceramic surface with hydrofluoric acid so as to prevent these materials from getting wet prior to the application of silane and bonding agent. Gutta-percha needed to be initially softened by heat and subsequently condensed laterally inside the screw access channel walls for better adaptation[7]. By so doing, it is likely that gutta-percha has contaminated the pre-treated ceramic surface and has damaged the chemical adhesion between the resin composite and the surface in question.

There was no significant difference between the ZNC and PNC groups (which had no filling material) and the ZPT and PPT groups. This shows that the pattern of adhesion between the sealing restoration and the ceramic surface played an important role in arriving at these results.

The treatment of the ceramic surface of the SAH, used in the present study, was based on repair procedures of fractures in metal-ceramics restorations (MCR). dos Santos et al.[20] evaluated the shear bond strength of different repair systems for MCR when the fracture involves only the porcelain body. They demonstrated that one of the best treatments in terms of efficiency was that of the airborne-particle abrasion, followed by etching with phosphoric acid, application of silane agent, adhesive and sealing with Z-100 resin composite. Karl et al.[3] (2008) investigated the effect of load cycling on metal ceramic screw-retained implant restorations with unrestored and restored screw access holes. The authors employed the following treatment in sealing the SAH: etching the ceramic surface with hydrofluoric acid, application of silane coupling agent and bond agent and finalizing the process with the insertion of the resin composite.

A strong and durable bond between the remaining restoration and the repair material is seen to be desirable in that it allows the repair procedure to bear the functional loads and to ensure clinical success[21]. The treatment mechanisms of ceramic surface which include sandblasting with aluminum oxide and etching with hydrofluoric acid or acidulated phosphate fluoride gel are aimed at facilitating micromechanical retention of the resin composite. Furthermore, the application of hydrofluoric acid and the subsequent use of silane coupling agent can enhance the resin composite for the ceramic bond[21]. In other words, the treatments of the substrate may be used to promote mechanical retention, or chemical adhesion between the repair material and the substrate. In view of that, it is common to see the use of several combinations of adhesive systems and resin composites in conjunction with several surface treatments[20].

It is important to be mindful that the intra-oral use of hydrofluoric acid can be hazardous to the human tissue, mainly in the face of an inadequate rubber dam isolation. In such a situation, the of use of this acid may not be practicable due to its in vivo biological risks, even though there have been studies that have reported its intra-oral use in porcelain repair[21]. Indeed, it is necessary to redouble care when it comes to its use in clinical situation.

The mechanical test used in the present study was aimed at emulating an occlusal contact of a cusp on the resin composite, as it may occur in the posterior teeth. In this sense, the resin composite needed to have an adequate resistance to withstand the force applied.

The two resin composites employed in our present investigation come with some underlying differences. The Z-100 is a universal hybrid composite while the P-60 is a packable hybrid composite. Both composites, however, have spherical fillers in their composition with the P-60 exhibiting relatively larger fillers compared to the Z-100[24]. Remarkably though, some authors have shown that both composites have similar shapes, size and distribution of inorganic particles and can be used in posterior region by virtue of the fact that they have a filler content volume percentage of approximately 60%[18].

There is a general consensus that concentration, morphology and particle size of the filler exert influence over the mechanical properties of resin composites[18,24]. Nonetheless, the best results found for P-60 cannot be possibly explained by the difference in the filler content of Z-100; this is because the difference is virtually small. This observation is in line with the findings of the study published by Ilie et al.[25] which showed that an increase was observed in the fracture toughness of the resin composites when the volume of the filler content underwent an increase of up to 57%; this was followed by constant values up to 65% (volume rate of P-60 and Z-100).

In the study published by Adabo et al.[18] P-60 showed a flexural strength greater than that of Z-100. This result was not influenced by the filler content volume percentage, but by a possible higher elastic modulus of Z-100 which contributed to a relatively easier development of fragile fracture. The authors[18] went further to describe another factor that may have contributed to the result: the organic phase composition. Z-100 has a resinous phase based on the combination of Bis-GMA and TEGDMA, while P-60 is constituted by Bis-GMA and the monomers, namely, BisEMA and UDMA, which replace part of the TEGDMA[13,24]. The diluent monomers of P-60, BisEMA and UDMA, have higher molecular weight compared to TEGDMA. This higher molecular weight leads to reduced ageing, less shrinkage, slightly softer resin matrix and higher viscosity[13]. Furthermore, the substitution of part of TEGDMA by UDMA results in an increase in tension and flexural strength[18]. In view of that, the aforementioned different composition of the two resin composites may have caused the better fracture resistance of P-60. One needs to emphasize, however, that differences in mechanical properties as shown in this in vitro study can only produce an effect in vivo after a longer observation time[10].

Finally, it is worth pointing out that the higher strength values were obtained by positive control simulating an intact surface of a cement-retained restoration. However, both the resin composites evaluated here presented average values of fracture resistance ranging from 300 to 880 N found to be greater than the maximum bite force for the first molar[4]. In other words, the guideline for sealing the SAH which has been tested here, at least in theory, is able to withstand occlusal stress. Most importantly, it is possible to allow a better distribution of occlusal contacts on the occlusal table and a generation of vertical or axial loading, thus, decreasing the stress on the implant-supported restoration as well as on the implant and the bone-implant interface.

Clearly, one ought to be mindful that this is an in vitro study and, as such, it has its inherent limitations. In this context, the outcomes must be interpreted cautiously when one aims to correlate them with real-life clinical situations. Additional studies need to be carried out in order to clinically assay the present sealing guidelines aiming at investigating the mechanical, biological and aesthetic effects of the different diameters of the screw access orifice with the resin composite sealing materials in screwed implants.

CONCLUSION

The following conclusions were drawn considering the limitations encountered in this in vitro study:

1. The filling materials exerted an influence over the fracture resistance of the resin composite. In addition, P60 presented the highest fracture resistance when it is associated with absorbent cotton as filling material;
2. The sealing guideline evaluated in the present study can be a good way to improve the distribution of the occlusal contacts in screw-retained implant restorations.

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CONFLICTS OF INTERESTS

The authors declare no conflicts of interest.

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