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Effect of Using Nano and Micro Airborne Abrasive Particles on Bond Strength of Implant Abutment to Prosthesis

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Connecting prostheses to the implant abutments has become a concern and achieving a satisfactory retention has been focused in cement-retention prostheses recently. Sandblasting is a method to make a roughened surface for providing more retention. The aim of this study was to compare effects of nano and micro airborne abrasive particles (ABAP) in roughening surface of implant abutments and further retention of cemented copings. Thirty Xive abutments and analogues (4.5 D GH1) were mounted vertically in self-cured acrylic blocks. Full metal Ni-Cr copings with a loop on the top were fabricated with appropriate marginal adaptation for each abutment. All samples were divided into 3 groups: first group (MPS) was sandblasted with 50 µm Al_2O_3 micro ABAP, second group (NSP) was sandblasted with 80 nm Al_2O_3 nano ABAP, and the third group (C) was assumed as control. The samples were cemented with provisional cement (Temp Bond) and tensile bond strength of cemented copings was evaluated by a universal testing machine after thermic cycling. The t test for independent samples was used for statistical analysis by SPSS software (version 15) at the significant level of 0.05. Final result showed significant difference among all groups ($p<0.001$) and MPS manifested the highest mean retention (207.88±45.61 N) with significant difference among other groups ($p<0.001$). The control group showed the lowest bond strength as predicted (48.95±10.44 N). Using nano or micro ABAP is an efficient way for increasing bond strengths significantly, but it seems that micro ABAP was more effective.

Key Words: implant abutments, sandblasting, surface treatment, temporary cement.

Introduction

As implant technology has been introduced, prosthodontics' science has been evolved. The use of implant-supported prostheses instead of missing tooth has gained acceptance among people all over the world (1,2).

One of the main concerns is the method of connecting prostheses to the implant abutments. With respect to all methods, two types of connection have been introduced: (A) Cement-retained and (B) Screw-retained prostheses (1,3,4). Cement-retained prostheses have the benefits of more passive superstructure, lower costs of laboratory procedures and optimal aesthetics in anterior region. Passive fitness is the most remarkable benefit of cement-retained restoration which declines the possibility rates of screw loosening, fractures and optimal occlusion due to lack of screw hole (2,3-5). In spite of the advantages, some disadvantages cannot be overlooked: the retrivability limitation when removing of crown is required; and more possibility of inflammation due to the remnant cement (4-6). However, both types have their aficionados and there is not any precise document about the superiority of each one (4,7).

Implant abutments need more consideration for enhancing higher retention during fabrication due to their limitations in diameter and tapering than natural teeth (8). The following factors influence the retention of implant prostheses: geometry of abutment preparation, abutment taper, surface area, abutment's height, surface roughness, and luting agent (1,2,9). Surface roughness and luting agents are more controllable clinically (2). As implants would not manifest signs of occlusal discrepancies in the first period of occlusal loadings, clinicians select provisional luting agents to maintain retrievability, evaluating oral hygiene and soft tissue response in follow ups (8). However, a loose restoration would not be acceptable, especially in anterior (5) and posterior regions with short abutments (heights of 3-4 mm). Therefore, sufficient retention for provisional luting is needed to retain the prostheses during function (6).

Most dental implants and abutments are usually manufactured from commercially pure titanium because of its biocompatibility and excellent mechanical properties (1). Using micro-sized particles, for making roughened abutment's surface, causes micro retentive ridge and groove patterns and results in more retention (10,11). Some methods are suggested to treat surfaces like: sandblasting, acid-etching, grit blasting and etc. Sandblasting with airborne abrasive particles (ABAP) is the most common method for treating abutment surface (12,13). Sahu et al. (9) investigated the effect of abutment surface modification on the further retention of restorations, which were cemented with polymer based cement. They declared that sandblasting was an effective method to increase the retentive strength. In another study, Kurt et al. (14) examined the effect of different surface treating methods on retention of single crowns. They tried CO_2 laser etching, ABAP sandblasting, titanium nitride coating and silicoating. Their final results showed the highest retention in sandblasted group. Wiskott et al. (15) claimed that sandblasting doubled the resistance to dynamic lateral loading. In another study, Al Hamad et al. (16) stated that sandblasting abutments with micro-sized ABAP significantly increased bonding strength in samples. There are varieties of ABAP which are used in sandblasting but the most commons are Al_2O_3 and TiO_2.

Nanotechnology has emerged in many branches of science such as medicine, chemistry and physics. It includes designs and fabrication of materials, devices and systems at nanometer (1-100 nm) dimensions. Therefore, materials are classified based on the structure as nanostructure, nano crystal, nano coatings, nano fibers and nano particles (17). Recently some studies focused on the use of nanoparticles for treating implant surfaces especially for higher osseointegration and survival rates (18).

Due to the importance of retention in implant-supported prostheses especially cement-retained ones, the purpose of this study was to compare nano and micro ABAP sandblasting and their effects on retention of cemented copings to implant abutments. The null hypothesis is that using nano ABAP might provide higher prepared higher surfaces for bonding to the cements

Material and Methods

In this observational-analytical study, 30 Xive implant screwed abutments with their exclusive analogues (4.5D GH1) (XiVE, Dentsply, Friadent GmbH, Mannheim, Germany) were used as the samples of this observation. All 30 analogues were mounted vertically in self-cured acryl (Meliodent, Heraeus Kulzer, Hanau, Germany) by a surveyor (Ney Surveyor, Dentsply, York, PA, USA) 2 mm above the margins. The titanium abutments were attached to each implant analogue and torqued to 35 N.cm.

Thirty copings were made by prefabricated burn-out caps with a loop on the occlusal surface of each coping for retention test. The patterns were invested in a phosphate-bonded investment (Ceravest Quick, GC, Tokyo, Japan) and casted in Ni-Cr alloy (Rexillium III, Pentron, Wallingford, CT, USA). Ultrasonic cleaner and hydrofluoric acid were used for divesting and cleaning the copings. The inner surfaces of the copings were observed under 4× magnification for detecting any irregularities. Silicon disclosing medium (Fit Checker, GC Co, Tokyo, Japan) was used for insurances of marginal fitness. A gyrator was designed by using a gearbox motor with a place for mounting samples, which turned around twice in 1 min in order to make sure that all the surfaces of the abutment were roughened equally (Fig. 1).

All samples were divided into 3 groups with 10 abutments in each of them. In the first group (named MPS), all samples were sandblasted with 50 *µm* Al_2O_3 micro ABAP (Edelkorund, Ernst Hinrichs GmbH, D-38644, Golsar, Germany) and the second group (named NPS) was sandblasted with 80 nm Al_2O_3 nano ABAP (US Research Nanomaterials, Inc.). The third group (named C) was assumed as the control group.

The sandblasting procedure was prepared by a sandblasting machine (Pieme, S.R.L, Lonigo, Vicenza, Italy) with 3.5 KPa from a 5 mm distance for 1 min (1). Only the titanium abutments were sandblasted in order to evaluate the effects of ABAP on roughening the abutments and bonding of cement to titanium (Fig. 2).

All copings were cemented to the abutments by Temp Bond cement (Kerr, Salerno, Italy) with 5 N forces for 10 min according to manufacturer instruction, respectively. All samples (meaning coping-abutment-analogue) were subjected to 5,000 thermal cycles between 5° and 55° in a themal cycler (Delta Tpo2, Nemo, Mashhad, Iran).

Tensile bond strength of cemented copings was evaluated by a universal testing machine (21046, Walter+bai, Switzerland) with crosshead speed of 5 mm/

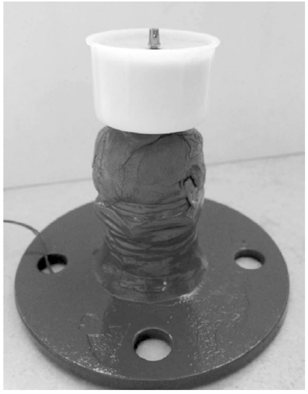

Figure 1. Designed gyrator for making roughened surface equally.

Figure 2. Macro view of sandblasted abutments of each group.

min and 500 kg force. The force was applied until observing the dislodgment of coping and failure of cementation.

Two walls of acrylic bases were trimmed slightly parallel to each other in order to become appropriate for observing whole surface of abutment under microscope completely. Therefore, the samples were embedded on two parallel sides of the bases and cement remnants were observed under stereomicroscope (Motic SMZ-168 Stereo Zoom Microscope, Ted Pella Inc., CA, USA) under 20× magnification. Two images were taken from each abutment and full coverage was achieved. The percentage of cement remnants was evaluated with Photoshop Software version 8 (Adobe Systems, San Jose, CA, USA).

Finally, analysis with a scanning electron microscope (Vega II Tescan, Tescan Orsay Holding, Kohoutovice Czech Republic) was proceeded to characterize the sandblasted surface of abutments and comparing the roughness which was caused by two types of nano and micro ABAP. In order to preparing samples for SEM analysis, the following stages were done: fixation, post fixation, washing, dehydration, decication, and gold coating (Edwards Ltd., London, UK).

The mean of tensile bond strength necessary to dislodge the copings from the abutments, were recorded and all data were analyzed by the t-test for independent samples using SPSS software version 15 (SPSS Inc., Chicago, IL, USA) at a significant level of 0.05.

Results

As the analysis variances were not homogeneous among the groups, the Kruskal Wallis test was done and significant difference in results was achieved ($p<0.001$). Then t-test for independent samples was administered to analyze the recorded data and the final results showed significant difference among all groups ($p<0.001$).

Table 1 demonstrates the mean values and standard deviations of tensile bond strengths, which were recorded from all groups. MPS showed the highest mean values of retention (207.88±45.61 N) with significant difference among other groups ($p<0.001$).

The NPS group (136.97±31.09 N) showed the higher retention value than group C (48.95±10.44 N) with significant difference ($p<0.001$). The control group showed the lowest retention value as predicted (48.95±10.44 N).

Table 2 presents the distribution of cement remnants on the abutments after dislodgment. The largest number of samples with ≥60% cement remnants were observed in the MPS group (n=4), while the lowest number of samples were observed in group C (n=0).

Figures 3 and 4 represent the SEM analysis of the abutment's surfaces that were roughened with 50 µm (Fig. 3) and 80 nm (Fig. 4) ABAP, respectively. Al_2O_3 particles became encrusted on the titanium surface because of the velocity and pressure and hit the surface, which made a mechanical bonding to the cements.

The 80 nm Al_2O_3 ABAP made very small interface, but 50 µm Al_2O_3 ABAP, which is mostly regular, appeared to make larger microstructure irregularities.

Discussion

There have been many studies about the effect of surface treatment on retention strengths of cemented prostheses to the abutments (4,5,9,11,14). However, few studies evaluated the effect of nano scale surface treating on retentive strength. Hence, the impact of nano and micro ABAP on retentive strength was investigated in cemented coping to implant abutments in this study. Factors that influence the amount of retention seems to have paramount role in cemented implant-supported restorations, including: taper or parallelism, surface area and height, surface finish or roughness and type of cement (2,9,14).

First of all, the results of present study confirmed that making roughened surface results in higher values of retentive strength as reported elsewhere (2,9,14,15,19,20).

Results of present study showed that the highest mean retentive strength were caused by 50 µm micro ABAP (207.88±45.61 N) with significant difference in comparison with the other groups ($p<0.001$). Also, the highest number of samples with ≥60% of remnant cements in MPS group might admit the fact that deeper and larger irregularities resulted in lesser detached cements. These findings reflect that micro ABAP created more retentive surface than nano ABAP, statistically. Larger with deeper projections and grooves made by micro ABAP, which were filled with cements, might cause more retention. The present results

Table 1. Mean values and standard deviations of retentive values (N) which were obtained from tensile test in all the groups

Groups	Mean retention value	Minimum retention value	Maximum retention value
C	48.95±10.44	32.78	63.09
MPS	207.88±45.61	146.72	275.73
NPS	136.97±31.09	68.26	192.49

Table 2. Distributions of cement remnant on the abutments of all groups

Groups	<30% remnant cement	30-60% remnant cement	≥60% remnant cement
C	7	3	0
MPS	2	4	4
NPS	4	4	2

are in accordance with those of a previous study in which 250 µm and 50 µm micro ABAP sandblasting were compared and higher retention values were caused by larger size of micro ABAP (4).

In another aspect, providing nano scale roughness hypothesizes more prepared surface roughness areas and might lead to higher retention values reasonably. However, the type of cement is another factor which affects the retention strength. Schmage et al. (21) stated that thin and homogeneous film thickness of cement has a paramount impact in providing passive fitness and impressively increases the retentive strength. These results are consistent with those of Wiskott et al. (15). Most probably, higher tensile bond strength values would be obtained when the cement flows into irregularities and then sets, which ends in higher inter-lockage (20). As mentioned before, many clinicians try to use provisional luting agents to maintain retrievability and evaluating occlusal discrepancies, oral hygiene and soft tissue response in follow ups (8). Temp Bond was used as a provisional cement in present study. The eugenol-containing luting agents can inhibit the growth of bacteria and further inflammations. Because of their lower cost and ease of handling many clinicians tend to use them as temporary materials (22).

According to Kim et al. (2), the method of treating surface depends on the provisional luting agent; and bond strength has liner correlation with wettability of the cement. The more the surface is getting wet with cement material, the more retention is gained (1). Temp Bond has low wettability and it might be the reason why NPS group showed lower retention values than the MPS group.

Sahu et al. (9) found that the mean retentive value was 743.8±62.4 N for micro ABAP sandblasted group with considering that polymeric implant cement was used for cementation. Additionally, sandblasting was administered for both copings and abutments with 110 µm. In present study, only the abutments were sandblasted in order to evaluate effects of ABAP on bonding of cement to titanium abutments not copings; and the size of ABAP was smaller (50 µm).

In another study, the mean retention values were recorded 506.02±18.04 N for micro ABAP group (14). The difference between two mentioned studies might be due to different types of cements and size of ABAP.

Kim et al. observed the effect of surface treating and different luting agents on retentive strengths. They used 50 µm ABAP with different luting agent, especially Temp Bond. They concluded that the tensile strength of Temp Bond was the lowest and sandblasting might be an effective method to increase retention of a provisional acrylic crown when Temp Bond NE (non-eugenol) was used (2).

The other factor, which affect the retentive strengths, is the height of abutments (23-25); meaning that higher abutments made higher values of retention. Saleh Saber et al. (6) evaluated the retention of cemented coping to abutments with 2 mm height without any prior surface preparation in one of their groups. Their result is comparable with the control group of present study. The mean retention was 9.92±4.11 N in that study; however the recorded retention was 48.95±10.44 in present study for the control group. The luting agent was the same, so deference magnifies the importance of abutments heights.

Depending on compared results, using other cements with higher wettability is suggested to evaluate the

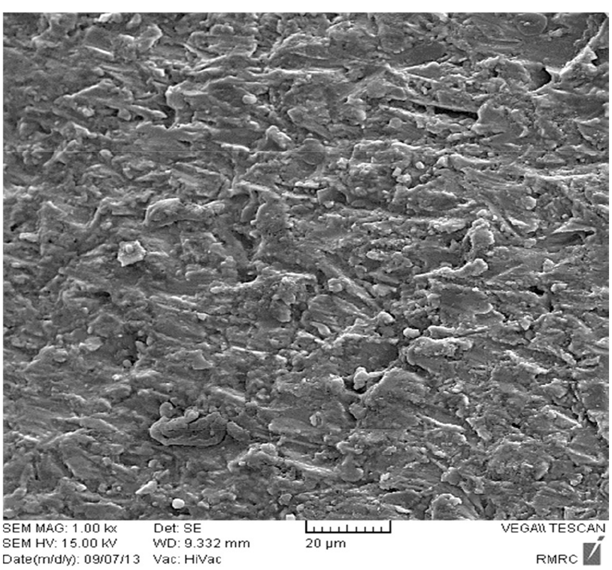

Figure 3. SEM image of abutment's surface sandblasted with 50 µm Al_2O_3 (1000× magnification).

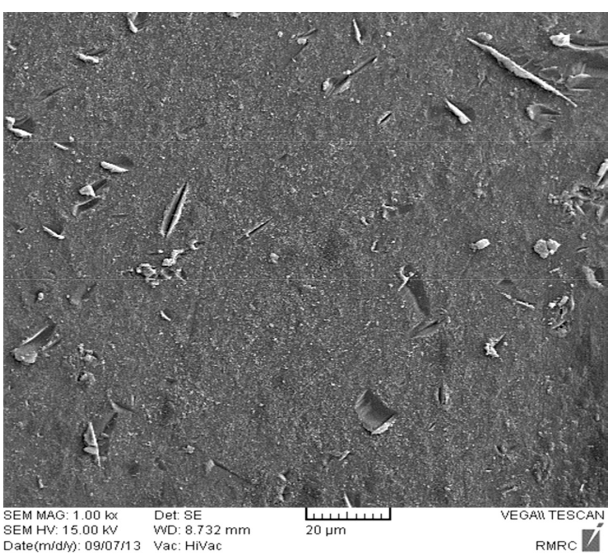

Figure 4. SEM image of abutment's surface sandblasted with 80 nm Al_2O_3 (1000× magnification).

capability of nano ABAP sandblasting technique more genuinely. Also, it is recommended to investigate other types of cements and implants with different heights; trying other treating methods with different size of particles; and roughening both crown and implant abutments to find more practical results in future studies.

Within the limitations of this study, it may be concluded that sandblasting with ABAP (nano or micro) is effective to make higher bond strengths. However, it seems that using micro ABAP is more efficient due to the fact that nano ABAP reduced the wettability of Temp Bond provisional cement.

Resumo

A conexão das próteses nos pilares dos implantes dentários é um fator de preocupação e a obtenção de uma retenção satisfatória tem sido objeto de estudos recentes em próteses com retenção cementária. O jateamento é um método de obter uma superfície áspera para aumentar a retenção. O objetivo do presente estudo foi comparar os efeitos de jateamento com nano- e micropartículas abrasivas para tornar áspera a superfície dos pilares de implantes e a consequente aumentar a retenção dos copings cimentados. Trinta pilares Xive com seus análogos (4.5 D GH1) foram montados na posição vertical em blocos de acrílico auto-polimerizados. Copings metálicos de Ni-Cr com uma alça no topo foram feitos com adaptação marginal apropriada para cada pilar. Todas as amostras foram divididas em três grupos: o 1° grupo (MPS) foi jateado com micropartículas de Al_2O_3 com 50 µm de tamanho médio; o 2° grupo (NPS) foi jateado com nanopartículas de Al_2O_3 com 80 nm de tamanho médio; e o 3° grupo (C) foi considerado controle. As amostras foram cimentadas com cimento provisório (Temp Bond) e a resistência à tração dos copings cimentados foi avaliada em máquina universal de ensaios após processo de termociclagem. O teste t para amostras independentes foi usado para fins de análise estatística empregando-se o software SPSS v. 15, com nível de significância de 0,05. Os resultados demonstraram diferença significante entre todos os grupos ($p<0,001$) e o grupo MPS mostrou o maior valor médio de resistência de união (207,88±45,61 N) com diferenças significantes em relação aos outros grupos ($p<0,001$). Conforme previsto, o grupo controle obteve o menor valor de resistência (48,95±10,44 N). O jateamento com micro ou nano partículas mostrou-se um modo eficaz de aumentar significativamente a resistência de união, mas aparentemente as micropartículas são mais eficazes.

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