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THE EFFECT OF PARTICLE SIZE OF AL_2O_3 ON THE BOND STRENGTH OF DENTAL METAL-CERAMIC JOINTS

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ABSTRACT

Background: Modern dentistry has led to the development of metal-free restorations (all ceramic restoration). But, metal ceramic restorations are still used widely since these restorations have good clinical performance and low cost. Many studies have been done to overcome on the failure of ceramic debonding. **Objective:** To evaluate the effect of particle size of Al_2O_3 on the bonding strength of dental ceramic to the metal framework. **Material and method:** Twenty metal samples made by lost wax technique with dimensions (25 x 3 x 0.5 mm), casting from Nickel-Chromium alloy. The metal samples sand blasting with aluminium oxide , two size of sand particle size are used , group A1 sand blasted with 125 µm Al_2O_3; group A2 sand blasted with 250 µm Al_2O_3. Ten samples for each group. Then the metal samples veneered with feld- spathic ceramic layer (8 x 3 x 1.1 mm). The metal-ceramic samples subjected to three points flexural test to evaluate the bonding strength for each sample. T-test was used in statistical analysis of this study. **Results:** the highest bond strength was recorded with used of 250 µm Al_2O_3. According to the T-test there is a significant different between group A1 and A2.

KEYWORDS: Bond strength, Metal-ceramic, Sand blast, Aluminium oxide Al_2O_3.

1. INTRODUCTION

In the last decades, the oral aesthetics becomes an essential factor in dentistry and beauty therapy developments[1]. Dental restoration is done by covering dental alloys by a specific type of a dental ceramic.[2] However, this requires verifying some physical and chemical requirements to achieve the optimum bonding for this dissimilar coupling. Bonding occurs between metal surface and ceramics layer due to chemical and mechanical mechanisms.[3]

The mechanical bonding strength is highly related on the metal surface roughness and topography. On the other hand, the chemical bonding depends on the oxide layer formation on the metallic alloy surface and consequently layer formation of elemental composition between metal and ceramic.[4]

Sand blast technique is frequently applied in dental alloys working element surfaces to achieve the appropriate treatment, enhancement as well as cleaning as the essential processes for facing with ceramic.[5] Sandblast technique for a surface may cause higher surface energy allowing higher surface wetting of metal during ceramic application. Many researchers suggest surface roughness can also provide mechanical locking and increase the surface area for porcelain-metal bonding through achieving various hooks (spots of uneven surface.)[6]

Several studies have found airborne-abrasion using alumina particles to be one of the most appropriate surface pre-treatment methods. Alumina particles are known to increase the roughness of the surface, to clean the restoration surface, and to remove organic contaminants, which helps to increase the surface activity.[7]

In implant technology, sandblasting with alumina grains is also used for surface roughening in combination with acid-etching to enhance osseointegration.[8]

This study is devoted to verify the optimum alumina particle size in sand blast technique that results the best bonding between dental ceramics and nickel chromium alloys.

Tolga Kulunk et al. 2011 used different air abrasion sand particles sizes of 110 µm and 60-80 µm and 30-50 µm of synthetic diamond. They found the highest bonding strength when 110 µm particle size is used.[3]

Krzyszt of. P et al. 2014 used different grain size of sand and different blasting angles, with constant basting pressure on cobalt-chromium samples veneered with inline porcelain. The strength test shows that the best effects were achieved for samples subjected to abrasive blasting material with 110 µm. there is no statistically significant in shear strength with difference blasting angles.[5]

Kavan A. Patel et al 2015, Used Al_2O_3 sandblasted with different grain size Al_2O_3 (50, 110 and 250 µm) in sand blasting of 40 Ni-Cr specimens, The Ni-Cr samples veneered with feldspathic ceramic layer. They used universal testing machine to evaluate the bonding strength between ceramic and metal frame. They were conclude, the greater particle size demonstrate higher bond strength.[9]

2. MATERIALS AND METHODS

2.1 Materials

Nickle-chromium alloy (Kera, NH, Germany) and feldspathic ceramic (Vita, VMK Master, Germany) were used in producing the dental metal-ceramic joints. Table 1 illustrates the chemical composition of the used materials. The samples were prepared in dimensions of (25 x 3 x 0.5 mm) for the metal alloy samples and (8 x 3 x 1.1 mm) for the veneered ceramic.

Chemical composition of Ni-Cr alloy				
Ni %	Cr %	Mo %	Si %	Others %
58	27.3	12.8	1.7	< 0.1

Table 2: Composition of Dental Ceramics.[10]

Ingredient	Functions
Feldspar (naturally occurring minerals composed of potash [K_2O], soda [Na_2O], alumina and silica).	It is the lowest fusing component, which melts first and flows during firing, initiating these components into a solid mass.
Silica (Quartz)	•Strengthens the fired porcelain restoration. • Remains unchanged at the temperature normally used in firing porcelain and thus contribute stability to the mass during heating by providing framework for the other ingredients.
Kaolin ($Al_2O_3.2SiO_2.2H_2O$ - Hydrated aluminosilicates)	• Used as a binder. • Increases moldability of the unfired porcelain. • Imparts opacity to the finished porcelain product.
Glass modifiers, e.g. K, Na, or Ca oxides or basic oxides	They interrupt the integrity of silica network and acts as flux.
Color pigments or frits, e.g. Fe/Ni oxide, Cu oxide, MgO, TiO_2, and Co oxide.	To provide appropriate shade to the restoration.
Zr/Ce/Sn oxides, and Uranium oxide	To develop the appropriate opacity.

This study based on twenty metal ceramic samples. Firstly the metal sample prepared by conventional lost wax technique.

Samples Preparation

The prepared metal-ceramic samples for the three points flexure test. Twenty rectangular metal samples of (25 x 3 x 0.5 mm) dimensions were veneered with ceramic layer of (8 x 3 x 1.1 mm) dimensions. Figure (1).

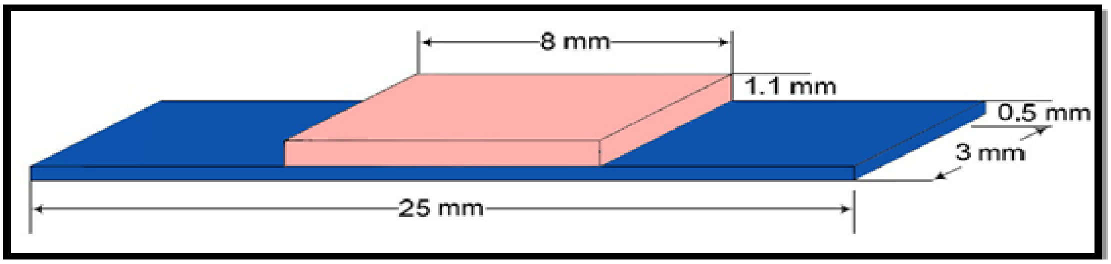


Figure (1): The prepared metal-ceramic sample dimensions.

Waxing

Twenty wax rectangular strips (25 x 3 x 0.5 mm) according to the International Organization for Standardization ISO-9693:1999 specification.[17] were cut from raw green sheet wax using a sharp knife with the aim of a ruler to produce straight edges for wax pattern[11] as seen in Figure (2). Then the wax samples spruing, investing and casting by conventional method.

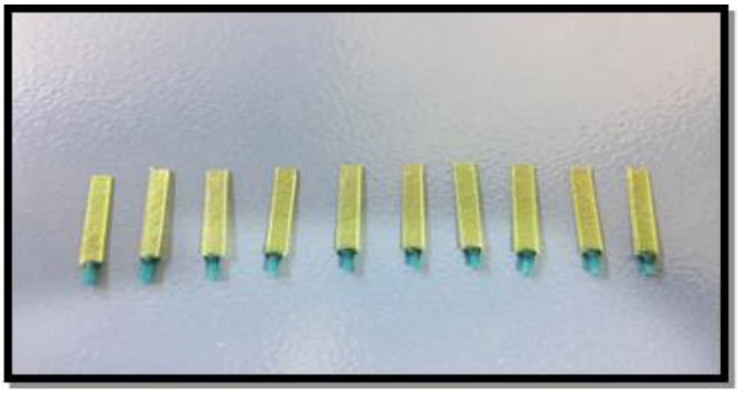


Figure (2): Wax Samples Preparation.

Divesting and Finishing

After the investment cooling, it divests by using an electric hammer to remove the mold materials that surrounding the metal samples. Then sand blasting technique is used to remove the residual investment material from the metal samples. Aluminum oxide (AL_2O_3) powder of particle size of 50 µm at a pressure of 3to 4 bar was used in the cleaning process for a period of 30 seconds. After that, all metal sprues were cut using a separating disk mounted on a laboratory dental hand piece. To attain precise dimensions, a digital caliper and a metallic Vernier were used to adjust the surface dimensions (25 mm x 3 mm) and the sample thickness (0.5 mm) respectively Figure(5).

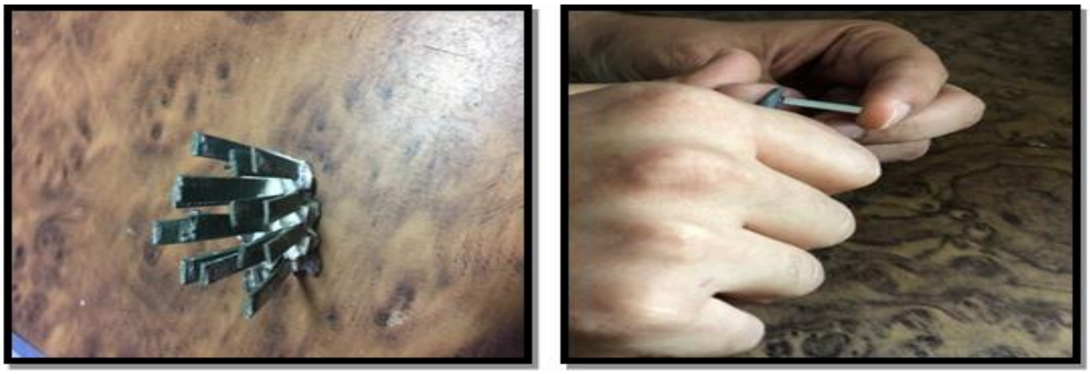


Figure (5): (a) divesting after casting, (b) smoothing the metal sample.

Sand Blast Technique

The metal sample attached with a twezeer from one ends and abraded in sand blast device as seen in Figure (6). According to the manufacturer instructions (Kera, NH ,Germany), aluminum oxide AL_2O_3 sand (125µm for A1 and 250µm for A2) was used at air pressure of 3 to 4 bar and a distance between the sample and sand nozzle of 10 mm for a time duration of 15 seconds.[12] It is worth mentioning that the metal samples should not touched by hands to prevent the contaminants such as grease and dust. Figure (7) shows the SEM images that taken for a sample from group A1 and another sample from group A2 at different magnifications values.

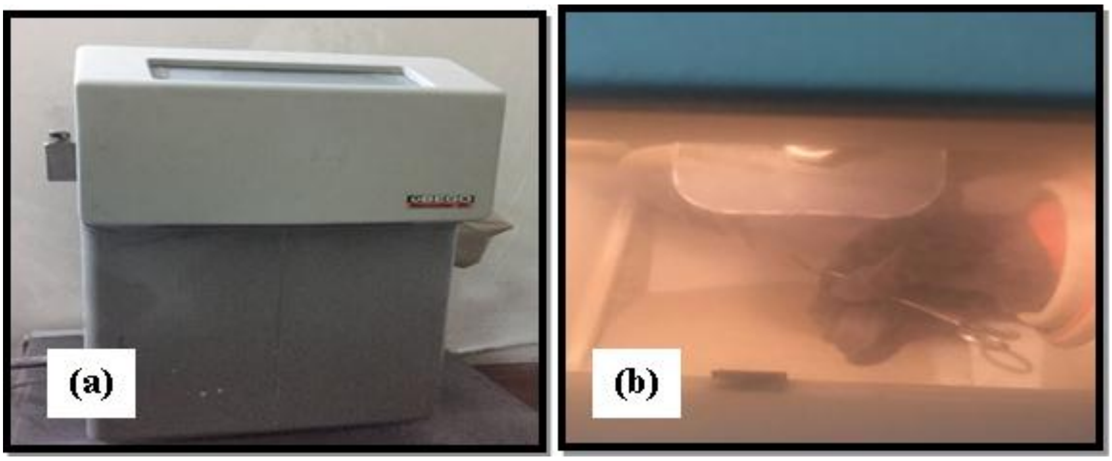
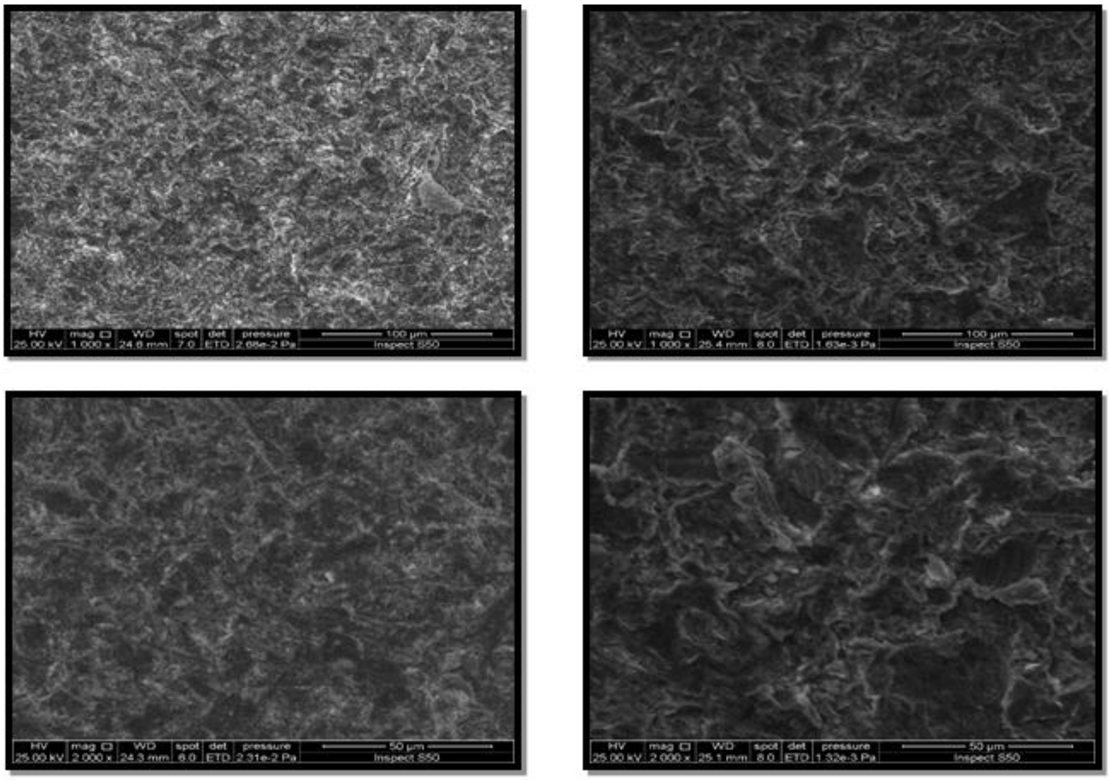


Figure (6): (a) The sand blast device, (b) A metal sample under sand blasting.



(a) (b)

Figure (7):
(a) SEM images for one of the A1 group samples (125µm sand particle size),
(b) SEM images for one of the A2 group samples (250µm sand particle size).

Porcelain Build Up

A hollow rectangular Teflon mold of 8 x 3 mm dimensions and 1.1 mm height, was designed and fabricated to set up the porcelain on the prepared metal surface.[11]

The Opaque Layer

The opaque ceramic was applied according to the manufacturer's instructions (Vita, Germany) with aid of Teflon mold.

Dentin Build Up

Opaque application for the samples is followed with the process of applying the dentin layer. The sample is placed in it's position in the lubricated Teflon mold, the dentin powder mixed with Vita modeling fluid RS to obtain a clay consistency. With the aid of a Renfert ceramic brush (size 6), the dentin mixture added inside the Teflon mold until filling. According to the manufacturer's instructions (Vita, Germany), the sample fired in a ceramic furnace at 930^{o}C for a holding time of one minute in vacuum. When the furnace door opens to cool the samples below 350^{o}C, the samples removed out and left on the bench to cool down to the room temperature Figure (8).

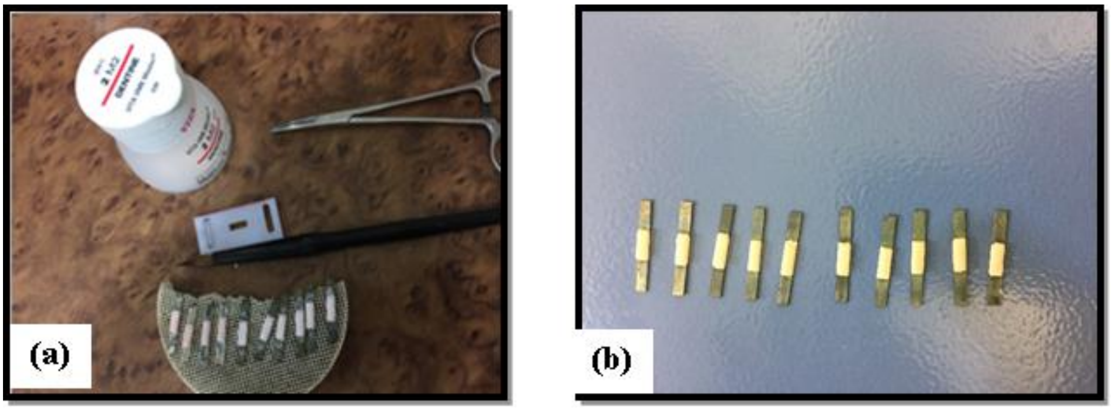


Figure (8): Dentin build up: (a) before firing, (b) after firing.

Three Points Bending Test

Metal-ceramic sample are tested with the three point bending test by using the three point bending apparatus (Instron).

The metal-ceramic samples were placed symmetrically on the fixtures where the ceramic side opposite the loading pin. The span between the support pins is 20 mm as shown in Figure (9). The applied force was transmitted through symmetrical aligned bending piston at a rate of 1.5 mm/min.[13]

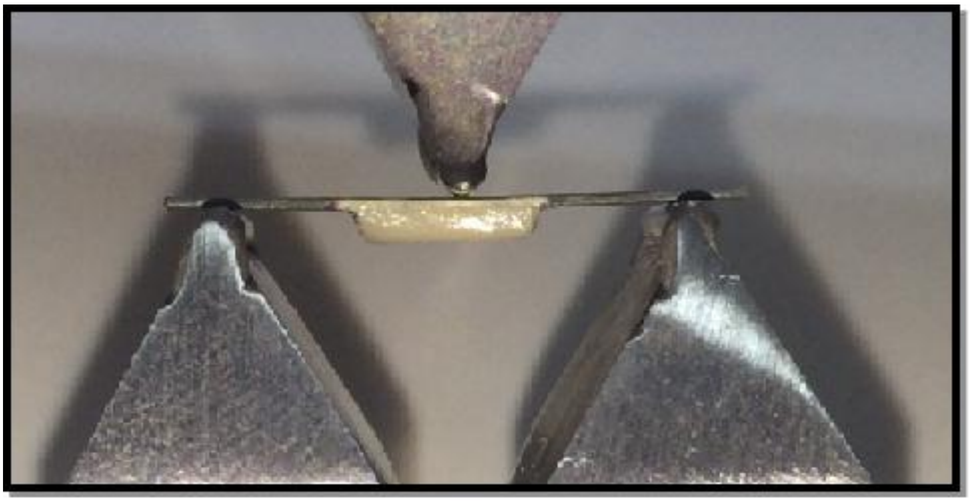


Figure (9): Three points bending test.

The debonding strength/crack initiation strength for loaded materials in a three-point flexure test configuration is determined by the relation:

$\tau_b = k\, F_{fail}$

where τ_b is the debonding strength/crack initiation strength in MPa, F_{fail} is the failure load in N when the ceramic debonded from the metal alloy and k is the coefficient which is a function of both the thickness of the metal and the elastic modulus of the alloy E.[14]

3. RESULTS

This section presents the findings of the data analysis systematically in tables and these correspond with the objectives of this study and as follows:

Normal Distribution Function (Goodness of Fit test)

Table (1): Normal distribution function test for two groups in relative to Sand blasted with Aluminum oxide AL2O3.

One-Sample Kolmogorov-Smirnov Test		
Groups	**Test Statistic and Comparison's Significant**	**Bond Strength test**
A1	**No.**	**10**
	Kolmogorov-Smirnov Z	**0.315**
	Asymp. Sig. (2-tailed)	**1.000**
	C.S. (*)	**NS**
	Test distribution are Normal	
A2	**No.**	**10**
	Kolmogorov-Smirnov Z	**0.528**
	Asymp. Sig. (2-tailed)	**0.943**
	C.S. (*)	**NS**
	Test distribution are Normal	

(*) NS: Non Sig. at P>0.05; A1: Particle size 125μm; A2: Particle size 250μm

Table (1) represented one-sample Kolmogorov-Smirnov test procedure comparing the observed cumulative distribution function for studied readings with a specified theoretical distribution, which proposed Normal shape (i.e. Bell Shape).

The results showed that test's distribution are normal for studied readings concerning different groups of (Bond Strength test) in relative of different techniques and profiles, since P-value are accounted at (P>0.05) the significant level, and that could be enables of applying the conventional methods of statistics, either for descriptive methods of estimations by points and interval, such as (mean, standard deviation, standard error, 95% confidence interval for population mean value, ….etc), or applying an inferential statistics, such as parametrical hypotheses, either for testing equal variances are assumed or equal means are assumed, which supposed data underlying data having (Normal Distribution Function).

Sand Blasted with Aluminum oxide AL2O3

Table (2): Summary Statistics of Sand Blasted with Aluminum oxide AL2O3 in different two groups.

Groups	No.	Mean	Std. Dev.	Std. E.	95% C.I. for Mean		Min.	Max.
					L.b.	U.b.		
A1: Particle size 125µm	10	58.10	4.20	1.33	55.09	61.11	51.00	64.60
A2: Particle size 250µm	10	63.26	5.90	1.87	59.04	67.48	55.25	76.00

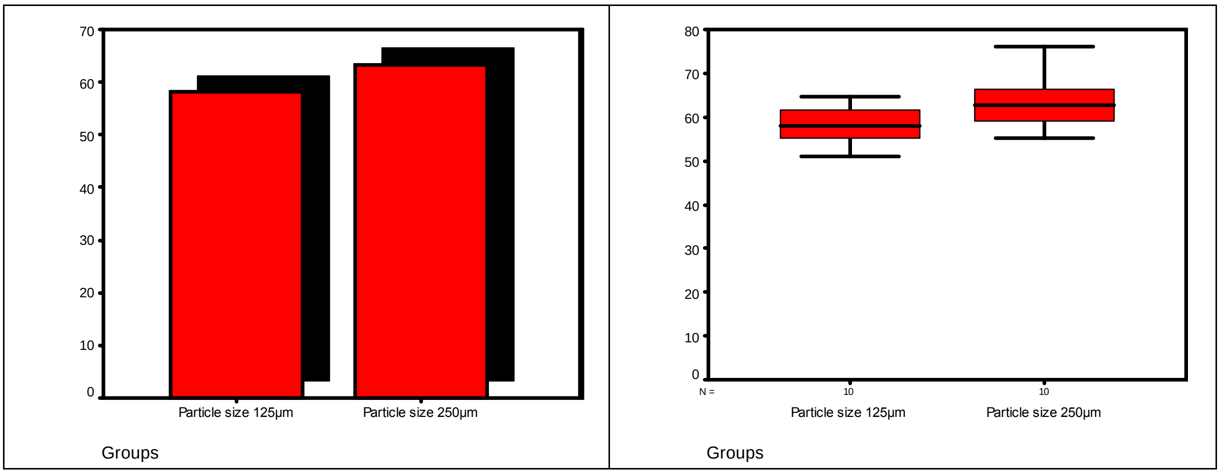


Figure (10): Mean values, and Exploring Behavior concerning Sand Blasted with Aluminum oxide AL2O3 distribution in different two groups.

Table (2) shows a summary statistics of (Bond Strength test with Aluminum oxide AL2O3) which were classified according to different groups, such that, mean values, standard deviation, standard error, 95% confidence interval of parameter mean of studied population, and the two extreme values (minimum, and maximum) of the measured readings. Figure (10) represent graphically plotting of bar chart regarding mean values of Bond Strength test with Aluminum oxide AL2O3 distributed in the studied groups as well as Stem-Leaf plot, for studying behavior of the two groups distribution. Regarding of group (A2) particle size 250µm, majority of readings were recorded compared with group (A1) particle size 125µm, with significant different at P<0.05 are accounted concerning equal mean values not assumed rather than no significant different are accounted for testing equal variances are assumed at p>0.05, and as illustrated in table (3).

Table (3): Testing equal variances and equal means for Bond Strength test with Aluminum oxide AL2O3 for studied groups.

Test	Testing Homogeneity of Variances		t- test for equality of means	
	Levene Statistic	Sig. (*)	t-test	Sig. (*)
Sand Blasted with Aluminum oxide AL2O3	0.509	0.485 (NS)	-2.251	0.037 (S)

(*)NS: Non Sig. at P>0.05; S: Significant at P<0.05

4. DISCUSSION

Because a correlation between surface roughness and the degree of adhesion between alloy and ceramic could be determined, it is important to promote mechanical bonding by conditioning the surface with Al_2O_3 air abrasion.[15]

In current study findings the mean of the bond strength between metal and ceramic of group (A1) 58.1 MPa which used aluminum oxide Al_2O_3 particle size 125µm group (control group) according to manufacturer instruction of (Kera, NH Germany). While mean of bond strength of group (A2) 63.26 MPa with used aluminum oxide Al_2O_3 sand particle size 250µm. Clear different in bond strength of ceramic to metal. the bond strength with aluminum oxide particle size 250 µm higher than bond strength with aluminum oxide Al_2O_3 sand particle size 125µm. this may be due to large size of sand produce great roughness on the metal surface as shown in SEM images. Roughening the surface area increases the wettability of the metal framework and improves the metal-ceramic bond.[16]

The result of this study agree with results of Patel KA, et al study. They found the highest shear bond strength achieved when the alloy is sandblasted with 250 µm particle size of aluminium oxide. So Patel KA, et al conclude the different aluminium oxide grit sizes affect the shear bond strength of metal-ceramic alloys. And the Greater particle size demonstrated higher bond strength.[9]

So the results of current study came in agreement with Külünk et al., 2011, they found the superior bond strength of dental ceramic to metal recorded when used larger particle size of aluminium oxide Al_2O_3 in sandblasting.[3]

5. CONCLUSION

According to the results of this study, the following conclusion can be derived:-

1. The mean of bond strength of ceramic to metal the twi groups (sand blast particle size 125µm and 250 µm) were within acceptable limit >25µm according to ISO (9693/1999).
2. Particle size of sandblast has effect on bond strength, larger particle size high bond strength.
3. The highest bond strength recorded when used 250 µm sand particle size.

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