Effect of soldering on shear bond strength of porcelain fused to metal. (In vitro study)

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ABSTRACT

Background: The insertion of metal frameworks is critical during the fabrication of metal-ceramic restorations to ensure adequate fit to the abutments. When fit is inadequate, sectioning of the metal framework is required, which is then soldered in the dental laboratory.

Materials and Methods: Forty cylindrical metal (Ni-Cr alloy) specimens were prepared; it has 8 mm diameter and 3 mm height. Half of these specimens were made in such a way so that it has perforation in the center of 1mm in diameter; the later group is then soldered. All the samples were oxidized, and then sandblasted with aluminum oxide. The ceramic material (vita VMK 95) was applied, the final thickness of ceramic was 1.5 mm, and then the samples was finished and glazed.

Half of the soldered and half of non soldered samples were stored in distilled water for one week, and then shear bond strength was evaluated for all samples. After the testing, all samples were inspected visually and microscopically to detect the nature of failure.

Results and Conclusion: The result revealed that the intact specimens (non soldered) has higher shear bond strength values than the soldered specimens, and there is no influence of the water storage on shear bond strength for both groups.

The visual and microscopical observations show that the non soldered groups have higher percentage of cohesive failure than soldered groups which has higher percentage of adhesive failure.

Key words: Soldering, Porcelain fused to metal, shear bond test.

INTRODUCTION

Soldering is defined as the joining of metal components by a filler material, or solder, which is fused to each of the parts being joined. [1]

Technically, soldering is performed at temperatures below 425°C and brazing at temperatures above 425°C. In dentistry, the latter procedure is commonly called soldering. [2]

According to ISO 9333 terminology, [3], the correct term for the materials and temperatures used in dentistry is ‘‘brazing,’’ although the term ‘‘soldering’’ has been extensively used in prosthetic dentistry to describe both processes. [2], [4]

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In fixed prosthodontics, solder material is used also to add proximal contacts, repair casting voids, and connect retainers and/or pontics in fixed partial dentures. [5]

Soldering alloys must have a liquidus temperature below the solidus temperature of the parent alloy components to be joined to allow for efficient interfacial flow. Therefore, these alloys always have different chemical compositions compared to dental casting alloys and will contain lower-melting metal components. In fixed prosthodontics, solder material is used also to add proximal contacts, repair casting voids, and connect retainers and/or pontics in fixed partial dentures. [5]

Manual torch brazing is the most frequent method used for repairs, but conventional or infrared furnaces may be used as well. [6], [7], [8]

Metal-ceramic frameworks may be joined by soldering either before or after the application of the porcelain. The terms ‘‘preceramic’’ and ‘‘postceramic’’ are used, respectively, to designate the two procedures. The physical, chemical, and mechanical properties of frameworks appear to be inevitably degraded by the soldering procedure.[9] Furthermore, the alteration in the chemical composition at the soldered area may affect the metal-ceramic bond strength as well. In addition to chemical bonding, the possible alteration of mechanical retention, van der Waals forces, and compression bonding [10],[11],[2], which contribute to the overall metal ceramic bond strength, should also be considered, these alterations may be associated with the higher failure rate of soldered fixed restorations.

MATERIALS AND METHODES

Forty metal ceramic specimens were constructed using a specially designed cylindrical stainless steel mold (Figure 1). [12] The mold has a central hole with 6 mm in depth and 8 mm in diameter, and an auxiliary 2.0mm diameter perforation across the mold up to the bottom of the central perforation that was used to remove the specimens using a metallic pin. The set of mold components also includes an 8.0mm diameter, 3 mm thick flat disc used as a spacer for standardization, (this permit standardized 3mm thickness and 8mm diameter for all specimens).

Type II blue inlay wax was used (Degussa, Germany) was softened by wax knife and flowed inside the metal mold with the flat spacer disk inside to produce the wax patterns of group A (figure 2) (control group without perforation), and with pinned spacer disk inside the mold to produce the wax patterns of group B (test group with perforation in the center of 1 mm diameter) (figure 3). The wax pattern then was sprued, invested using Phosphate bonded investment (Gilvest, Hoyermann Chemie GMBH. Germany), burned out, and casted using Ni-Cr alloy (wiron 99). The samples were then divested and finished with diamond disks followed by sandblasting with 250 µm alumina particles according to manufacturer instructions.

Soldering of group (B) was performed according to the protocol described by [1]. A Platinum foil, which acts as a matrix over which solder can flow, was adapted on the undersurface of the test sample and affixed to the casting with sticky wax.

The sample was placed over a fresh mix of carbon-free phosphate-bonded investment in a casting ring until the investment set. A pencil was used to outline all the metal surface of the sample around the hole and limit the solder flow around the perforation (the solder will not attach to the surface over which the pencil is passed). The casting was placed on a tripod and warmed slightly for about 5 seconds, and a small quantity of flux (just enough to fill the hole in the casting) was placed into the hole. A rod of high-fusing white ceramic solder (Wiron soldering rods (Bego, Germany)) was placed over the hole. The casting was heated by torch until solder flowed in the area. All test samples were soldered by the same investigator, and then the samples were finished with finishing kit and sandblasted. The finished metal samples of both groups figure (4) were ready for ceramic application. Ceramic application was done by the use of specially designed syringe for standardized ceramic thickness for all samples. Vita VMK95 ceramic material was used; the final ceramic thickness was 1.5 mm.

Half of the samples of the group A (10 samples), and half of the samples of the group B (10 samples) were stored in distil water bath at room temperature for one week period.

The sample grouping is as follows:

A1 10 samples not soldered and not stored.
A2 10 samples not soldered and stored.
B1 10 samples soldered and not stored.
B2 10 samples soldered and stored.

All samples were subjected to shear bond test evaluation using Instron testing machine (Instron Corporation 1195 England).

RESULTS:

The mean, minimum, maximum, standard deviation, standard error and coefficient of variance are shown in table (1), This table shows that; the highest mean value of SBS was recorded in group **A2** is (24.437 ± 1.252), followed by group **A1** (23.491 ± 0.988), followed by group **B1** (12.945 ± 1.411), while the lowest mean value of SBS was for group **B2** is (11.867 ± 1.036).

This difference in mean values between groups was clearly shown in figure (5).

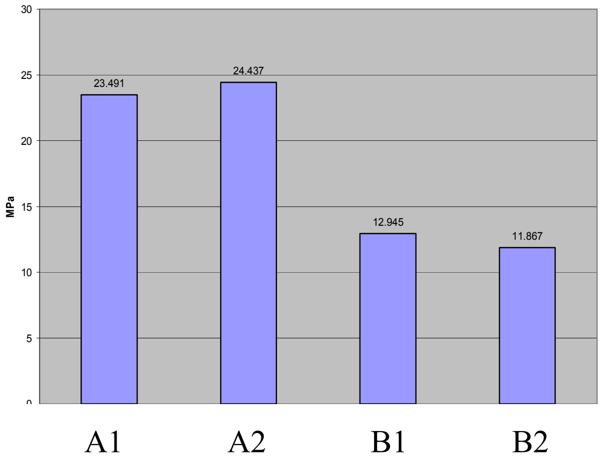

Fig.5: Means of all groups

In order to see weather this difference in mean values were significant or not, statistical analysis of the mean values of different groups using (ANOVA) test (table 2) were carried out, this table shows that there are high significant difference among the tested groups at ***p***<0.0001.

In order to statistically verify the significance of difference between the tested groups, statistical analysis of the data (mean values) of the different groups using t-test was performed.

T-test was applied between groups (A1-B1) (A2-B2) and (A1-A2) (B1-B2) as seen in table (3).

T-test revealed that there are high significant influence of soldering on shear bond strength at ***p*** value (p<0.0001) and that there are no significant influence of storage on shear bond strength between groups at (p>0.05)**.**

	Sum. Of squares	df	Mean squares	F	Sig.
Between groups	1346.197	3	448.732	320.194	0.000
Within groups	50.452	36	1.401		
Total	1396.649	39			

Table 1: Descriptive statistics of all groups

		Mean Mpa	**SD(±)**	**SE**	**Min Mpa**	**Max Mpa**	**C.V%**
Non soldered	**Without water storage**	23.491	0.988	0.312	22.071	24.987	4.205
	With water Storage	24.437	1.252	0.396	22.730	26.241	5.123
Soldered	**Without water storage**	12.945	1.411	0.446	10.974	15.169	10.899
	With water Storage	11.867	1.036	0.328	10.340	13.316	8.730

Table 2: ANOVA test

	t-test	P-value	Sig.
A1-B1	19.4	0.000	HS
A2-B2	24.47	0.000	HS
A1-A2	1.88	0.077	NS
B1-B2	1.95	0.069	NS

Table 3: t-test for all groups

DISSCUSION

The samples were tested in shear pattern, statistical analysis of the data showed that there is a high significant influence of soldering on shear bond strength at ***p*** ($p<0.0001$).

The results obtained shows that the non soldered PFM samples has higher SBS value than soldered samples.

The debonded porcelain of the fractured samples for soldered groups generally were covered by dark gray layer, which was assumed to be the metal oxide, these observations may be due to over production of oxide layer by the solder material which may result in less bond strength, these finding agreed with that of ***Papozoglou*** *[13]*, in contrast to that, the observation of the debonded samples of non soldered groups rarely shown oxide layer on metal surface.

Unfortunately the oxide formation behavior of solder material is not provided in the manufacturer paper which is a critical factor in bonding mechanism.

Also the coefficient of thermal expansion of solder material is not provided by the manufacturer which, if mismatched with that of porcelain, may greatly influence the bonding between the ceramic and metal.

The statistical difference between the soldered and non soldered specimens might also be related to the problems of the soldering technique that can't be avoided like inevitable gas inclusions which is created due to soldering temperature leading to small surface defects , also uncontrolled temperature of the torch flame could overheat the solder and the metal causing excessive oxidation with ion diffusion from the parent alloy to the solder or vise versa which is referred to ion diffusion zone or heat affected zone of the solder joint, it might contribute to lack of chemical homogeneity of the materials and reduction in bond strength. *[14]*

Some researchers noticed that there were a wide variety detected between the intact and soldered specimens, these variation might be due to variability of the technical factors and imperfections during the casting or the soldering procedures. *[15]*

The amount and concentration of flux materials used may also influence the bond strength because high concentration may results in more flux inclusion bodies occurred, more anomalous crystals may be present, and this will affect the surface quality of soldered area. It's extremely difficult to apply the same amount of flux materials to all samples. *[16]*

Possible inclusion of alumina particles that was used during sandblasting might result in an increase in the amount of surface alumina, which might result in a significant metal surface modification. The alumina particles might have different interaction with intact metal surface and a solder material, which might contribute to a decrease in bond strength by limiting the surface area available for porcelain bonding, also the alumina particles may act as stress concentration between the porcelain and metal where cracks might initiate and propagate.

Some researchers *[17]* study the influence of soldering on shear bond strength, they found that there is no statistical difference between the soldered and intact samples, however the P value was greater than 0.05, this might attributed to using different materials and technique and using 3 point bending test with very small group size.

Other researchers [18] study the effect of soldering on repaired metal ceramic specimens they found that there are no statistical difference this might be attributed to using different materials and technique and using 3 point bending test and the hole size to be soldered was very small, in addition the visual examination show a significant difference in residual porcelain between the test and control samples.

Statistical analysis of the data showed that there was no significant influence of water storage on shear bond strength at ***p***-value ($p<0.05$).

These results agreed with that of *[19]* who found that there was no significant difference in shear bond strength of metal ceramic samples with and without water storage. They conclude that when using appropriate technique, the samples will not deteriorates for up to one year at room temperature.

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