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The Influence of Abutment Surface Treatment on Pull-off Bond Strength Between (5)Yttria Stabilized Zirconia Crown and Titanium Implant Abutment

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Abstract

Aim: The objective of this study was to investigate the effect of bur, sandblast and plasma surface treatments for Ti-implant abutment (Dentium/Korea) on the bonding strength with (5)Y-TZP crown. **Materials and Methods:** (40) Ti-abutments of implant were used in this study and divided in to four groups (n = I0 for each group) according to the surface treatment methods of titanium abutment: group (I) without surface treatment of Ti-implant abutment (control group), group (II) bur surface treatment of Ti-abutment, group (III) surface treatment for Ti-implant abutment with sandblast (50-µm aluminum oxide), group (IV) surface treatment of Ti-abutment with plasma. Then, (40) implant analogs were positioned vertically in acrylic mold. Each abutment was fixed on each analog with torque of (35 N/cm). Forty (5)Y-TZP crowns fabricated by CAD/CAM system that had special design with occlusal O-hole, then all crowns luting to all abutments using Allcem resin cement. All samples were then storage in thermos-cycling with (5000) cycles, finally the vuniversal testing machine record tensile bond strength for all samples, these results were evaluate using a one-way anova analysis of variance at a significance level of ($p < 0.0I$) .

Results: bur treated abutment (group II) showed the highest bond strength values, followed by sandblast treated abutment group (III) and plasma treated abutment group (IV). Group (I) had the lowest value of tensile bond strength. Conclusion: Surface treatments of Ti-implant abutment had excellent effect on tensile bond strength between Ti-implant abutment and (5)Y-TZP copings, roughness of abutment surface by Bur and sandblast increase bond strength , plasma cause increase in chemical activity of abutment surface and so elevate tensile bond strength.

Keywords : Titanium implant abutment, (5)Y-TZP, tensile bond strength, Cold atmospheric plasma (CAP), Al_2O_3 sandblast.

1. Introduction

Dental implants are one of suitable treatment which have high capability to restore missing teeth, esthetic and function of missing teeth, since they have high success rate and long durability (Simonis *et al.*, 20I0) . Dental implant system consists of three portions are: fixture that surgically placed inside jaw bone, abutment that connect fixture to prosthetic super-structure and prosthetic restoration such as crown or bridge (Krennmair et al, 20I0).

An implant abutment is the second part of dental implant system that is an inter-mediate and connection between the dental implant fixture and the super-structure indirect restoration, so its function to support and retain prosthesis and soft tissue profiles of an implant supported restoration (Blatz et al, 2009).

The implant supported restoration may be retained with screws or luting agent (Akin and Güney, 20I2; Wahl et al, 2008). Using of screwed or cemented type depended on clinical situation of case, cemented type used in esthetic area, less technique sensitivity and easy cleaning(Sheets et al, 2008). But screw retained restoration is simple to retrieve and less peri-implantitis (Chaar et al, 20II).

The most important factor that effect on retentive force is choice of cement, many types of cement used for luting of zirconia crown and Ti-abutment but the most effective type is resin-based luting (Maltzahn et al, 20I6) .

Type of two-piece implant system, abutment made from titanium and restoration fabricated with zirconia materials and cementation between these different two materials stays the problem, Zirconia is poly-crystalline, inert and biocompatible elements, its problem was the difficulty of chemical bond with titanium, so Kim, et al. (20I3) investigate that in environment with static loading, the two pieces implant system offers de-cementation between the zirconia crowns and the titanium base abutments, reduced inter-occlusal space between upper and lower arches is example for this problem and when using a short titanium base abutment, which has possibility of de-cementation between zirconia restorations and Ti- abutments (Nouh et al, 20I9). The weak point of this system is adhesion between zirconia crowns and Ti- abutment (Ebert et al, 2007).

Cementation of luting agent to a metal surface depends on micro-mechanical interlocking and physico-chemical bond, so many different methods for surface treatment have been introduced to enhance the bonding between Ti-abutment and zirconia crown these are micro-mechanical retention, chemical bonding, and combination of micro-mechanical retention and chemical bonding (Fonseca et al, 20I2).

To increase micro-mechanical retention, using sandblast with Al_2O_3 particles that is effective method for this purpose (Tsuchimoto et al, 2006), also bur treatment used for surface roughening and its available and easy used for modification of materials surface. These methods clean the surface of material, improve the wetting of its surface, elevate the surface area for adhesion, but these methods may weaken the treated material if used aggressively (Bertolotti, 2007).

The gaseous mixture known as plasma, a metastable state of matter, is composed of protons, electrons, reactive oxygen species, and ultraviolet photons at varying densities and temperatures. Unlike ordinary matter, plasmas may survive at very high temperatures without losing their physical properties. British scientist William Crookes made the discovery of plasma in I879; Irving Langmuir named it in I929 (Suresh, et al., 2022).

The aim of this study was to investigate the effect of different methods of surface treatment such as (bur, sandblast and plasma) on tensile bond strength between coping of (5) Yttria stabilized zirconia and Ti-implant abutments, so the null hypothesis of this study was that no difference in pull-off bond strength between (5) Yttria stabilized zirconia crown and Ti-implant abutment whatever the surface treatment method type.

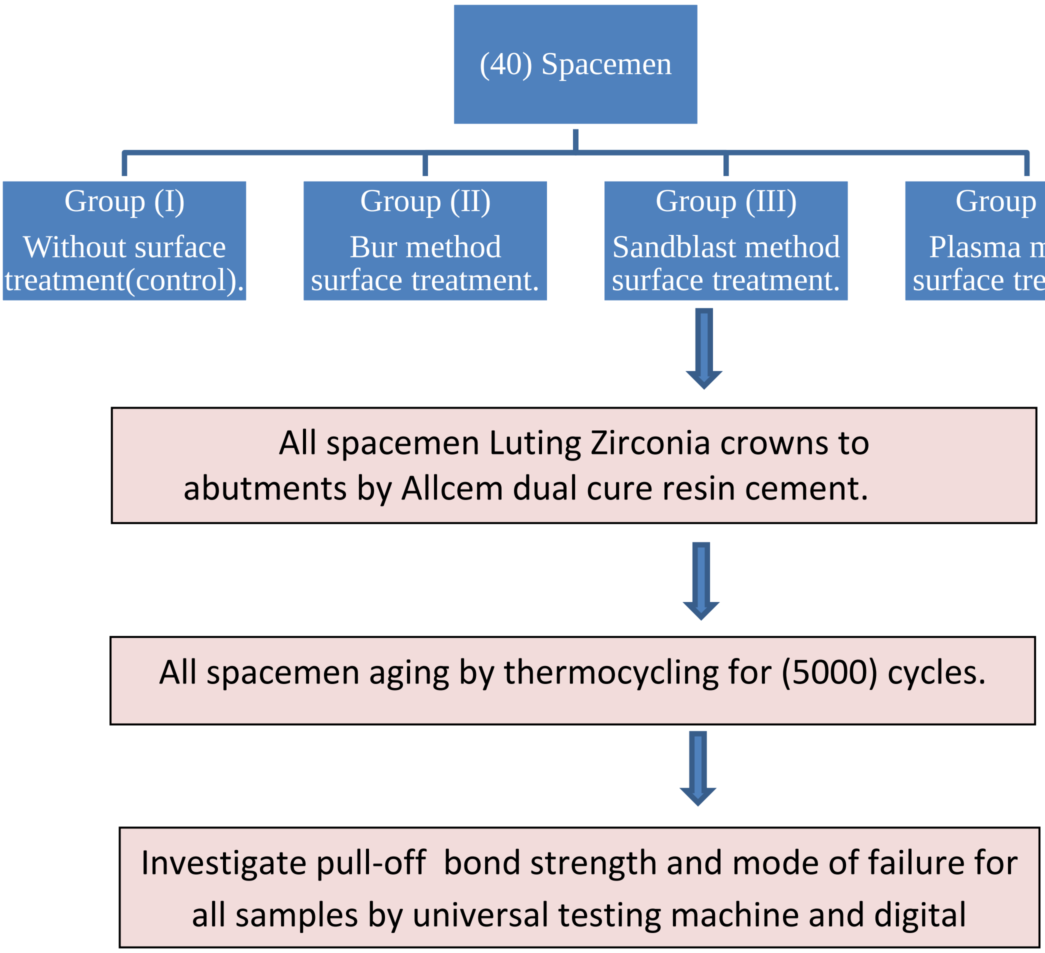
2. Materials and Methods

2.1 <u>Preparation of Samples:</u>

Forty standard titanium abutments (Dentium System/ Korea) ; with (4.5mm) in diameter and (5.5mm) height, , were employed in the study. A screw was used in the construction of each titanium abutment to secure it to its laboratory equivalent. Then, forty laboratory analogs measuring 4.5 mm in diameter and I2 mm in height were to be utilized in this investigation, every titanium abutment was first fitted into an acrylic mold after being screwed onto its corresponding laboratory counterpart and torqued of (35 N/cm) by using a torque-controlled ratchet.

2.2 Flow of the study:

In this study, forty samples of implant abutments and zirconia crowns were used and divided into four groups as shown in (figure I)



Figure(I): Study flow

2.3 Zirconia Crown Fibrication

To conduct the tensile bond test in this study, forty were required; these crowns were made using a CAD/CAM technology in a unique design with an O-ring on the occlusal surface, as seen in figure (2) (Kim, 20I3). Five (5) Yttria stabilized zirconia copings (5Y-TZP/VITA, shade white, VITA Zahnfabrik, Germany) were the type of zirconia employed in this investigation.

2.4 Surface Treatment for Ti-abutments

- Group (I): This group serves as a control and consists of ten specimens with untreated titanium abutments.
- Group (II): Consisting of ten specimens, the titanium abutments were treated for one cycle using a modified dental surveyor (Technology 780.8C Two Striper FG Friction Grip Coarse) with an abrasive bur (3).
- Group (III): samples were cleaned using de-ionized water and an Ultra-conic device as shown in figure (4). Titanium abutments were subjected to sandblast treatment using Al2O3 at a (50mm) diameter for (20seconds) at (2.0bar) of pressure. The nozzle was positioned (3cm) from the astronauts and perpendicular to them (Turker et al. 2020).
- Group (IV): Consists of I0 specimens whose titanium abutments were plasma-treated using CORE plasma activator. The manufacturer of this equipment states that the titanium abutments were exposed to plasma for 90 seconds, as shown in figure (5) (Altaie and Alkhalidi, 2024).

2.5 Cementation and Thermocycling

Before cementation, each abutment hole should be sealed with a small piece of cotton and temporary filler. Next, using resin cement self-adhesive dual cure (Allcem dual, FGM, shade A2), copings were luted with implant abutment. The bonding materials were then exposed to a light cure machine of (Eighteeth, China) for about a minute, with a weight of one kilogram, an intensity of II80 mW/cm2, and a wave length of 450 nm.

All samples were cementated, and then they were put through 5000 cycles in a thermocycling machine (I00 SD Mevhatronic, Germany). Two deionized water containers, one at five degrees Celsius and the other at five degrees Celsius, make up the machine. The dwell period of the containers is thirty seconds, while the transfer time is ten seconds.

2.6 Tensile Bond Strength measurement

An Universal Testing Machine was used to measure the tensile bond strength. All copings were pulled with speed of crosshead at (0.5cm/min). The data was then moved to the computer and recorded, indicating the pulling force at which the bonding fracture between the copings and theTi-implant abutment occurred on the meter that was attached to the machine of tensile strength.

3. Results

After the experimental procedure is finished. In each group, the pulling forces required to detach the Ti-implant abutments from the copings were calculated in Newton. After the binding strength values were recorded for every group, these data were subjected to a descriptive analysis. The mean, standard deviation, lowest and maximum values, and other statistics are reported in Table (I). This table displays the descriptive analysis of the research findings, which indicate that the bur group (438 N) had the highest retentive mean bond strength, followed by the sandblast group (209 N), and the abutment plasma surface treatment (I43 N). On the other hand, the control group's mean value was the least retentive, with (64 N).

As indicated in Table (2), (one way ANOVA) the analysis of variance was performed to determine whether there are any significant differences between the surface treatment groups. P-value < 0.0I) indicates that there are significant differences between the groups in this table. This indicates that one or more of the applied surface treatment groups differ from the others. Duncan's multiple range test was created to determine which group in this study is noteworthy in comparison to the others. According to the results of the Duncan's Test, as indicated in Table 3, all groups differ from one another at a (p-value of less than 0.0I).

Group (II), which had bur treatment, had the highest separation force value compared to the other groups, with a p-value of less than 0.0I, followed by groups (III) and (IV), which received sandblast and plasma treatment, respectively. Group (I) (without surface treatment for Ti-abutment) had the lowest tensile strength value, with a (p-value of less than 0.0I).

4. Discussion

This study set out to assess the effects of different surface treatments on the pull-off bond strength (tensile bond strength) of Ti-implant abutments with (5) Yttria zirconia crowns. The findings refuted the null hypothesis, indicating that a variety of surface treatment techniques for Ti-abutments have no effect on the (pull-off) tensile bond strength of Ti-abutments with (5) Yttria stabilized zirconia crowns. The pull-off strength between Ti-implant abutment with zirconia copings was considerably impacted (P<.0I) by the surface treatment techniques of sandblast and plasma.

Group (I) exhibited a lower tensile bond strength between Ti-implant abutments and zirconia copings. Śmielak et al. (20I5) and Seekaewsiu et al. (2022) reported that the control group (I) had the lowest bond strengths due to the lack of surface treatment and the smooth surface of the abutment, which results in a very weak retentive force when compared to a rough surface.

According to Maltzahn and Kohors' (20I9) research, there is no residual cement on titanium implant abutments due to adhesive mode of failure between titanium implant abutment and resin cement. The fracture pattern analysis indicates that the bonding architecture is most vulnerable in the vicinity of the titanium surface. After then, the writers focused on how to modify titanium surfaces to make the bond stronger (Seekaewsiu and Sirimethawong, 202I).

These results are consistent with research by Sethi et al. (2020), which found that applying diamond bur treatment to the abutment improved the retention of cemented-retained prosthesis to the implant abutment, so Group (II) in this study, which is the abutment surface treated by bur had the higher value oo pull-off bond strength in comparison with the other groups.

This is consistent with the findings of our study because bur causes titanium's surface to become rougher, increasing the wettability of surface and surface area of material. It also enables the interlocking with resin cement, improving the bond between titanium implant abutment and resin cement. Shrivastav (20I8) conducted another study in which he used diamond bur to treat the surface of short abutments and found an increase in retention of cement-retained prosthesis.

According to Ganbarzadeh et al. (2012), a diamond bur enhance the retentive force of metal copings on Ti-implant abutments. The research of Badawi et al., discovered that the surface of Ti-abutment when treated with diamond-bur as a circular grooves was an efficient way to elevate the strength of bonding between crown and non-eugenol temporary cement (Badawi et al., 2015). These results were agree with the findings of Sahu et al. (20I4), the cohesive mechanism of failure was in cement, that means the failure happened within the cement and left excess cement on the surface of Ti - implant abutments and the inner surface of crowns according to the study of Fonseca et al. (20I2).

The results of this research showed that sandblasting enhance the bonding strength between titanium abutments and zirconia crowns, so the retentive force of group (III) sandblast treated abutment was higher than that of group (I) the control group. Our research results agree with studies of Kurt et al. (20I3) and Turker et al. (2020), They discovered that sandblasting is the effective way of surface treatment to enhance the bond between titanium implant abutments and zirconia crowns, also according to Alkhadashi et al. (2020), the titanium implant abutment treated with sandblast strengthened the shear bonding between the lithium-disilicate crown and titanium implant abutment. In a research of Seekaewsiu and Sirimethawong (2022), Lubas et al. (2022) treated the titanium implant abutment surface with sandblast and different types and quantities of acids. They found that in comparison with the other groups, group that treated with sandblast had a cohesive mode of failure. They speculated that this due to the sandblast has a rougher surface than that with acid and more mechanically interlocks with resin cement, Our research results in line with their explanation. Because sandblasting produces more roughness on the surface and more surface area for adhesion than plasma treatment, the research's results indicate that sandblast-treated implant abutment group (III) had a higher tensile bond strength than plasma-treated implant abutment.

Pull-off strength was higher in group (IV) (plasma treatment for Ti-implant abutment) than in group (I) (control group), but lower than in other groups. Strong chemical bonds are formed during the plasma surface treatment procedure, which also improves wettability and creates chemically active areas for molecule-to-molecule adhesion. These results are consistent with those of Seker et al. (20I5); Degirmenci and Saridag (2020) found that plasma surface treatment of a titanium abutment reduces the contact angle of the surface when compared to a control group, increases bond strength without changing the structural characteristics of the titanium surface in contrast to bur and sandblast, which alter the morphology of the Ti surface, and leaves the roughness value unchanged. Additionally, our findings concur with those of Ozyetim et al. (2023), who discovered that atmospheric plasma treatment considerably increased the retentive force value between the zirconia crown and Ti-abutment as compared to the control group (P <.0I).

The effectiveness of Cold Atmospheric Plasma (CAP) in reducing the water contact angle (WCA) of plasma-treated titanium surfaces and thereby improving the hydrophilic properties of the material's surface allows for the modification of titanium surfaces' physico-chemical properties without compromising their microstructure (Lai Hui, et al. 2020).

Conclusion:

- Different methods for surface treatment of Ti-abutment had positive effect on pull-off (tensile) bond strength in compare to smooth surface without treatment.
- Using of bur and sandblast for treatment of Ti-abutment increased bond strength by causing rough surface and improve wettability and adhesion with resin cement and zirconia crown.
- Plasma treated method is effective and non-invasive technique for increasing tensile bond strength between Ti-abutment and zirconia crown.

Conflict of interest

The authors reported that they have no conflicts of interest.

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Fig. (2): Design of zirconia crown.

Fig. (3): Bur surface treatment fot Ti-abutment.

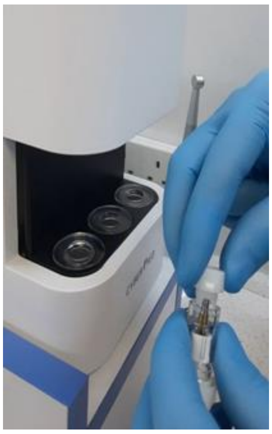

Fig. (5): CORE Plasma activator device for plasma surface treatment

Fig. (4): Sandblast surface treatment for Ti-abutment.

Table (I): Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
control	I0	50.00	8I.00	64.I000	9.84829
bur	I0	4I0.00	475.00	438.5000	I8.86355
plasma	I0	I27.00	I50.00	I43.2000	6.49444
sandblast	I0	I80.00	255.00	209.0000	2I.83270
Valid N (listwise)	I0				

Table (2): One-Way Anova test results.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	779075.400	3	25969I.800	I069.057	.000
Within Groups	8745.000	36	242.9I7		
Total	787820.400	39			

Table (3): Duncan test results

CODES	N	I	2	3	4
GROUP (I)	I0	64.I000			
GROUP (4)	I0		I43.2000		
GROUP (3)	I0			209.0000	
GROUP (2)	I0				438.5000
Sig.		I.000	I.000	I.000	I.000