Original Article

Evaluation of Bond Strength between Grooved Titanium Alloy Implant Abutments and Provisional Veneering Materials after Surface Treatment of the Abutments: An *In vitro* Study

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Abstract:

Introduction: Titanium has become the material of choice with greater applications in dental implants. The success of the dental implant does not only depend on the integration of the implant to the bone but also on the function and longevity of the superstructure. The clinical condition that demands long-term interim prosthesis is challenging owing to the decreased bond between the abutment and the veneering material. Hence, various surface treatments are done on the abutments to increase the bond strength. **Aim:** This study aimed to evaluate the bond strength between the abutment and the provisional veneering materials by surface treatments such as acid etching, laser etching, and sand blasting of the abutment. **Materials and Methods:** Forty titanium alloy abutments of 3 mm diameter and 11 mm height were grouped into four groups with ten samples. Groups A, B, C, and D are untreated abutments, sand blasted with 110 µm aluminum particles, etched with 1% hydrofluoric acid and 30% nitric acid, and laser etched with Nd: YAG laser, respectively. Provisional crowns were fabricated with bis-acrylic resin and cemented with noneugenol temporary luting cement. The shear bond strength was measured in universal testing machine using modified Shell–Nielsen shear test after the cemented samples were stored in water at 25°C for 24 h. Load was applied at a constant cross head speed of 5 mm/min until a sudden decrease in resistance indicative of bond failure was observed. The corresponding force values were recorded, and statistical analysis was done using one-way ANOVA and Newman–Keuls *post hoc* test. **Results:** The laser-etched samples showed higher bond strength. **Conclusion:** Among the three surface treatments, laser etching showed the highest bond strength between titanium alloy implant abutment and provisional restorations. The sand-blasted surfaces demonstrated a significant difference in bond strength compared to laser-etched surfaces. The results of this study confirmed that a combination of surface treatments and bond agents enhances the bond strength.

Keywords: *Acid etching, laser etching, provisional restoration, sand blasting, shear bond strength*

Introduction

Adhesive dentistry has received a pioneer in 1955, Dr. Buonocore who brought in the technique of etching in the enamel with 85% phosphoric acid for 30 s.[1] Since then, the application of the technique of etching and bonding has become a debatable topic with continuous research and development. Parallelly, titanium has made a remarkable entry into dentistry with its superior properties and excellent biocompatibility. Progressively, titanium and its alloys have become the material of choice for dental implants. A successful dental implant not only relies on the implant itself but also on the prosthodontic superstructure and also its adhesion to the underlying implant abutments. Among the prosthodontic phase of implant therapy, the provisional restorative phase plays a key role in determining the success of the dental implant. The provisional restoration gives a sneak peek of the esthetics and function of the final restoration. Provisional restorations can be either screw- or cement-retained abutments. Screw-retained provisional abutments are preferred over cement-retained abutments for their flexibility, retrievability, and good soft-tissue responses.[2] When the clinical condition demands a long-term interim prosthesis, the most common problem encountered is the delamination of the veneering material. This may interfere with the treatment outcome, disturb the cellular biology around the implant with

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the entry of microorganism into the gap, and retard the osseointegration process. Various efforts have been taken in the past with manufacturers incorporating mechanical grooves in the abutment. The surface treatments such as airborne particle abrasion,[3] silica coating,[4] and acid etching of the abutment have been evaluated to prevent the delamination of the veneering material. With advancements in technology, the recent years have witnessed the use of laser beams in altering the microtopography.[5] Owing to its high chemical reactivity, titanium produces hard and brittle surface by the reaction of the molten metal with the investment material.[6] The Nd: YAG laser-treated cast titanium, on microstructural evaluation, exhibited improved mechanical properties.[7] New interim materials such as bis-acrylic resin composites and Urethane dimethacrylate are preferred recently over the conventional PMMA owing to its better handling properties, better mechanical properties, and predictable results.[8,9] The retention of the interim crown with the implant abutment by eugenol-free temporary cements was further enhanced by surface treatments of the abutments or the surface treatment of the tissue surface of the crown.

The objective of the present study is to evaluate bond strength between grooved titanium alloy implant abutments and provisional veneering materials after surface treatment of the abutments by sand blasting, laser etching, and acid etching. The bond strengths after various surface treatments were compared to choose the best surface treatment to achieve long-term retention of the prosthesis.

Materials and Methods

Forty titanium alloy (Ti-6Al-4V-Genesis implant, India) internal connection grooved implant abutments were used. The abutments were 3 mm in diameter and 11 mm in height above the platform. An hollow die of stainless steel (15 mm × 15 mm × 20 mm) was made. Dental stone was filled in the die after application of petroleum jelly in the die, and implant analogs of 4.7 mm width and 10 mm length are inserted into the dental stone and made sure that the threads were not exposed and all implant abutments were screwed on to the implants. These abutments are divided into four study groups on the basis of surface treatment where Group A: control group, Group B: sand blasting, Group C: acid etching, and Group D: laser etching (*n* = 10).

A custom grooving on the abutments to full length of tapered flat-end diamond bur (700-10P Mani dental diamond burs, Japan) along the long axis of the implant abutment 0.5 mm short from the finish line was done. The depth of the groove is kept to half the diameter of the bur using a high-speed hand piece at the speed of 1,50,000 Rpm.

In Group A, the surface of the abutment was cleansed with distilled water in ultrasonic cleaner (GTsonic, China) and used without any surface treatment as control group. In Group B, the surface of the abutment was cleansed with distilled water in ultrasonic cleaner and abraded with 110 microns aluminum oxide (Aluminox-delta, India) particles for 30 s with air pressure of 0.28 Mpa from a distance of 10 mm. In Group C, the surface of the abutment was cleansed with distilled water in ultrasonic cleaner and etched with 1% hydrofluoric acid and 30% nitric acid for 30 s. In Group D, the surface was cleansed with distilled water in ultrasonic cleaner and laser etching was done (Nd: YAG laser: 4.0J/cm and a pulse length of 3 μs – Fontona laser unit, USA) [Figure 1]. The surface-treated titanium implant abutment samples were examined under a scanning electron microscope (CARL ZEISS, Pvt., Ltd., UK, MODEL: EVP MA15) with a magnification of 300 μm for the surface topography [Figure 2].

A power analysis before the study showed that a minimum of nine specimens per group would determine statistical difference between groups (α = 0.05). Each abutment was screwed on to the implant analogs using the hex drive

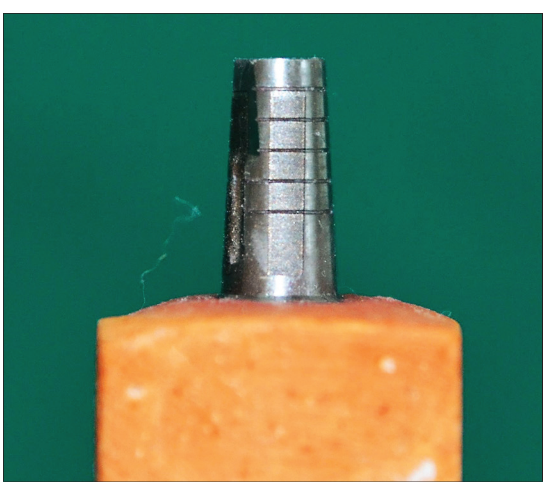


Figure 1: Laser-etched implant abutment

Figure 2: SEM image of laser-etched abutment

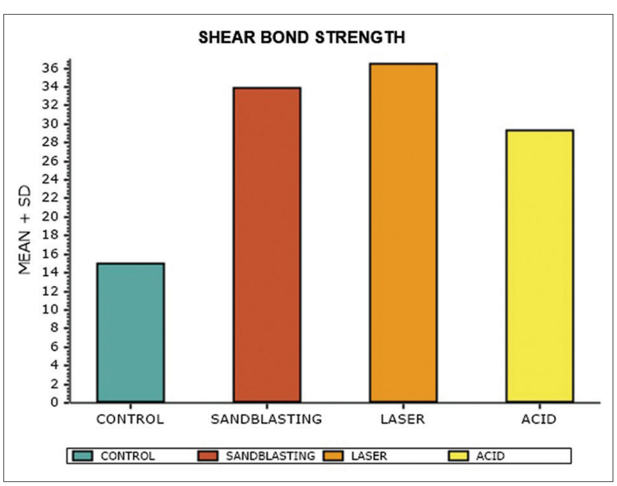
provided and cleaned with steam for 10 s and air-dried with a three-way syringe under a pressure of 30 psi. Impressions were made with polyvinyl siloxane (two stages with putty and light body - Photosil Soft Putty, India). Casts were made with die stone over which a die spacer was applied to get a cement thickness of 25-40 µm. Wax patterns were fabricated corresponding to the dimensions of maxillary first premolar as described in literature[10] using PKT instruments.

Acrylic crowns were fabricated using Protemp (3M ESPE, Germany). Once polymerization is completed, the acrylic crowns were cleaned. All specimens received minimal finishing removing excess veneering material; the specimens were inspected under SEM to ensure that that there is no visible flash, voids, or cracks. Then, a primer-bonding agent (3M ESPE, Germany) was applied to the surface of all the forty abutments. This agent was dispensed into a clean mixing well, and a clean nylon bristle brush was used to wet the surface of the treated implant abutments and they were dried for 5 min. During the entire treatment process, there should not be skin contact to avoid contamination.

After the surface treatment was completed, the assemblies of the implant abutments were mounted on to the implant analogs. The acrylic crowns were cemented to the implant abutments using provisional cement–eugenol-free zinc oxide cement (Provicol® Cement Voco, Germany). All specimens were stored in 25°C water for 24 h before testing and allowed to dry in room temperature.

The modified Shell–Nielsen shear test was performed in a universal testing machine (INSTRON® CORP 3382, USA). The specimens were loaded at a constant cross head speed of 5 mm/min. Force was applied in areas as close as possible to the interface between the implant abutments and veneering materials. The load was increased until the testing machine detected a sudden decrease in resistance, indicative of bond failure, and the values were recorded.

The obtained values of Group A, Group B, Group C, and Group D were compared statistically. Data were collected for each group and were analyzed using one-way analysis of variance (*ANOVA), with the value of statistical significance set at the 0.05 level, and a *post hoc* Student–Newman–Keuls test.



Graph 1: Graphical representation of the bond strength

Results

Table 1 shows the shear bond strength values obtained from each sample of Groups A, B, C, and D. These groups showed bond strength value that ranges from 13.93 MPa to 39.12 MPa. In Group A, minimum bond strength was 13.93 MPa and maximum bond strength was 16.49 MPa. In Group B, minimum bond strength was 33.01 MPa and maximum bond strength was 35.22 MPa. In Group C, minimum bond strength was 34.13 MPa and maximum bond strength was 39.12 MPa. In Group D, minimum bond strength was 26.34 MPa and maximum bond strength was 31.75 MPa.

Table 2 shows the mean bond strength of provisional veneering material to titanium implant abutments for Groups A, B, C, and D. Mean bond strength for Group A was 15.02 ± 0.93 MPa, Group B was 34.13 ± 0.96 MPa, Group C was 36.49 ± 1.41 MPa, and Group D was 29.36 ± 1.72 MPa.

Table 1: Basic data of shear bond strength values obtained for each sample in Groups A, B, C, and D

Samples	Group A	Group B	Group C	Group D
1	15.21	34.21	37.54	31.69
2	14.08	35.01	35.12	29.26
3	16.49	33.17	36.12	28.75
4	15.19	34.01	36.19	29.42
5	14.08	34.17	37.36	28.10
6	14.17	33.01	39.12	31.04
7	13.93	33.02	34.13	28.06
8	16.05	35.22	37.45	29.26
9	15.93	34.40	36.20	31.75
10	15.12	34.10	35.67	26.34

Table 2: Mean bond strength values between various groups

Source of variance	Sum of squares	Mean sum of squares	*F* ratio	*P*
Between group	2755.084	918.367	542.147	0.000
Within groups	60.982	1.694		
Total	2816.066			

Table 3: Statistical analysis (one-way analysis of variance) of shear bond strength values of Groups A, B, C, and D

Groups	Mean (MPa)±SD	Minimum	Maximum
Group A	15.0250±0.931	13.93	16.49
Group B	33.9320±0.960	33.01	35.22
Group C	36.4900±1.419	34.13	39.12
Group D	29.3670±1.724	26.34	31.75
Total	28.70350±8.29922	13.93	39.12

SD: Standard deviation

Table 3 shows the values after statistical analysis of shear bond strength of provisional material to titanium alloy within the groups and between various groups. Using the one-way analysis of variance (ANOVA), $P < 0.000$ was determined which showed significant difference in *post hoc* Newman–Keuls test. The statistical analysis showed significant difference between the Groups A, B, C, and D. All groups were statistically significant to other groups.

Graph 1 shows the bar diagram of the values obtained for shear bond strength of provisional material bonding to titanium implant abutments using various surface treatments. Group C shows greater bond strength when compared to other groups [Graph 1].

Discussion

Provisional restorations are an integral part of implant therapy. They improve the esthetics and function of the patient until osseointegration is complete. An optimum interim restoration must satisfy interrelated biologic, mechanical, and esthetic factors, including fracture resistance, color stability, wear resistance, tissue compatibility, ease of manipulation, and cost. The provisional restoration can be the most important diagnostic tool for the restorative dentist. It is a key factor in communication, tissue management, and patient management before finalizing the prosthodontic treatment.

A long-term interim prosthesis always has the risk of fracture and de-bonding. This type of complication can result in patient dissatisfaction, additional chair time for repair, entry of microorganisms into the gap, tissue irritation, and disruption of the osseointegration process. To avoid such complications, it is often necessary to improve the bond between the abutment and the provisional restoration.

Since permanent luting agents are contraindicated in cementing an interim restoration, research is underway to improve the mechanical retention between the abutment and the restoration. Numerous studies have already been done on the surface treatment of implant to improve the osseointegration process. Similarly, surface modifications of the abutments can also be done to improve the bonding between the abutment and the interim prosthesis.

On analyzing the results of the study, the laser-etched implant abutment with Nd: YAG showed higher bond strength with the veneering material. Sand blasting has also showed comparable bond strength with laser etching. All groups showed >28 Mpa of mean bonding force except for the untreated abutments that showed 15.02 Mpa. Scanning electron micrograph shows the surface roughness after various surface treatments. The mechanical retention can be enhanced by altering the bonding surface and increasing the surface energy. This could be achieved by sand blasting, acid etching, and laser etching. The alteration in the surface roughness will alter the surface chemistry and phase composition.[11] In contrast to the previous studies by Wei *et al*.[12] that showed decrease in the bond strength between the implant abutments and provisional veneering materials after airborne particle abrasion and silica coating, this study showed a significant increase in bond strength after air abrasion with 110 μm alumina particle with the mean bond strength value of 33.93 Mpa. Mean shear bond strength of laser-etched abutment (36.49 Mpa) was significantly higher than acid-etched surface (29.36 Mpa) ($P = 0.00$) on statistical analysis by one-way ANOVA. The scenario differs in the enamel of the natural tooth. Studies by Insua *et al*. show that adhesion of brackets to dental hard tissues after Er: YAG laser etching was inferior to that of the conventional acid etching.[13] Gadelmawla explained that the surface characteristics of the material vary with the manufacturing and the application process. He explained the surface roughness parameters with 59 formulas.[14] Sand-blasted titanium surfaces are anisotropic consisting of craters and ridges with microroughness of 0.5–2 μm.[15] In this study, sand-blasted titanium abutments exhibited a mean difference of 18.907 compared to the untreated implant by *post hoc* Newman–Keuls test. The bond strength of laser-etched samples showed a mean difference of 21.46 with untreated abutments and a mean difference of 2.55 with the sand-blasted abutments with statistical significance set at $P = 0.000$. Comparison of the bond strength between the four surface treatment methods showed that laser etching produced higher bond strengths between the abutment and the veneering material followed by air abrasion with alumina.

This was an *in vitro* study, hence the masticatory forces could not be mimicked in the testing machine. In the universal testing machine, the load increases progressively until the resistance to the force is lost, whereas the masticatory loads are cyclic and the bond strength should be evaluated after cyclic fatigue. Apart from the bonding by the luting cement between the treated abutments and veneering materials, the presence of saliva in the oral cavity may influence the properties of the cement and alter the bonding which is not evaluated in the current study.

Conclusion

Among the three surface treatments, laser etching showed the highest bond strength between titanium alloy implant abutment and provisional restorations. The sand-blasted surfaces demonstrated significant difference in bond strength compared to laser-etched surfaces. The results of this study confirmed that combination of surface treatments and bond agents has the potential to enhance bond strength between the provisional restorations and titanium alloy implant abutment.

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Conflicts of interest

There are no conflicts of interest.

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