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The Effect of Surface Treatment of Co-Cr on Metalo-Ceramic Shear Bond Strength

Nadira A. Hatim[1], Abdullah J. Mohammed[2], Alaa I. Dawood[3]
[1]Professor, Department of Prosthetic Dentistry, College of Dentistry, Mosul University, Iraq
[2]Asst. Lect., Department of Prosthetic Dentistry, College of Dentistry, Mosul University, Iraq
[3]Asst Lect., Department of Operative Dentistry, College of Dentistry, Mosul University, Iraq

Abstract: Aim of the study: The preparation of metals before porcelain application can affect the metal-to-porcelain bond. This study investigated the influence of metal finishing and sandblasting on porcelain-metal shear bond strength failure load. Material and methods: Forty square cast metal samples were divided into 4 test groups: (A) polished (B) oxidized (C) oxidized / sandblasted (D) oxidized / sandblasted/ oxidized. The porcelain cylinder applied in the center of these specimen was 1.5mm thick. Results: Mean loads at failure (MPa) were as follows: A (2.16820), B (4.53160) C(7.67420) D(10.01900) There were significant differences between the groups at P=5%. Conclusion: oxidation alone and polishing alone had the least shear bond strength between the groups while those engaged sandblasting with the oxidation had higher values, first oxide layer were unfavorable while the second layer after sandblasting were the superior one in regard to shear bond strength.

Introduction

The texture of metal surfaces before porcelain application can affect the metal-to-porcelain bond. Localized pits, and small holes[(1-3)]. may result in localized areas of stress that can lower porcelain resistance to fracture[(4)]. Air entrapment and contamination may be the result of pits and small holes on the finished metal surface this contamination may cause porosity in the porcelain during firing. The metal-porcelain interface may be affected also by the direction of metal during finishing process. Many researchers have suggested that the finishing of the metal surface with abrasive stones and carbide burs should be done in one direction[(5-7)]. Metal projections that can collapse on each other may be resulted by finishing in different direction, and these projection can entrap air and investment particles. These contaminants can cause gas formation during firing, resulting in porosity in the porcelain. These porosities may serve as areas of stress concentration and be focal points of crack propagation[(1-8)]. Sandblasting process can remove these projection air entrapments and other contaminants. A sandblasted surface may have higher surface energy that allowing higher surface wetting of metal during porcelain application[(9)]. investigators suggest that this surface roughness can also provide mechanical locking and increase the surface area for porcelain-metal bonding[(10)]. The oxide that is formed after sandblasting differs from that is formed before sandblasting, furthermore, the rough metal surface may result higher shear bond strength of ceramometal interface [(11,12)]. The oxide layer have a great influence on the metal-porcelain bond strength[(13-18)]. Many methods have been used to measure the strength of this bond, anyway the 3-point flexural and shear bond tests are frequently used[(19-28)]. All these methods were aiming to find the influence of surface texture and pitting on the oxide layer composition and formation [(29,30)]. The purpose of this study was to reveal whether oxidation or the sandblasting itself has the greater influence on this bond. Cobalt-chromium (Co-Cr) casting alloys have high physical properties that make it widely used in removable partial denture frameworks[(29-32)]. The performance of an abrasive powder depends on the hardness, size, and shape of the particles. In general, an abrasive powder needs to be harder than the material being surfaced, the harder the abrasive . Particle size is the second important factor that influences performance. Abrasive particles have impact energy: they hit the surface and generate defects[(33-36)].

Materials and methods

Four groups of 10 specimens, Metal plates (10X10X1mm) were fabricated from sheets of wax. These square samples were sprued and invested in a phosphate-bonded investment (Biosint-supra, Degussa, Germany) (4 specimens in each ring), according to manufactures instruction. The alloys (Biosil, Degussa, Germany) were melted in crucibles[(1)]. The metal was melted in broken arm centrifuge (Motor-cast, Degussa, Germany) using gas-oxygen torch[(1)]. The sprue was removed using carborandum wheel. The specimens were finished with aluminum oxide stones (74µm grit). Then, the side to which the porcelain was bonded further grinded with carbide bur in one direction and polished with rubber disks[(1)]. The forty square metal samples were divided into four groups: groupA: ten samples of this group were lift in the polished state. groupB: the samples of this group were treated after polishing by oxidation in the IVOclar (Ivoclar, oven, programat X1, Germany) oven as recommended in the manufacturer program as shown in table (1). The group C: the samples of this group were oxidized in the same manner of group B and sandblasted in the sandblasting machine (Perstrahl 2, Degussa, ,Germany) with aluminum oxide (125 µm) this procedure were standardized with device that kept the metal samples at a constant distance (4.5 cm) from the sandblaster nozzle at 6-7bar of pressure with the nozzle at 90º angle to the metal surface for 30 second [37] . The forth group (D) were oxidized and sandblasted in the same manner of group C, then they were oxidized again in the Ivoclar oven as shown in table (1). After surface treatment that was suggested for each group the porcelain (Vivadent, Germany)were applied as follows: an opaque porcelain layer were applied in the center of the square metal specimen using a copper ring 5mm in diameter and rubber piston to control the thickness of the opaque layer which was approximately 0.2mm this was done by two firing cycles in an IVOclar oven as shown in table (1). A dentine layer of the porcelain then applied using the copper ring and the piston which was hold vertically and perpendicularly to condense the porcelain against the metal surface of the specimen to achieve 1.5mm total thickness of the porcelain layer, the dentine layer were cycled in the oven according to standard oven program shown in table (1), each layer thickness were checked and adjusted to the required thickness using digital vernier. The porcelain cylinder of each specimen was embedded in a self cure acrylic resin cylinder using plastic ring to match the direction of the applied shear force. The metal was completely separated from the acrylic by a thin cellophane layer with an opening exposing the porcelain layer alone [38]. Each acrylic tube with embedding specimen was fitted into special constructed metal device and the specimens were loaded to failure by applying a shear force to the exposed metal part of the specimen as the porcelain part was embedded in acrylic, until bond failure occurs. The blade of testing machine was applied as close as possible to the metal/porcelain interface. Shear bond strength was then measured with a universal testing machine at cross-head speed of 0.5 mm/min [39,40]. Shear bond strength calculated by = F/A (F=force per unit area, A= circular area of porcelain mm²) was expressed in Megapascals (MPa).

Table 1: Standard IPS classic program of firing recommendation of Ivoclar programat X1 oven

	Stand by temperature °C	Closing time minute	Temperature increase rate °C/min	Holding Temperature °C	Holding time min	Total Time min
Oxidation	403	0.30	140	980	1	6.15
Opaque	403	6	80	980	1	9.11
Dentine	403	4	60	920	1	10.40

Result

The statistical results of shear bond strength have shown the mean values of group(A, B, C, and D) were: (4.53160, 2.16820, 7.67420, 10.01900) MPa, respectively these results have shown in table 2. One way ANOVA, and Duncan's multiple range tests revealed a significant differences between the groups at (p=0.05) as shown in table 3,and figure 4. Tests have shown that group A (polished) shear bond strength were significantly higher than that of group B (oxidized) and lower than that of group C (oxidized, sandblasted) and group D (oxidized, sandblasted, oxidized) significantly. Group B had the lowest range of shear bond strength, while group C had significantly higher values than groups A,B and lower range than group D, whereas, group D had significantly higher range than the other three groups.

Table 2: Descriptive data of the four groups

groups	No.	Mean	Std. Deviation	Std. Error	Minimum	Maximum
A	10	4.53160	.340518	.152284	4.063	4.959
B	10	2.16820	.160083	.071591	1.971	2.390
C	10	7.67420	.413809	.185061	7.170	8.305
D	10	10.0190	.961805	.430132	9.261	11.352

Table 3: One way ANOVA test results

	Sum of Squares	df	Mean Square	F-value	p-value
Between Groups	178.778	3	59.593	192.563	.000
Within Groups	4.952	36	.309		
Total	183.729	39			

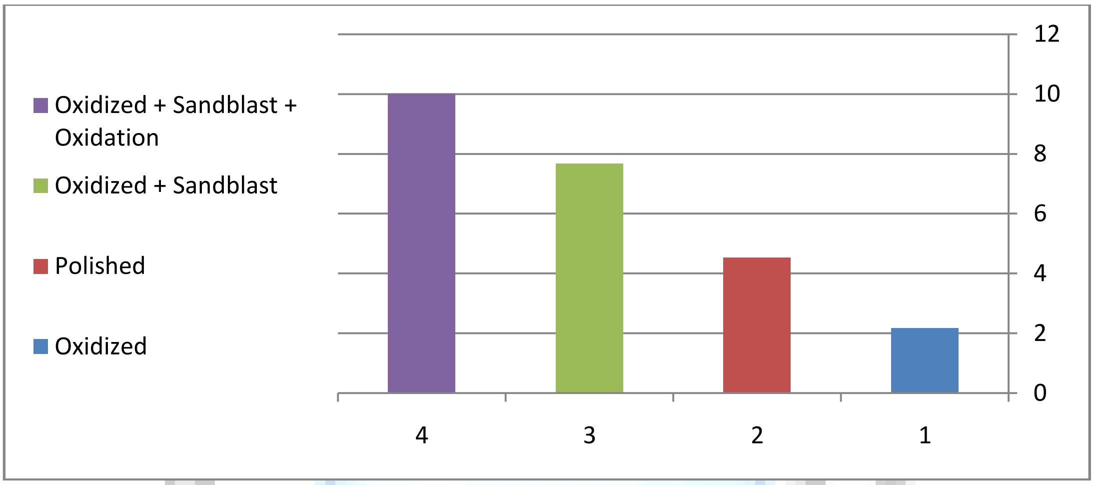

Figure 1: Duncan's multiple range test

Discussion

Full understanding of the metal-porcelain interface bond is necessary to evaluate the factors that can affect this bond, the surface conditions whether, polished, oxidized or sandblasted are well known factors that affect this bond, unfortunately these factors cannot be measured in isolation from each other, Bonding between porcelain and metal is possible by means of three mechanisms: Van der Waals' forces, mechanic retentions and chemical bonding. In the current study results have shown that the polished surfaces had higher bond strength than those with oxidized (both were not sandblasted) this result can be explained by formation different gases that liberate from the oxide layer, where these gases can form porosities in the metal-porcelain interface or in the porcelain layer itself, these porosities can greatly decrease the resistance of the bond to fracture [14,17]. However, both groups (A and B) had significantly lower ranges than that of groups (C and D) which were sandblasted before the application of the porcelain layer, this increase in the bond strength because of the sandblasting is due to that the sandblasting can increased the surface area to which the porcelain is attached, Sandblasting the finished surface though to remove furrows, overlaps, and flakes of metal created by the grinding process. A sandblasted surface may have higher surface energy that alloys increased wetting of the metal during ceramic application. Evidence suggested that this roughened surface could also provide mechanical interlocking and increase the surface area for metal-ceramic bonding[41]. Another finding in this study was that group D specimens had higher bond strength than those of group C, this finding support the finding of other authors in that the oxide film that generates on the metal surface before sandblasting differs from that forms after sandblasting, also the first oxide layer (degassing layer) differs from the second oxide where the degassing oxide layer can negatively affects the metal-porcelain bond strength[11,41].

Conclusion

Under the limitation of the current study, the following conclusions were drawn:

1. The first oxide (degassing) layer is the weakest surface treatment of metal before porcelain application, also it differs from the oxide layer that is formed with oxidation after removing the degassing layer.
2. Sandblasting can increase the strength of the metal-ceramic bond.
3. The highest bond strength can be obtained by removing the first oxidation layer with sandblasting, then a second oxide layer by heating in the oven under atmospheric pressure.

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