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Surface Treatment and Resin Cement Effect on Ni-Cr Metal to Shear Bond Strength of Adhesive Bridge

[1] Sumitro [2] Haslinda Z. Tamin, [3] M. Indra Nasution, [4]Ricca Chairunnisa

[1]Resident, Departement of Prosthodontics, Faculty of Dentistry, Universitas Sumatera Utara, Medan, Indonesia
[2]Professor, Departement of Prosthodontics, Faculty of Dentistry, Universitas Sumatera Utara, Medan, Indonesia
[3]Lecturer, Faculty of Engineering, Universitas Sumatera Utara, Medan, Indonesia
[4]Lecturer, Departement of Prosthodontics, Faculty of Dentistry, Universitas Sumatera Utara, Medan, Indonesia

Abstract

Adhesive bridge or resin-bonded fixed denture has been known for more than 40 years. Bonding resistance of this type of denture relies heavily on the adhesion of the resin cement to both metal surface and tooth. Adhesive bridge consists of a pontic anchored to the supporting tooth using a metallic metal wing retainer. Disadvantages of adhesive bridge is lack of success rate of adhesive bridge. Mainfactor failure of adhesive bridge is debonding or denture removal due tomastication force. Factors that can affect bond strength of adhesive bridge are surface treatment of the metal wing retainer and type of resin cement used. This study aimed to determine the effect of surface treatment and resin cement on the shear bond strength of adhesive bridge. This type of research is an experimental laboratory. Thirty samples were made of cylindrical metal samples with a diameter of 5mm and a height of 3mm at UJI dental laboratory Faculty of Dentistry University Sumatera Utara. This metal sample further categorized according to three surface treatment groups used which is sandblast, metal primer, andcombination of sandblasting with metal primer. Subsequently, each group was further divided into two groups based on the resin cement used, particularly total-etch resin cement and self-adhesive resin cement. Value measurement of shear bond strength was performed using a universal testing machine. Differences in the effect of surface treatment and resin cement were analyzed using two-way ANOVA test and the T-test. Results show the effect of surface treatment and resin cement on the shear bond strength. Highest average value of shear bond strength was in combination of surface treatment sandblasting and metal primergroup with self-adhesive resin cement (37.56 $\pm$ 3.36 MPa). Usage of combination of surface treatment sandblasting and metal primer with self-adhesive resin cement is recommended as an option for cementation procedures to achieve long-term success in using adhesive bridge.

Keywords: Surface Treatment, Resin cement, Shear Bond Strength, Failure Type, Adhesive Bridge.

Introduction

Adhesive bridges or resin-bonded fixed partial dentures have been known for more than 40 years. Bonding resistance of this denture relies heavily on adhesion of resin cement to both the tooth and metal surface. Adhesive bridge consists of a pontic anchored to the supporting tooth using a metallic wing retainer made of metal1,2,3. Adhesive bridge provides the advantage of requiring only minimal preparation and can maintain a more healthy tooth structure than conventional bridges, and requires minimal clinical time.2,3This is consistent with the philosophy of prosthodontic treatment, which is "not only to replace what is lost but also to maintain what is still available."

An adhesive bridge indicated in cases where the supporting teeth are in good health, without caries and restorations, and there is sufficient enamel for adhesion procedures, fixed retainers after orthodontic procedures, tooth splinting, and in cases where the patient is frightened of anesthetic needles. Adhesive bridge is contraindicated in cases where the abutment teeth do not have adequate enamel for adhesion, and the abutments are small or peg-shaped, the abutments suffer from malposition and mobility, and in patients who are allergic to metals.3Material often used for adhesive bridge restoration is porcelain fused to metal. Porcelain fused to metal restorations combine the strength and accuracy of cast metal with aesthetics of porcelain. Nickel-chromium metal (Ni-Cr) is commonly used in adhesive bridges. The advantages of nickelmetal, when combined with chromium, will form metal with high corrosion resistance.4

Success rate of adhesive bridge reaches 87.7%5,6within five years. Other studies have stated that the success rate of adhesive bridges reaches 83.6% in five years.7Another study in 2015, from 771 adhesive bridges the estimated success rate is 80.4% at ten years, and most adhesive bridge failures occurred within the first four years. The main cause of failure of adhesive bridge is debonding or adhesive failure.8Another retrospective study on 221 adhesive bridges also found that debonding was the main cause of adhesive bridge failure.9

One way to increase bond strength between restoration and cement is to perform surface treatment on the inside of the restoration. Surface treatment is a treatment process applied to change the properties or characteristics of the metal on the metal surface. Some surface treatments that can be done on metal surfaces to adhere well to cement are macro mechanical surface treatment, micromechanical surface treatment, and chemical surface treatment. Various surface treatment on metals, such as chemical etch or electrical etch, air particle abrasion (sandblasting), metal primer, tin plating, and silica coating, have been studied and are intended to increase the bond strength of restorations with cement.10The most often surface treatment used in dentistry is sandblasting. Sandblasting is a process of cleaning the surface by firing sand particles into the surface of the material causing friction or collision with the aim of cleaning and removing contamination on material to create a profile (roughness) on the metal surface and increase the surface area, resulting in a higher shear bond strength due to micromechanical retention.11Sandblasting with Al2O3 particles is the most commonly used method for obtaining micromechanical retention. These particles have different sizes. Preparation with Al2O3 particles of 50µm size produces the highest shear bond strength with Ni-Cr metal.12

Metal primer is used to obtain a strong adhesion between metal and resin-based materials. Metal primer containing 10-methacryloyloxydecryl dihydrogen phosphate (10-MDP) reacts chemically with the oxide layer on the metal surface and increases bond strength between the resin cement and metal. Fundamental factor to consider is the composition of the oxide layer on metal surface, which will produce a chemical reaction with the monomer.13Chemical reaction between MDP monomer and oxide on metal surface that has been sandblasted will produce a solid and durable bond between resin and rough surface of the metal material. Dihydrogen phosphate in MDP monomer has a high potential to react with aluminum oxide in materials that have been sandblasted. Methacryloyloxydecryl functions to polymerize MDP monomer on metal primer with matrix monomer in resin cement. This adhesion reaction will prevent water penetration into the resin cement structure, reducing the degree of hydrolysis.14

Adhesion between adhesive bridge and the teeth originates from attachment of the teeth with resin cement and attachment between resin cement and metal on adhesive bridge wing retainer. Most common adhesion failure is the adhesion failure between resin cement and Ni-Cr metal. The choice of resin cement type will affect the adhesion strength between the resin cement and the metal, thereby would affecting success of adhesive bridge restoration. Another factor that can affect adhesion strength is surface treatment. One of the most common surface treatment methods is sandblasting and usage of metal primers to increase bond strength between resin cement and metal. Attachment of adhesive bridge to tooth is on the retainer wing on the buccal and lingual parts of the supporting teeth. Occlusion load force will push adhesivebridge from the occlusal direction resulting in adhesion failure. This chewing pressure will be parallel to adhesion of the adhesive bridge. Shear bond strength test can simulate the pressure of occlusion force parallel to adhesion of the adhesive bridge. The purpose of this study was to evaluate the effect of surface treatment and resin cement on ni-cr metal toshear bond strength of adhesive bridge.

Materials and Methods

Compositions of resin cement and metal alloys used are summarized in Table 1.

Table 1. Resin Cement Composition and Metal Alloy Used

Material	**Composition**	**Manufacturer**
Total etch resin cement (e-cement)	Base : Yttrium fluoride (10-20%) Bisphenol A Diglycidylmethacrylate (10-30%) Urethane Dimethacrylate (10-30%) Yterbium Oxide-Silica (1-5%) Tetrahydrofurfuryl Methacrylate (1-5%) Trimethylolpropane Trimethacrylate (1-5%) Catalyst : Bisphenol A Diglycidylmethacrylate (10-30%) Dibenzoyl Peroxide (<1%)	Bisco, USA
Self adhesive resin cement (Duo-Link Universal)	Base : Yttrium fluoride (10-20%) Bisphenol A Diglycidylmethacrylate (10-30%) Urethane Dimethacrylate (10-30%) Yterbium Oxide-Silica (1-5%) Tetrahydrofurfuryl Methacrylate (1-5%) Trimethylolpropane Trimethacrylate (1-5%) 3-(Trimethoxysilyl)propyl-2-methyl-2-Propenoic Acid (<2%) Catalyst :	Bisco, USA

	Bisphenol A Diglycidylmethacrylate (10-30%) Dibenzoyl Peroxide (<1%)	
Metal Primer (Z-Prime Plus)	Ethanol (75-85%) BisGMA (5-10%) 2-hydroxyethyl Methacrylate (5-10%) 10-Methacryloyloxydecyl Dihidrogen Phosphate (1-5%)	Bisco, USA
Ni-Cr Alloy (Kera N)	Ni 61,27%; Cr 26,44%; Mo 10,46%; Mn 0,001% dan C 0,02%	Eissenbacher Dentalwarren GmbH (Germany)

Sample of Ni-Cr metal cylindrical measuring 5mm in diameter with a thickness of 3mm following specification of ANSI/ADA no. 96 and ISO 9917-2: 201715,16as much as 30 samples (Figure 1). The sample was then planted into a square acrylic block measuring 20mm x 20mm x 20mm. The metal surface was made level with the acrylic surface (Figure 2).

The samples were then randomly selected and grouped into three based prior to surface treatment to be performed. Ten samples were given sandblasting surface treatment, ten samples were treated with the metal primer surface treatment, and ten samples were given combination of sandblasting and metal primer surface treatment. The sandblasting surface treatment was carried out using Al2O3 particles with a size of 50µm from a distance of 10mm for 20 seconds with pressure of 35psi, then cleaned by ultrasonic cleaning using distilled water for 10 minutes and then dried with air spray. Samples treated with metal primer were carried out by covering the metal primer on the surface of the sample using a micro brush, then after 15 seconds was dried with air spray. For the sample group treated with a combination of sandblasting and metal primer, this group was treated with a combination of both.

Samples from each of the above treatment groups were then divided into two groups prior to type of resin cement used. The first group used total-etch resin cement and the second group used self-adhesive resin cement. Both types of resin cement were mixed using an automix syringe. During the cementation procedure, the sample was given a pressure of 0.5kg for 10 minutes to ensure a uniform thickness of cement. The excess cement was then cleaned, and an oxygen barrier was applied then cured using a light cure LED for 20 seconds at a distance of 2mm from the sample surface. Subsequently, the sample was stored for 24 hours in an incubator at 37oC.

Measurement of shear bond strength was performed using Universal Testing Machine (Tokyo Testing Machine MFG Co., Ltd., Japan) at the Material Strength Laboratory, Faculty of Mechanical Engineering, University Sumatera Utara (USU). Measurement of the shear bond strength was carried out with crosshair speed of0.2 mm/minute. The measurement results of shear bond strength value were digitally recorded and graphed in Newton (N) units. Results of this data were then divided by surface area of the metal (mm2) to produce Mega Pascal units (MPa). These results were immediately recorded in testing computer (Figure 3). The results of the force received by each sample can be seen on the indicator and were recorded. The results of the data obtained were then analyzed with two way ANOVA test to examine the effect of sandblasting surface treatment, metal primer, and a combination of sandblasting and metal primer with total-etch resin cement and self-adhesive on ni-cr metal on the shear bond strength, and advanced with T-test.

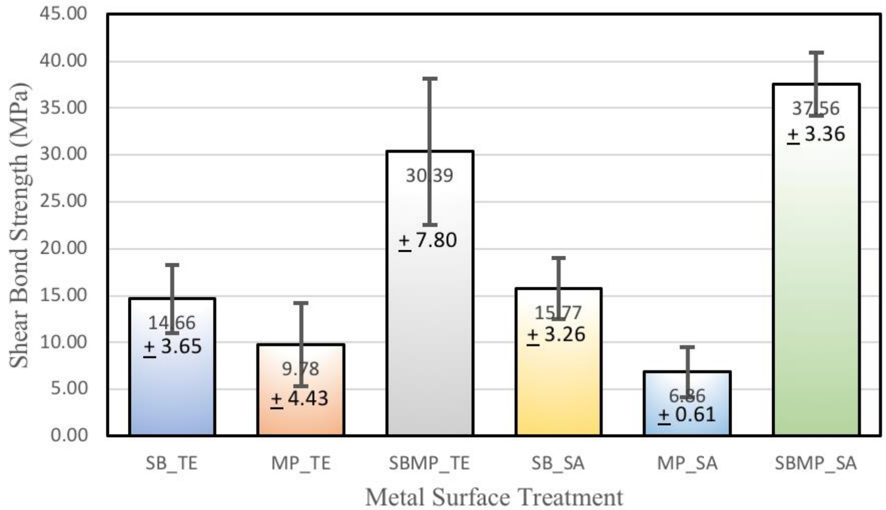
Result

Measurement of shear bond strength of six groups above was performed using UTM, and the results were recorded on a computer. In sandblasting surface treatment group with total-etch resin cement, the smallest shear bond strength value was 11.55 MPa, and highest was 20.55 MPa. In the metal primer surface treatment group with total-etch resin cement, the smallest shear bond strength value was 4.43 MPa, and highest was 15.53 MPa. In combination of sandblasting and metal primer surface treatment group with total-etch resin cement, the smallest shear bond strength value was 19.90 MPa, and highest was 36.76 MPa. In sandblasting surface treatment group with self-adhesive resin cement, smallest shear bond strength was 10.78 MPa, and highest was 18.93 MPa. In metal primer surface treatment group with self-adhesive resin cement, the smallest shear bond strength was 6.33 MPa, and highest was 7.61 MPa. Whereas in the surface treatment group combination of sandblasting and metal primer with self-adhesive resin cement, the smallest shear bond strength was 33.95 MPa, and the highest was 40.65 MPa (Table 2). The smallest mean and standard deviation values for each group were found in the metal primer + self-adhesive group with a value of 6.86 + 0.61 MPa. Highest mean and standard deviation values were found in the sandblasting and metal primer + self-adhesive groups with a value of 37.56 + 3.36 MPa (Graph 1).

Table 2. Mean shear bond strength according to surface treatment and resin cement used.

Surface Treatment	**Resin Cement**	**Mean + SD (MPa)**	**p Value**
Sandblast (SB)	Total etch (TE)	14,66+3,65	0,794
	Self Adhesive (SA)	15,77+3,26	
Metal Primer (MP)	Total etch (TE)	9,78+4,43	0,011
	Self Adhesive (SA)	6,86+0,61	
Sandblast + Metal Primer (SBMP)	Total etch (TE)	30,39+7,80	0,010
	Self Adhesive (SA)	37,56+3,36	

Graph 1. Mean Shear bond Strength According to Surface Treatment and Resin Cement Used



The measurement results of shear bond strength are shown in Table 1. The greatest average value of shear bond strength using total-etch resin cement was the combination of surface treatments and blasting and metal primer group, both in the group with total-etch resin cement or self-adhesive. In T-test to determine the effect of total-etch resin cement and self-adhesive resin cement with surface treatment sandblasting on Ni-Cr metal on the shear bond strength of adhesive bridge, the value of p = 0.794 (p> 0.05) was obtained. There was no effect of the resin cement type with sandblasting surface treatment on the shear bond strength of adhesive bridge. T-test results of effect of total-etch resin cement and self-adhesive resin cement with surface treatment of metal primer on Ni-Cr metal on shear bond strength of adhesive bridge obtained a value of p = 0.011 (p <0.005); thus, it can be concluded that there was effect of total-etch resin cement and self-adhesive resin cement with metal primer surface treatment on Ni-Cr metal against the shear bond strength of adhesive bridge. The t-test to determine the effect of total-etch resin cement and self-adhesive resin cement with a combination of sandblasting surface treatment and metal primer on Ni-Cr metal on the shear bond strength of adhesive bridge obtained a value of p = 0.010 (p <0.005) (Table 4.8); thus it can be concluded that there was an effect of total-etch resin cement and self-adhesive resin cement with a combination of sandblasting surface treatment and metal primer on Ni-Cr metal on the shear bond strength of adhesive bridge.

Discussion

Adhesive bridge is a denture with minimal preparation. The main success criterion of an adhesive bridge is a solid and permanent bond between the tooth surface and the metal surface. One of the factors causing the most failure of adhesive bridge is the failure of adhesive bridge attachment between metal and resin cement. According to ADA specification no. 15, the minimum shear bond strength between resin cement and Ni-Cr metal is 3 MPa.15 According to ISO Specification 10477, the minimum shear bond strength between resin cement and metal is 5 MPa. The choice of combination of ni-cr metal surface treatment with available resin cement to obtain the best shear bond strength is the main factor of this study.

Sandblasting surface treatment aims to form surface roughness, remove contamination and increase surface area and provide micromechanical retention with resin cement. Sandblasting surface treatment will cause the metal surface to become rough, clean residual contamination, and facilitate mechanical bonding for adhesive material, thereby increasing the bond strength with resin cement. This sandblasting process will produce microporosity on the metal surface; therefore, the resin cement will be able to flow into microporosity created by this sandblast process and produce micromechanical retention. The existence of surface roughness due to this microporosity will increase the metals surface area, which will also increase the adhesion surface area between the resin cement and Ni-Cr metal. Surface treatment of sandblasts using Al_2O_3 particles with a size of 50μm will produce the highest shear bond strength of Ni-Cr metal.12

Metal primer surface treatment shows the lowest shear bond strength, both on total-etch resin cement or self-adhesive resin cement. This group only relies on chemical bonding between the metal and resin cement. Metal surfaces that are not treated with a surface treatment to roughen or form an oxide layer on the metal surface will not provide sufficient adhesion strength.13 From this study, it can be observed that the sole use of metal primer without the support of other surface treatments will cause a much lower shear bond strength compared to the group given the sandblasting surface treatment or a combination of sandblasting and metal primer surface treatment.

In the surface treatment group, the combination of sandblasting and metal primer shows the highest shear bond strength;this is consistent with research by Tenggara.15 This is because MDP monomer will bond chemically with aluminum oxide molecules trapped in the rough metal surface after sandblasting surface treatment, thereby significantly increasing the shear bond strength. The chemical reaction between dihydrogen phosphate ($H_2(PO_4)_3$) on MDP and aluminum oxide (AL_2O_3) will produce aluminum phosphate $Al_2(PO_4)_3$ and water (H_2O). Based on the results of the ANOVA test, the sandblasting surface treatment and metal primer group were significantly different from the other surface treatment groups.17

The resin cement used in this study was a dual-cure total-etch resin cement (E-Cement, Bisco, USA). Several studies have recorded the relatively high adhesion strength of the use of this resin cement.18 The choice of this resin cement was due to the ease of obtaining this resin cement compared to other available total-etch resin cement, while the self-adhesive resin cement used was Duo Link Universal (Bisco, USA), which came from the same brand as the total-etch resin cement used. These two types of cement have the same primary content, particularly Bisphenol A Diglycidylmethacrylate (Bis-GMA) and Urethane Dimethacrylate (UDMA). Bis-GMA plays a vital role in reducing volumetric shrinkage, increasing the reactivity of composites, and increasing the conversion rate to some extent. Some of the important characteristics of Bis-GMA include small polymerization shrinkage, high fatigue resistance, high fracture resistance, resistance to pressure, low heat conduction coefficient, and aesthetics.19,20 Bis-GMA will bond chemically with the Ni-Cr metal oxide. Test results on the sandblasting surface treatment using total-etch resin cement and self-adhesive resin cement do not significantly affect ($p = 0.794$) because the two resin cement contain almost the same material. Surface treatment group using solely metal primer shows a significant effect between use of total-etch resin cement and self-adhesive ($p = 0.011$). However, the test results show that the numbers are considerably low compared to the use of other surface treatments. The use of combination of surface treatments and blasting and metal primer shows a significant difference ($p = 0.010$).

Research by Hattar states that adhesive ability in self-adhesive resin cement to bind with metal is due to phosphoric and carboxylic functional groups. This monomer causes adhesion of self-adhesive resin cement to the metal surface. This combination of surface treatments and blasting and metal primer produces highest shear bond strength in both groups of resin cement. The results of this study are the same as the research by Tenggara S15because the resin cement will bind to the metal by micromechanical and chemical retention. Usage of metal primers containing 10-MDP monomer will increase the shear bond strength between resin cement and Ni-Cr metal. According to Fonseca et al.13, MDP monomer also promotes polymerization of primers and monomer matrices in resin cement. Dihydrogen phosphate monomer is acidic. This acidic property will bind to the oxide layer that is created on the metal surface. The acidic nature of this dihydrogen phosphate will react with the alkaline properties of the metal oxide layer to cause an acid-base reaction between aluminum oxide and dihydrogen phosphate to produce aluminum phosphate and water. The chemical reaction is as follows Al2O3 + 3H2PO4 = Al2(PO4)3 + 3H2O. This dihydrogen phosphate molecule will promote the adhesion between the resin cement and the metal surface, the decyl group will prevent water from entering the bond between the metal and resin cement, and this decyl group will reduce or prevent hydrolysis. Therefore, it does not decrease shear bond strength. Self-adhesive resin cement will alter the acidity level from pH 2.1-2.3 to a lower acidity level of pH 5.6-6.0.21

Resistance to shear bond strength in clinical conditions ranges from 10-13 MPa.20 From this research, it can be observed that usage of sand blasting and metal primer surface treatment combination can increase shear bond strength, choosing the right type of resin cement can also significantly increase shear bond strength. Further research with thermocycling is needed to determine the durability of the use of surface treatment and resin cement.

Conclusion

Usage of sandblasting and metal primer surface treatment combination will increase the shear bond strength by more than 100 percent compared to the sole use of sandblasting surface treatment. Self-adhesive resin cement will also increase the shear bond strength by 10-20 percent compared to total-etch resin cement. The combination of surface treatments and blasting and metal primer with self-adhesive resin cement contributes the greatest shear bond strength value in the test results. From the statistical results, it was also discovered that there was a significant difference between total-etch resin cement and self-adhesive. Using this self-adhesive resin cement when used in conjunction with sandblasting surface treatment and metal primers on Ni-Cr metal can be recommended for clinical applications.

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Figure List

Figure 1 1. Metal Cylindrical Sample

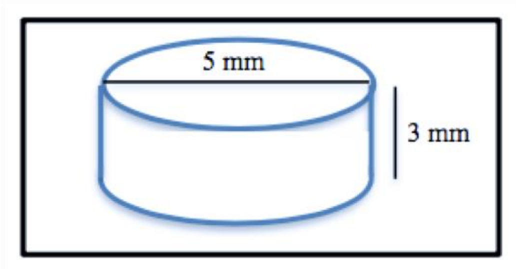

Figure 2. Metal Cylindrical Sample Planted into a Square Acrylic Block Measuring 20mm x 20mm x 20mm

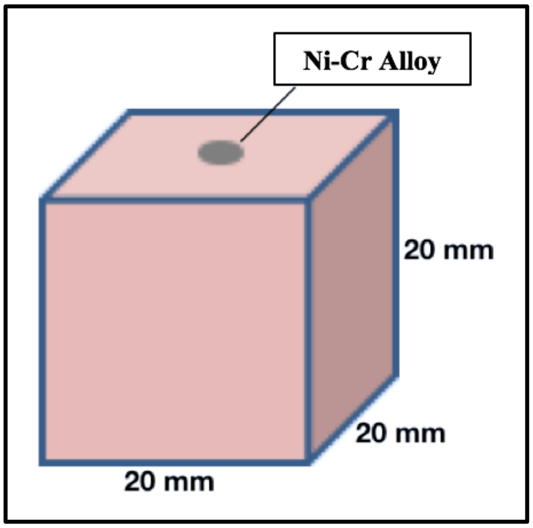

Figure 3. Sample Testing Method