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Influence of Abutment Type and Esthetic Veneering on Preload Maintenance of Abutment Screw of Implant-Supported Crowns

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Abstract

Purpose: The effect of veneering materials on screw joint stability remains inconclusive. Thus, this study evaluated the preload maintenance of abutment screws of single crowns fabricated with different abutments and veneering materials.
Materials and Methods: Sixty crowns were divided into five groups ($n = 12$): UCLA abutment in gold alloy with ceramic (group GC) and resin (group GR) veneering, UCLA abutment in titanium with ceramic (group TiC) and resin (group TiR) veneering, and zirconia abutment with ceramic veneering (group ZiC). Abutment screws made of gold were used with a 35 Ncm insertion torque. Detorque measurements were obtained initially and after mechanical cycling. Data were analyzed by ANOVA and Fisher's exact test at a significance level of 5%.
Results: For the initial detorque means (in Ncm), group TiC (21.4 ± 1.78) exhibited statistically lower torque maintenance than groups GC (23.9 ± 0.91), GR (24.1 ± 1.34), and TiR (23.2 ± 1.33) ($p < 0.05$, Fisher's exact test). Group ZiC (21.9 ± 2.68) exhibited significantly lower torque maintenance than groups GC, GR, and TiR ($p < 0.05$, Fisher's exact test). After mechanical cycling, there was a statistically significant difference between groups TiC (22.1 ± 1.86) and GR (23.8 ± 1.56); between groups ZiC (21.7 ± 2.02) and GR; and also between groups ZiC and TiR (23.6 ± 1.30) ($p < 0.05$, Fisher's exact test).
Conclusions: Detorque reduction occurred regardless of abutment type and veneering material. More irregular surfaces in the hexagon area of the castable abutments were observed. The superiority of any veneering material concerning preload maintenance was not established.

Osseointegrated implants are an alternative for rehabilitation of edentulous areas with fixed or removable dental prostheses.[1] Despite the biological success of osseointegration, failures with single restorations are usually related to the screw joint between abutment and implant, and screw loosening is a common technical complication.[2-7]

The screw can be compared with a spring stretched and kept between the threads by friction. Any external force that may cause slippage between the threads decreases the tension generated in the screw, named preload.[8,9] At the first stage, the higher the preload, the higher the resistance to loosening.[10,11] At the second stage, a preload below a critical level means any external force or vibration may lead to complete loosening.[12]

Therefore, the fit between the components influences the preload maintenance of the abutment screw, since the presence of irregularities resulting from casting may damage screw joint stability.[13] Kano et al[11] demonstrated that castable abutments submitted to casting present irregular surfaces and lower torque maintenance than machined abutments. Similarly, Byrne et al[14] reported better fit between implants and machined abutments than castable abutments. Accordingly, the selection of prosthesis material is important for stress distribution to the crown-abutment screw-implant assembly and supporting structures.[1,15-26]

The long-term success of gold cylinders and casting in gold alloy for implant restorations results from proper fit and biological/physical properties, but with a high cost.[27] The use of titanium is advantageous due to biocompatibility, resistance to corrosion, elasticity modulus close to the implant, low potential to release residual components, and a favorable cost.[22,28] However, considering that metal presents a nonesthetic color and absence of translucency, ceramic abutments in alumina or zirconia[29,30] are indicated due to proper chemical and dimensional stability associated with the high mechanical resistance to support occlusal load.[31,32]

Considering the esthetic veneering materials, ceramics exhibit structural durability and stability of esthetic characteristics.[32] However, ceramic processing is meticulous regarding color control and restoration fragility.[31,33] Alternatively, resin-based materials with wear resistance similar to natural teeth have been developed. Nevertheless, these materials present disadvantages such as degradation due to humidity and mechanical efforts.[17,21] Therefore, it is important to understand the effect of esthetic veneering of implant-supported crowns on screw joint stability[18] in order to increase the predictability of implant treatment and to avoid failures such as screw loosening.

Considering that detorque value measured after screw loosening is a direct measurement of remaining preload,[5,9,10] the aim of this study was to evaluate the influence of different abutments and esthetic veneering materials on torque maintenance of abutment screws of implant-supported crowns submitted to mechanical cycling. The research hypothesis assumed that the abutment type and esthetic veneering material influence the torque maintenance of the abutment screw.

Materials and methods

Specimen fabrication and group division

Different abutments (Biomet 3i Inc., Palm Beach Gardens, FL) and veneering materials were used (n = 12): Group GC—Gold UCLA abutment in gold alloy and ceramic veneering, group GR—Gold UCLA abutment in gold alloy and resin veneering, group TiC—castable UCLA abutment in titanium and ceramic veneering, group TiR—castable UCLA abutment in titanium and resin veneering, and group ZiC—zirconia abutment fabricated with a CAD/CAM system and ceramic veneering. The Gold UCLA abutments from groups GC and GR had a gold cylinder with a plastic waxing sleeve that was cast in gold alloy as further described. The castable UCLA abutments used in groups TiC and TiR were made of plastic.

The specimen fabrication has been described previously.[34] In summary, the frameworks presented a conical shape (6.5 mm in height, 5.0 mm in the major diameter) with a unilateral plane (30°) in the occlusal surface. The abutment sleeves of groups GC, GR, TiC, and TiR were coated with self-polymerizing acrylic resin (Duralay; Reliance Dental Mfg. Company, Worth, IL).

The patterns of groups GC and GR were invested with a phosphate investment (Gilvest HS; Servo Dental do Brasil, São Paulo, Brazil) and cast in ceramic gold alloy (Gold Ceramic; CNG Soluções Protéticas, São Paulo, Brazil). Group TiC and TiR patterns were invested with magnesia-alumina investment material (Rematitan Ultra; Dentaurum, Ispringen, Germany) and cast with pure titanium grade 2 (Realum Ind. e Com. de Metais Puros e Ligas Ltd, São Paulo, Brazil) in specified equipment (Rematitan Autocast; Dentaurum).

All abutments were finished with aluminum oxide burs (Pedra Ninja; Talladium do Brasil, Curitiba, Brazil) followed by sandblasting (50 μm aluminum oxide for GC and GR abutments, 80 μm aluminum oxide for TiC and TiR abutments; Elf Geral de Eletrofusão Ltd, São João da Boa Vista, Brazil) under 2.8 bar pressure for 13 seconds. The blasting material was directed perpendicular to the metal surface at a distance of 1 cm.

The zirconia abutments of group ZiC were fabricated through scanning of a metallic abutment of group GR using a CAD/CAM system (Procera Scanner Mod 50; Nobel Biocare, Göteborg, Sweden). The scanned data were transferred to Procera software v2.2 (Nobel Biocare).

Medium fusion ceramic (Compact Ceramic System/Carmen; Dentaurum) and low-fusion ceramic (Triceram-Titanium Ceramics; Dentaurum) were used for veneering group GC and TiC/ZiC abutments, respectively. Light-curing resin (VitaVM LC; VITA Zahnfabrik H. Rauter GmbH & Co. KG, Bad Säckingen, Germany) was used for veneering GR and TiR abutments. After veneering, the crowns presented a conical shape (8 mm in height, 8 mm in the major diameter) with a 30° plane in the occlusal surface.[3]

A metallic matrix was used for embedment of 60 external hexagon implants (3.75 mm diameter, 15.0 mm length, 4.1 mm platform; OSSEOTITE Implant; Biomet 3i Inc.) with self-polymerizing acrylic resin (Jet; Artigos Odontológicos Clássico Ltd, São Paulo, Brazil). The implants were positioned perpendicular to the horizontal plane. Each crown was attached to an implant with a gold abutment screw (Gold-Tite Square Uniscrew; Biomet 3i Inc.). Specimens were randomized into groups, and were randomly selected for evaluation of torque maintenance and mechanical cycling.

Detorque measurement and mechanical cycling

The replicas were positioned in a device for a 35 Ncm torque insertion and detorque measurement using an analogic torque gauge (BTG36CN-S; Tohnichi Mfg. Co. Ltd, Tokyo, Japan; Fig 1). Before mechanical cycling, two initial detorque measurements were obtained for each replica with a 3-minute interval between torque insertion and detorque measurement.[26] Thus, the abutments were retorqued with 35 Ncm, and the replicas were submitted to mechanical cycling in an electromechanical machine (MSFM—ELQUIP; Equipments for Dental Research, São Carlos, Brazil). Replicas were immersed in distilled water under controlled temperature (37 ± 2°C). Vertical loading of 50 N on the occlusal plane of each crown was conducted at 2 Hz. To provide the placement of the loading device during mechanical cycling, a unilateral occlusal slide was fabricated in each crown. The 4-mm diameter metallic loading indenter was located on the occlusal slice of each crown previously lubricated with a thin layer of grease (Graxa Azul Universal; FBS Lubrificantes Especiais, Araçoiaba da Serra, Brazil) to

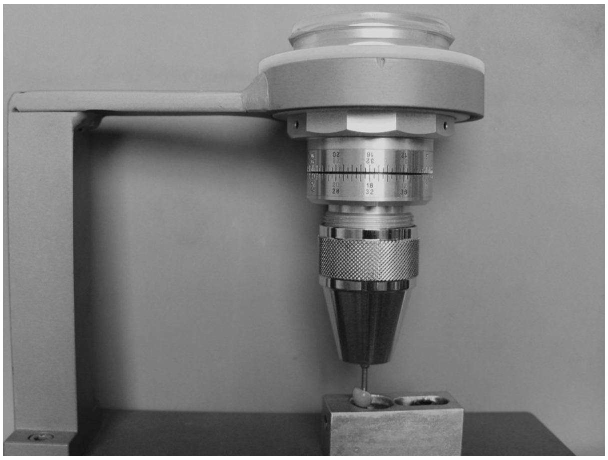

Figure 1 Device for positioning of replica and analogic torque gauge for torque insertion and detorque measurement.

Table 1 One-way ANOVA for initial detorque means of groups GC, GR, TiC, TiR, and ZiC

Source	df	SS	MS	F	p
Group	4	73.098	18.275	6.205	0.0003[a]
Error	55	161.975	2.945		

[a]$p < 0.05$ denotes statistically significant difference.

Table 2 One-way ANOVA for final detorque means of groups GC, GR, TiC, TiR, and ZiC

Source	df	SS	MS	F	p
Group	4	41.321	10.330	2.957	0.0277[a]
Error	55	192.148	3.494		

[a]$p < 0.05$ denotes statistically significant difference.

reduce friction. Detorque values were obtained after each period of 1×10^5 cycles until completion of 1×10^6 cycles to obtain a detorque mean after mechanical cycling. After each cycling period, the abutment screw was retightened with 35 Ncm torque. Two crowns of each group were randomly selected and submitted to scanning electron microscopy (SEM; JEOL-JSM-7401F—Field Emission Electron Microscope; JEOL Ltd., Tokyo, Japan) to obtain illustrative images of the hexagon area before and after mechanical cycling at 25× and 50×.

Statistical analysis

One-way ANOVA and Fisher's exact test ($p < 0.05$) were used for comparison of the detorque means of the groups obtained initially and after mechanical cycling.

Results

ANOVA showed statistically significant differences ($p < 0.05$) among the groups comparing the detorque means obtained initially (Table 1) and after mechanical cycling (Table 2). Considering the percentage of initial torque maintenance, group GR exhibited the highest percentage, followed by groups GC, TiR, ZiC, and TiC (Table 3). After mechanical cycling, group GR kept the highest percentage of torque maintenance, followed by groups TiR, GC, TiC, and ZiC (Table 4).

Table 3 Fisher's exact test for initial detorque means (Ncm) of groups GC, GR, TiC, TiR, and ZiC

Group	Mean (SD)[a]	Torque maintenance ± SD (%)
GC	23.9 (0.91)[a]	68.48 ± 2.58
GR	24.1 (1.34)[a]	69.07 ± 3.80
TiC	21.4 (1.78)[b]	61.43 ± 5.58
TiR	23.2 (1.33)[a]	66.33 ± 3.80
ZiC	21.9 (2.68)[b]	62.60 ± 7.67

[a]Means followed by different letters represent statistically significant difference ($p < 0.05$).

Table 4 Fisher's exact test for final detorque means (Ncm) of groups GC, GR, TiC, TiR, and ZiC

Group	Mean (SD)[a]	Torque maintenance ± SD (%)
GC	23.2 (2.44)[a,b,c]	66.36 ± 6.93
GR	23.8 (1.56)[a]	67.95 ± 4.43
TiC	22.1 (1.86)[b,c]	63.29 ± 5.30
TiR	23.6 (1.30)[a,b]	67.60 ± 3.67
ZiC	21.7 (2.02)[c]	62.02 ± 5.78

[a]Means followed by different letters represent statistically significant difference ($p < 0.05$).

Considering the initial detorque means, groups TiC and ZiC exhibited statistically lower torque maintenance than groups GC, GR, and TiR ($p < 0.05$; Table 3). After mechanical cycling, there was statistically significant difference ($p < 0.05$) in the detorque means between groups TiC and GR, between groups ZiC and GR, and also between groups ZiC and TiR (Table 4). The SEM images revealed more irregularities in the hexagon area of the titanium frameworks (groups TiC and TiR) than the gold (groups GC and GR) and zirconia (group ZiC) frameworks (Fig 2).

Discussion

According to ANOVA, the research hypothesis was accepted, since there was a statistically significant difference ($p < 0.05$) among the groups initially and after mechanical cycling; however, according to Fisher's exact test, it was not possible to establish the superiority of any group for preload maintenance. The detorque means of all groups were lower than the insertion torque of 35 Ncm. The same result was observed by Weiss et al[4] who demonstrated a progressive decrease of detorque value after 200 cycles of tightening/loosening of the abutment screw.

Despite the reduction of the insertion torque, no group presented detectable screw loosening initially and after mechanical cycling. So, the remaining torque would maintain the screw joint stability within the loading conditions of this study; however, additional studies including longer cycling periods and different loading conditions are suggested to assess preload maintenance during longer periods at clinically acceptable levels.

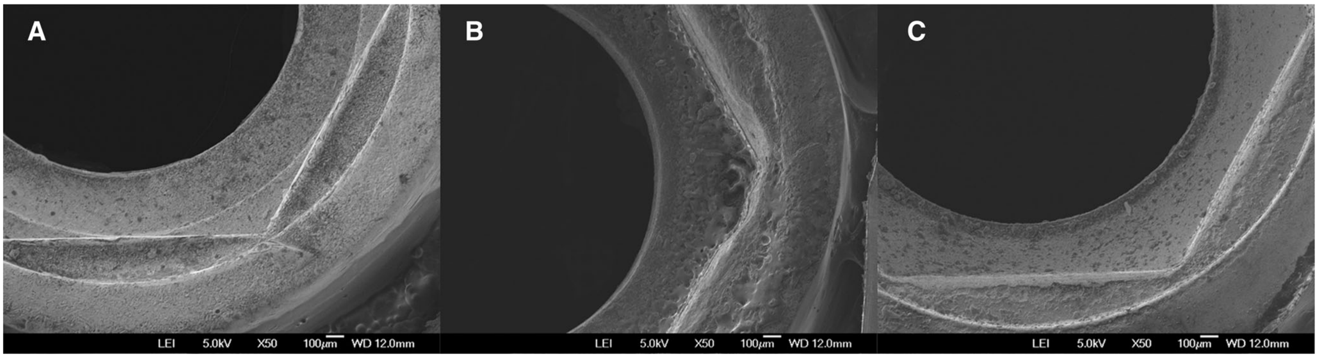

Figure 2 SEM of hexagon area of gold (A), titanium (B), and zirconia (C) abutments (50×).

The initial torque reduction partially results from the phenomenon of embedment relaxation of the abutment screw. Considering that threads of implant and abutment screw exhibit microrugosities, the wear of the metallic surfaces reduces the distance between the mating surfaces,[11] and 2% to 10% of initial preload is loss.[35] The amount of embedment relaxation results from the severity of irregularities on the mating surfaces, hardness of implant and abutment screw surfaces, and system loading.[2]

The difference observed among the initial detorque means of the groups may result from the level of misfit between the implants and the different abutments. According to the SEM images (Fig 2), the abutments cast in gold alloy (groups GC and GR) exhibited less expressive irregularities than the titanium abutments (groups TiC and TiR). The irregularities between the mating surfaces may have caused preload loss[9,13] to fit the components, which resulted in reduced detorque value, as also demonstrated by Burguete et al.[8]

According to Koke et al[24] this characteristic is inherent to the machining process, since castable abutments are required for titanium casting, which may increase misfit.[22,28] The same results were observed by Byrne et al[14] and Kano et al[11] who demonstrated better fit and higher torque maintenance for machined abutments than for castable abutments. In addition, porcelain firing for fabrication of group TiC crowns may be an additional factor for misfit[23,25] and consequent detorque reduction in comparison to group TiR. According to Vigolo et al,[20] the temperature range for casting and porcelain application may alter the abutment surface contacting the implant, negatively influencing the horizontal fit at this interface.

Mechanical cycling may have minimized the irregularities generated by processing, as also demonstrated by Hecker and Eckert.[27] This may explain the higher final detorque value in comparison to the initial value for groups TiC and TiR; however, it is important to consider the effect of stress distribution of different esthetic veneering materials[18] after loading on torque maintenance. Previous studies[1,15] showed that acrylic resin preserves the restoration system, absorbing part of the loading while the stress is directly transferred to the alveolar bone when ceramic and metal are the restorative materials.

For Cibirka et al,[16] there is no significant difference among composite resin, gold, and porcelain regarding force absorption. Soumeire and Dejou[19] confirmed that there is no difference of stress absorption for a microparticle composite resin and a low-fusion porcelain compared to conventional porcelain and gold.

Similarly, Wang et al[22] showed similar stress in the peri-implant bone tissue for resin, gold, and porcelain single restorations. Nonetheless, Ciftci and Canay[21] and Stegaroiu et al[17] found greater displacement and higher stress in the framework for resin with reduced elasticity modulus than for porcelain. In this study, it is important to highlight that the screw retightening between the cycling periods may have influenced the effect of esthetic veneering on preload maintenance of the abutment screw.

Although the abutments of group ZiC present esthetic advantages and better fit to the implant as a result of CAD/CAM processing,[29] the detorque values were lower than the other groups. This result may represent a greater rotation misfit of these components in comparison to abutments with a metallic base, as also demonstrated by Garine et al.[30] According to Cibirka et al,[10] the fit between implant and abutment hexagons is considered a primary cause of abutment screw loosening. Binon[3] reported that rotational misfit up to 5° reduced by 63% the number of cycles necessary to loosening, while the absence of rotational misfit generated resistance to loosening after 5 million cycles.

Furthermore, the crowns of group ZiC may present stress distribution less favorable to torque maintenance than the other groups due to the characteristics of the veneering material associated with the zirconia abutment. According to Vult von Steyern et al,[31] ceramics are brittle materials since the atomic planes do not allow separation during loading. Therefore, ceramics do not support deformation without fracture. Besides, preexisting cracks may act as a target point to fracture.

In this study, some crowns of group ZiC exhibited ceramic cracks and fractures during mechanical cycling, even considering that the unidirectional load applied during mechanical cycling reproduced only one force vector of chewing cycle.[32] The access hole for the abutment screw may be an additional factor for ceramic cracks, since it represents a weak point of ceramic veneering of implant-supported restorations.[33]

According to a previous study,[31] zirconia may exhibit increased fracture tenacity after external loading; however, this characteristic may damage the bonding between zirconia and porcelain veneering due to a deformation superior to the elastic capacity of porcelain. Therefore, the fractures observed in this study may result from these limitations, which suggest additional studies to evaluate the applicability of this material. Although the conditions of this in vitro study have not demonstrated the superiority of some material regarding the screw joint stability, the selection of abutment type and esthetic veneering material should be judicious due to its relevance to stress distribution on implants and supporting structures.

Conclusions

Within the limitations of this study, it was concluded that:

1. The detorque value was reduced in comparison to the insertion torque, regardless of the abutment type and esthetic veneering material of the crowns.
2. The castable abutments exhibited more irregular surfaces in the hexagon area than the machined and zirconia abutments.
3. The superiority of any veneering material for preload maintenance of the abutment screw was not established.

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