Effect of various surface treatments of implant abutment and metal cope fitting surface on their bond strength to provisional resin cement

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Abstract

Objectives: The purpose of this study was to examine the effect of different surface treatments of implant abutment and metal cope fitting surface on their bond strength to provisional resin cement.

Materials and methods: Sixty implant analogs and standard titanium abutments of 6 mm height were embedded vertically in autopolymerizing acrylic resin blocks. Metal copings with a loop on the occlusal surface were fabricated using nickel chromium (Ni−Cr) alloy. Samples were divided according to their surface treatment into three groups (n = 20 for each group); Group (1) air borne particle abrasion with 50 μm Al2O3 powder. Group (2) air borne particle abrasion plus alloy primer. Group (3) samples were silicoated and silanated using cojet system. Each group was subdivided into two subgroups (n = 10 for each subgroup) according to storage condition and stressing; Subgroup (A) short-term water storage and Subgroup (B) short-term water storage and thermocycling plus mechanical loading corresponding to 6 month of clinical use. The copings were luted using provisional resin cement under static load of 3 kg. Samples were tested for tensile bond strength using a universal testing machine at a crosshead speed of .5 mm/min. Statistical analysis of the results and comparison between each two groups were performed using One Way ANOVA (significance at P ≤ 0.05) followed by post-hoc tests.

Results: Silica coating using Cojet system recorded significant highest mean values (5.190 MPa) followed by air borne particle abrasion (3.698 MPa), while using alloy primer on air abraded surface recorded the lowest bonding values (1.998 MPa). Subjecting the samples to short term water storage and thermocycling plus mechanical loading has led to significant loss of retentive values.

Conclusion: Cojet surface treatment and air borne particle abrasion recorded the superior results in this study.

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Keywords: Implants; Titanium abutment; Air borne particle abrasion; Alloy primer; Cojet system and provisional resin cement

1. Introduction

Dental implants have shown high capability to restore esthetic, proper function of lost teeth and they have a long durability and success. Long term implant survival and success rates of dental implants have been demonstrated [1].
Today, Cement retained prosthesis, supported by implant, is more popular due to several advantages such as loading along linear axis, better passivity fit, small occlusal table due to the lack of accessibility hole and lower fracture of porcelain due to lack of screw accessibility hole. The only considerable advantage of screw-retained prosthesis is its retrieval [2].

Retrievability is advantageous for replacement or salvaging of the restorations and implants necessitated by (1) The need for periodic replacement of prosthetic components (2) Loosening or fracture of the fastening screws (3) Fracture of abutments (4) Modification of the prosthesis after loss of an implant (5) Surgical reintervention [3].

Therefore, retrievability of implant prosthetic components can be a significant safety factor. The retrievability of fixed implant-supported prostheses is therefore an important consideration in delivering patient-oriented treatment outcomes [4]. Therefore, it is totally advisable to cement all implant-supported cement-retained prosthesis with provisional cement at delivery appointment to have the capability of retrieval. However, when crown is luted with provisional cement, diminished retention can cause dislodgement of the crowns. So it is advisable to increase retention by other means such as electrolytic etching, bur roughness, laser etching and chemical etching.

Surface modification of abutments and crown may increase the retentive strength of cemented casting. It was postulated that the retentive strength of restoration cemented with different cements could also be modified by the roughness and surface characteristics of implant abutment in comparison to the uniform dental abutment surface [5].

The micromechanical retention surface treatment involves air abrasion with alumina particles. This creates surface defects in the metal surface that result in an increase in surface roughness and surface area [6].

Simplified bonding procedure with fewer steps and reduced chair-side time has become the hallmarks of modern dental adhesive systems. Backed by revolutionary advances in bonding technology and aggressive research efforts, The development of dental adhesive systems has moved toward single-bottle, multi-purpose primers or adhesives which could deliver strong and durable adhesion [7].

Alloy primer is a metal conditioning agent used to enhance the bond strength between dental metals and resin base materials. It contains 6,4-vinylbenzylpropyl amino-1,3,5-triazine-2,4-dithione (VBATDT) and 10-methacryloxydecyl dihydrogen phosphate (MDP) which enhances the bond strength to high noble, noble and also base metal alloys [8].

Many bonding systems have been developed by different manufacturers include Rocatec, Silicoater and Kevloc bonding systems. Studies have shown that these treatments, which are based on silica coating/ silanization are effective in increasing the bond between resins and metals [9]. The system enhances the bond strength between such systems as composite-to-metal, composite-to-ceramic, and composite -to-composite [10].

Cojet system one known method has achieved both bonding mechanisms tribochemical silica coating. This method uses air borne-particle abrasion with silica-modified Al2O3 particles in conjunction with silanization. Cojet Sand has a particle size of 30 µm, is applied in a single step and is indicated for chair side application with the use of a chair side air abrasion device. Next silane coupling agent is applied and creates a chemically reactive surface [11].

For implant systems in which the suprastructures are cemented to the abutments, the provisional luting agent must be strong enough to resist functional forces, but weak enough to allow easy removal of the suprastructure when necessary without harm to the abutment and implant fixture [12].

The purpose of this study was to examine the effects of different surface treatments on the tensile bond strength of metal cope on Implant abutments cemented with provisional resin cement.

2. Materials and methods

Sixty standard titanium abutments1 with 6 mm length beginning from the top of the abutment to the finish line (chamfer finish line) and 3.5 mm diameter were used in the study. Sixty implant analogues with 12 mm length and 3.5 mm diameter were used. With the aid of dental surveyor2 analogues were handled vertically inside metal mold in which a self-cure acrylic resin was poured.3

The acrylic blocks were finished by removing excess and polished by water and pumice. Each abutment was tightened onto the implant analogue using hex driver. All abutments’ screw access the channels were filled with two compacted cotton pellets and sealed with composite resin4 up to the level of occlusal.

1 Tut dental implant system, Cairo, Egypt.
2 Ramses, Alex, Egypt.
3 Acrostone dental supply, Egypt.
4 Z-250 XT, 3M ESPE, USA.
surface to restore the original contour of all of the abutments.

Die spacer material\(^6\) was applied on the abutment with its whole length using a fine brush leaving 1 mm before the margin without die spacer to allow precise marginal fit of the suprastructure on the abutment.

Wax patterns\(^5\) were constructed with blue inlay wax by dipping method until obtaining 0.5 mm thickness of the wax. After finishing the wax pattern, a small wax loop was constructed on the top (occlusal) side of the suprastructure.

Wax patterns were sprayed and invested with phosphate-bonded investment\(^7\) and casted with nickel/chromium alloy\(^8\) on a centrifugal casting machine. The casted suprastructures were cleaned from the remaining investment using ultrasonic cleaner and then finished and polished as conventional casted metal crowns.

Copings fitting surfaces were carefully inspected for deformation or any nodules, only copings of good surface texture were selected. Thicknesses of the metal copings were measured with a caliber to make sure of .5 mm thickness.

Stability was assessed by applying finger pressure vertically to the crown while seated on the abutment and considered acceptable if the crown did not have any rotational movement on the abutment.

Sixty samples were divided into three main groups according to type of surface treatment of both implant abutment and metal cope fitting surface. Each main group was subdivided into two equal subgroups according to storage plus stressing condition before testing (Table 1).

Auto mix tips provided with provisional resin cement\(^9\) were used for introducing it to the fitting surface of the metal cope. After application of the cement, the metal copes were fitted to the corresponding abutments and held in place under static load of 3 kg for 10 min using custom-made device. Excess cement was removed with explorer [13].

The tensile force necessary to debond each cope was measured after exposure to two conditions. The first group were stored in distilled water for 24 h at 37 °C (n = 10), and the second group were stored in distilled water for 24 h at 37 °C then subjected to thermocycling for 5000 cycles (5–55 °C) with a 30-s dwell time, 20 s transfer time. The thermocycled mean ± standard deviation of tensile bond strength values (MPa) were represented in box plot graph Fig. 1.

Testing the samples after short-term water storage (Table 2), there was a significant difference between air borne-particle abrasion and air borne-particle abrasion

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### Table 1

Samples classification according to surface treatments and storage plus stressing condition.

| Metal surface treatment (main group) | Storage condition and stressing (subgroup) |
|-------------------------------------|-------------------------------------------|
| Group (1)                            | (A1) After 24 h water storage (10 samples) |
| Air borne-particle abrasion          | (B1) After 24 h water storage and thermocycling plus mechanical loading (10 samples) |
| with 50 µm Al\(_2\)O\(_3\) particles\(^a\) |                                           |
| (20 samples)                        |                                           |
| Group (2)                            | (A2) After 24 h water storage (10 samples) |
| Air borne-particle abrasion          | (B2) After 24 h water storage and thermocycling plus mechanical loading (10 samples) |
| then treatment with alloy primer\(^b\) |                                           |
| (20 samples)                        |                                           |
| Group (3)                            | (A3) After 24 h water storage (10 samples) |
| Silicoating and silanization         | (B3) After 24 h water storage and thermocycling plus mechanical loading (10 samples) |
| (cojet system)\(^c\) (20 samples)    |                                           |

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\(^a\) Al\(_2\)O\(_3\) particles, Shera, Germany.
\(^b\) Kuraray, Sakazu, Japan.
\(^c\) 3M, ESPE, USA.

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plus alloy primer. Air borne-particle abrasion has significant higher bonding values than that of alloy primer.

Also there was a significant difference between air borne-particle abrasion and cojet system, copings treated with cojet system were found to have significantly higher bonding values than that treated with air borne-particle abrasion.

There was a significant difference between air borne-particle abrasion plus alloy primer and cojet system. Copings treated with cojet system have higher bonding values than that treated with air borne-particle abrasion plus alloy primer.

While testing the samples that after short-term water storage and thermocycling plus mechanical loading (Table 3), there was a significant difference between air borne-particle abrasion and air borne-particle abrasion plus alloy primer was recorded. Air borne-particle abrasion alone has significant higher bonding values than that with alloy primer.

Copings treated with cojet system showed non-significant higher bonding values than that treated with air borne particle abrasion.

There was a significant difference between air borne-particle abrasion plus alloy primer and cojet system. Copings treated with cojet system have higher bonding values than that treated with air borne-particle abrasion plus alloy primer.

4. Discussion

In the present study, there were many treatment procedures such as air borne particle abrasion, silicoating and metal primer application that were used to produce irregularities on the internal surface of the casting and abutment. These treatments include surface roughening to provide micromechanical retention, chemical bonding between the luting agent and titanium, or treatments that combine both a roughening and a chemical component.

After short-term water storage, Tribochemically silicoated samples using cojet system of this study recorded the highest bonding values. This could be as a result of two reasons. First, the surface roughness resulting from mechanical air abrading providing a larger surface area for micromechanical retention. Second, additional chemical bonding with the silica and silane application was reported to the existing mechanical retention by promoting chemical bond to resinous material through increasing the surface energy and improving the surface wettability to resin, thus improving the overall bond strength. These findings were in agreement with Atsu et al. [14].

The air borne particle abrasion promotes micromechanical retention. Silanes establish a chemical bond between the resin matrix and the metal surface due to their bifunctional characteristics. The non-hydrolyzable organic group contains carbon—carbon double bond which can polymerize with monomers of the resin-based materials. The hydrolyzable groups react with an inorganic hydroxyl-rich (—OH) surface such as silica-coated (SiO2) metal surfaces. This justifies the superiority of silane in the group abraded with Cojet Sand, observed in the present study. This is in agreement with the finding of previous investigation [15].

Some studies have shown evidence of the surface topography of the tribochemical cojet surface treated

| Table 2 | LSD test for short term water storage group. |
|---|---|
| Groups | Mean difference | Sig. |
| Air-borne particle abrasion | Air-borne particle abrasion plus alloy primer | 1.6996(*) | .000 |
| Cojet system | -1.4952(*) | .000 |
| Air-borne particle abrasion plus alloy primer | Air-borne particle abrasion | -1.6996(*) | .000 |
| Cojet system | -3.1922(*) | .000 |
| Cojet system | Air-borne particle abrasion | 1.4925(*) | .000 |
| Air-borne particle abrasion plus alloy primer | 3.1922(*) | .000 |

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abutment by demonstrating the stippled and crater like appearance characteristic of mechanical air abrading with the silica-modified Al₂O₃ particles of cojet surface treatment [16].

In the current study, the effect of air borne particle abrasion only was more significant to increase the retention of the metal copings than the effect of air borne particle abrasion plus alloy primer.

The bonding results obtained with aluminum oxide air abraded samples surface resulted in high bonding values and cohesive mode of failure, confirming the result obtained with Shakal and Bahannan [16,17].

The inferior tensile bond strength value of this study was recorded with air borne particle abrasion plus alloy primer surface treatment. This could be due to three reasons. First, using of a primer in this surface might have partially filled out the irregularities formed by air born particle abrasion, what would explain the highest variation in the group where it was applied. It should be emphasized that there were statistical significant differences [18]. Second, the provisional resin cement not containing MDP which is a phosphate ester monomer found in many resin cements, including Panavia F. It is a unique group that allows effective bonding to metal oxides. Kunt et al. noted that when air borne particle abrasion plus Panavia F alloy primer was used, increased bond strength was achieved between the abutment and crown. This is most likely due to the content of MDP in alloy primer, which apparently is as effective as the MDP contained in Panavia F. Third, alloy primer containing VBATDT and MDP to improve the bond strength. Titanium is a base metal, the surface of which is covered with a passive layer of metallic oxides. Experiments have shown that functional monomer in alloy primer VBATDT have affinity to noble metals but not to base metal [19].

Our results showed that short-term water storage and thermocycling plus mechanical loading caused a significant reduction in the bonding values.

Creating microgaps inviting the ingress of water at the interface layer with water storage, might interpret the drop of the bonding values and the change of the form of the bonding failure, supporting the findings and the conclusion of Shakal and Smith [16,20].

The change in mechanical properties after thermocycling could result in a tendency toward bond failure due to weakened resin tags, which exist between etched abutments, metal cope and resin [21].

Aluminum oxide air abraded sample surface resulted in high bonding values, confirming the result obtained with Chang et al. [22] who has recorded a considerable drop of the bonding after thermocycling.

Copings treated with cojet system showed the highest bond strength value obtained after short-term water storage and thermocycling plus mechanical loading.

Copings treated with cojet system showed non-significant higher retentive values than that treated with air born particle abrasion. These results agree with those of Fernandes et al. [23] who investigated the effect of thermocycling on bond strength, they found that thermocycling significantly decreased the bond strength in the groups studied. This negative effect of thermocycling is in accordance with most of the other studies. Accounting for all groups, thermocycling reduced the bond strength from 8.08 MPa to 6.29 MPa, a decrease of 22%. Individually, the cojet group was the most affected with decreases in bond strength of 44-46%.

The increased drop of bonding values and mixed mode of failure of tribochemically silicoated samples could be explained by the possibility of stress distribution within the thicker ceramic layer developed with cojet system causing its cracking upon testing together with the possibility of loose silica particles presence over the sample surface [16].

5. Conclusions

Within the limitations of this in vitro study, the following conclusions can be drawn:

1. The tensile bond strength was affected by the surface treatments applied to implant abutments and fitting surface of metal copings.

| Groups | Mean difference | Sig. |
|--------|----------------|------|
| Air-borne particle abrasion | 1.9293(*) | .002 |
| Cojet system | 0.6209 | .106 |
| Air-borne particle abrasion plus alloy primer | 1.9139(*) | .000 |
| Cojet system | 0.6209 | .106 |
| Air-borne particle abrasion plus alloy primer | 1.9139(*) | .000 |

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2 Cojet surface treatment and air borne particle abrasion recorded the superior results in this study.

3 The least effective group was the air borne particle abrasion plus alloy primer.

4 Short term water storage and thermocycling plus mechanical loading significantly decreased the bond strength regardless of the surface treatment used.

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