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# The Effect of Surface Treatment on the Shear Bond Strength of Porcelain by HF Acid Etching and Sandblasting Technique on Chrome-Cobalt Alloy That Fabricated by 3D Printer and Conventional Casting

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## Abstract

Objectives: The search designed to assess the impact of several surface treatments on the CO-CR alloy and fused feldspathic ceramic's shear bond strength. fabricated utilizing two different techniques lost wax and 3-D-printed laser melting.

**Methods:** A total of 40 rectangular pillars (CO-CR) alloys utilizing two various techniques (lost wax technique and 3D-printed) were separated into 2 groups with subgroups based on the surface treatment (n=10). To obtain a shear bond test a universal testing machine was used after surface treatment of the specimen with sandblasting by aluminum oxide and etching by HF acid. The result of the Shear bond strength test as well as, there was a failure mode identified. and analyzing data using LSD tests (a 0.05).

**Result**: Bond strength was noted stronger in CO-CO specimens with the 3D-printed technique with sandblasting surface treatment than etching by HF acid.

**Conclusion**:Using sandblasting with aluminum oxide on different CO-CR alloys improves the bonding strength with ceramic.

## Introduction:

Metal casting is pouring molten metal into a special device that can be designed from a special wax model. Recently, more and more metal manufacturing methods have been developed(1). Some errors in dental laboratories can be caused by the metal substructure and modern methods can be used to reduce failures in the construction of prostheses for example. The use of computer-aided design/computer-aided manufacturing (CAD/CAM) techniques for rapidly creating fixed restorations has become more common (2). Selective laser melting (SLM) is a form of additive manufacturing (AM) that has emerged as asubstitutional to the traditional lost-wax method for fabricating Co-Cr dental devices. Findings from scientific research indicate that the mechanical properties and metal release of Cr-Co components produced.(3).3D–printed laser technology is another face of laser sintering and relies on melting metal in a 3D-printed Manner .This method in building fixed dental restorations is cheap and labor-effective, while the lost-wax technique is more expensive and gives more laboratory time but both methods have high quality for the final restoration (4) . To enhance the bond strength, one effective approach involves subjecting the metal surface to aluminum oxide particles through the process of sandblasting, which serves to roughen the metal surface and subsequently augment the bond strength. (5). The maximum bond strength was achieved after $AL_2O_3$ air particles and in the case of a particle size of 110 microns (6). Conversely, the inclusion of aluminum (AL) in the alloy composition reduces the thickness of the oxide layer by enhancing the oxidation rate through the formation of $AL_2O_3$ . (7). Different methods such as etching with hydrofluoric acid (HF) have been proposed to enhance the bond strength between metal pillars and feldspathic ceramics. Evidence suggests that etching treatment can increase the scratch on the metal surface to give more roughness to enhance the mechanism of bonding between metal and ceramic(8). This study set out to evaluate the binding strength of dental ceramics and Co-Cr alloys that were cast and 3D printed using aluminum oxide sandblasting and hydrofluoric acid acid etching.

## Materials and Methods

**Sample grouping:**

Forty rectangular pillars (12 x 4 x 4) mm in total were used in this study (9) . were constructed to CO-alloy for casting (Adentatec, Germany) and 3D-printed (Mediloy, S-Co BEGO, Germany) and then divided for2 groups (20 pillars for every group, depending on their different surface treatment and fabrication technique , as follows: -

•Group A: Conventionally cast with sandblasted aluminum oxide surface treatment.
•Group B: Conventionally cast with hydrofluoric acid etched surface treatment.
•Group C: 3D-printed with sandblasted aluminum oxide surface treatment.
•Group D: 3D- printed with hydrofluoric acid etched surface treatment

All metal pillars were veneered with their corresponding ceramic material (4 x 4) mm surface area) to a final thickness of 3 mm, following the manufacturer's instructions and established design guidelines:(10), (11).

**Manufacturing of Metal Pillars**
**Group A and B:**

To create the 20 rectangular samples, the method of lost wax casting was employed.addition to prepare the wax pattern. CAD/CAM technology was used in the production of all wax samples to ensure same thickness and diameter. Wax samples were designed similarly to CAD/CAM manufactured Co-Cr samples utilizing computer-aided design software (Galway, Germany), and a five-axis milling machine was utilized to mill wax patterns from CAD/CAM blank wax (Galway, Germany). Co-Cr pillars were created in a centrifugal casting machine utilizing a phosphate-bonded investment (Bego-Bilafost SH, Germany). After removing the castings, the particles were air-abraded for 15 seconds using powdered aluminum oxide with a diameter of 110 micrometers. at a distance of 2 cm and an angle of 90 degrees from the sandblasting machine's nozzle, at 3 bar of pressure (6).

**Group C and D:**

A commercial 3D-printing technique was used to create twenty samples. and a laser was used (EP-M150METAL DENTAL 3D PRINTER) to manufacture the metal pillars. The design file from Co-Cr was converted to the 3D -printed part (E Plus 3D PRINTER control), equipped with a 100-watt Yb laser. The samples' axes of distance measurement were positioned perpendicular to the build platform.. Co-Cr powders used have particle sizes ranging from 10 to 45 micrometres, respectively. 3D-printed laser selective device was used with the appropriate laser (e.g., Nd: YAG laser with a wavelength of about 1060-1100 nanometres and a sufficient laser energy density of 200 watts or surface energy density of 25 kilowatts per square millimetre, according to the instructions) to selectively melt the granules using a protective gas (e.g., nitrogen). Bego has parameter settings for the( EOS M270) 3D-printed machine, Including production specifications , and can be installed on customer equipment. To reduce the residual stresses resulting from the localized laser heat input and to adjust the microstructure to upgrade the mechanical effectiveness, the pillars were annealed at 1050 C° for 1 hour in a vacuum furnace.

**Surface treatment of metal substructure: -**

**A- Roughness surface by sandblasting machine**

Twenty metal substructure pillars were treated with Al2O3 particles of 110μm size using a sandblast machine. The working surface of each metal specimen was abraded vertically with air pressure at 3 bar for 15 seconds. A fixed distance of 20 mm was maintained between the nozzle of the sand machine and the surface of the specimens by using a red pencil note inside the sandblast device. After 15 seconds of steam cleaning, the pillars underwent an 8-minute ultrasonic cleaning in distilled water.

**B- Roughness surface by Acid etching with hydrofluoric acid: -**

The 20 metal substructures of CO-CR alloy were fabricated by lost wax technique and 3D–printed laser selective method technique that was treated with hydrofluoric acid (FGM, DENTSCARE LTDA, Joinville/SC, Brazil) at 10% concentration. It's part out the brush in 60 seconds with one layer and rinsed with water carefully. when the specimens were dry the buildup steps should be obtained.

**Porcelain veneering of Co-Cr pillars:**

Air-abraded pillar bases were used to create the foundation for the porcelain construction, and Co-Cr substrates were covered with conventional low-fusing feldspathic ceramic (VITA VMK Master, VITA Zahnfabrik, Bad Säckingen, Germany). . A specially designed plastic mold was used. First, for Co-Cr groups, a thin cover of opaque porcelain was applied manually and fired (thickness 0.5 mm), followed by two layers of ivory porcelain – the second correcting the first layer shrinkage (thickness 2 mm) – and glaze firing (Vita Vacumat 6000 M furnace, VITA Zahnfabrik, Bad Säckingen, Germany). The manufacturer's recommendations were followed for adjusting the firing times.Table(1) displays the group and material specifications used in this investigation.

**SBS testing and failure mode**

A universal testing apparatus was used to ascertain each group's shear bond strength (SBS). (Instron (WDW-50 large universal testing machine, China). The sample assembly, as well as the custom-designed test device, which consists of a low-friction base and stainless steel upper pieces, is shown in Figure (1). The device's upper component loads the metal-ceramic contact until failure occurs by sliding down the fixed part's grooves at a crosshead speed of 0.5 mm/min. SBS values were noted. To examine the fracture samples under the samples adigital microscope was used . (DinoLite, Taiwan) with a magnification of X100 to recognize the failure mode. Failure modes were classified as follows to describe them: (1) adhesion failure cases, which occur between the metal oxide/ceramic and metal; (2) cohesion failure cases, which occur entirely within the ceramic; and (3) mixed failure cases, which are a combination of cohesion and adhesion failure cases (16).As shown in figure (2).

**Statistical analysis**

To examine and evaluate the results Statistical methods were used, including descriptive statistics (standard deviation, mean, standard error, , bar graph of mean SBS values, maximum and minimum values of SBS test) and least significant difference (LSD) statistical analysis.

# Results:

**Shear bond strength measurement**

The SBS test of PFM was compared in this study.. The specimens were fabricated utilizing different manufacturing processes of Co-Cr alloys, including traditional casting techniques and 3D printing. The calculated percentage of bond strength to every porcelain applied to the samples, Table (2),(3) shows the descriptive statistics that include the calculated percentage of bond strength obtained for each sample used in this study with sandblasting using aluminum oxide and acid etching by hydrofluoric acid (mean, standard deviation, minimum and maximum values) of shear bond strength (MPa). The results showed that the highest mean value of shear bond strength was recorded by (a 3D printed group with sandblasting) which was (38.8712), while the lowest mean value was associated with (the casting group with sandblasting) which was (26.6930). As shown in table (2) and figure( 3).

**Least significant difference test**

LSD test have been used in the present study to determine the source of variance between the two groups as shown in table (4).

**The mode of failure**

During the investigation, most of the rectangular samples exhibited adhesive failure, it was discovered. This included cohesive and mixed failure in the porcelain with a porcelain fragment in contact with the metal. Though certain samples lacked coherence, the results aligned with the predictions derived from Oliveira de Vasconcellos et al. 12). As shown in table (5).

# Discussion:

Coefficient of thermal expansion (CTEs), chemical bonding, precise mechanical interlocking, and the metal substrate used in the manufacturing process all have an impact on the strength of the interfacial contact between metal and ceramic.. This study was primarily concerned with the chemical affinity at the interface, and care was taken to use different manufacturing techniques to manufacture dental alloys in order to minimize the impact of other variables (8). In this investigation, a comparison was performed , where SBS was conducted for PFM specimens using different manufacturing processes of cobalt-chromium dental alloys, including lost wax and additive technologies, For the casting and 3D-printer laser melting groups, there was no statistically significant difference in the shear bond strength depending on the production methods used. but it was a graphical effect. This study agrees with (Serra et al., 2014) (6), Depending on the production process, there was no variation in binding strength. The air-abrasion methods with Al2O3 particles helped to increase the bond strength between the metal and ceramic due to the excessive roughness of the metal substrate, which produces stress accumulation at the interface. In addition, the sharp edges hinder the molten porcelain from soaking into the deep valleys on the metal surface sufficiently, leading to the formation of pores at the contact (5). As a result, choosing the right size of Al2O3 particles is critical. According to a prior study, highest bond strength was obtained after air-abrasion using 110 μm-sized Al2O3 particles (15) where this particle size was used in this research the metal substrates' SEM depth profiles are displayed. The thickness of the surface oxide layer appears to be larger for Co-Cr and CNC-machined Co-Cr by more than 19 μm. During the entire etching procedure, In this sample, the oxide/substrate interface was not achieved. On the other hand, the fast oxygen droplet in SLM samples shown the existence of thinner surface oxide layers, 12 µm due to the excessive roughness of the sample in addition to the resulting shadowing(16).

Certain laboratory processes can damage objects made from metal-ceramic due to metal contamination, insufficient metal oxides, thermal expansion compatibility issues and voids in the alloy(13). Chemical bonds create ionic, covalent, and metallic interactions with the oxides present in the opaque ceramic layer .The metal framework's oxide layer provides the fundamental mechanism for the interaction between metal and ceramic. (15). As a result, the oxidation process is used to generate an oxide layer on the porcelain-bearing surfaces and to remove impurities. Chemical adsorption occurs by dispersion at the metal-ceramic interface, resulting in chemical bonding (11). The oxide layer present between the metal and ceramic has an impact on this. The disparate bond strength between the groups in this research could be related to the thickness of the oxide layer. In comparison to grinding and SLM, Wang et al. found that cast substrates exhibit a lower bond strength between the metal and ceramic, in addition to a greater oxide layer between the alloy and ceramic. Akova et al. and SerraPrat et al. have also noted that various manufacturing techniques result in varying thicknesses of the oxide layer (14).

This study compared the SBS values of PFM samples fabricated using various Co-Cr alloy manufacturing methods, including CAD/CAM fabrication and conventional casting. For each group of metal substrate and ceramic, the mean values of SBS were obtained, and the estimated bond strength percentage for every porcelain sample used was obtained. Group 3D-printed with sandblasted aluminum oxide surface treatment recorded the highest mean value of (SBS) (38.8712) while the lowest mean value of (SBS) was recorded for group Conventionally cast with sandblasted aluminum oxide surface treatment. (26.6930).

The failure mode analysis revealed that the majority of the samples had adhesive failure, which included both cohesive and mixed failure in the porcelain. Adhesive was the mode of failure for all three groups (Table 5), indicating that there was a crack in the metal and ceramic . Adhesive failure is not typically a perfect condition, as this indicates a weaker bond between the metal and the ceramic compared to the bond within the ceramic, and disconnecting them requires less damaging forces (15).

The mixed failure establish in this investigation was identical to that found in Suliman and Styern's study. As well as , based on Babazoglu and Brantley, the mixed type of failure allows for excellent bond strength between the ceramic and metal (14). This is in contrast to the findings of Maja Antanasova(17).

## Conclusion:

1- Surface treatment by sandblasting and HF acid etch of metal substructure increases bond strength with feldspathic ceramics.

2- No statistically significant difference between the traditional casting group and the 3D-printed laser melting group without surface treatment of metal substructure.

3- The shear bond strength of the sandblasting of 3D-printed laser-melting CO-CR pillar groups was significantly higher than that recorded for all groups.

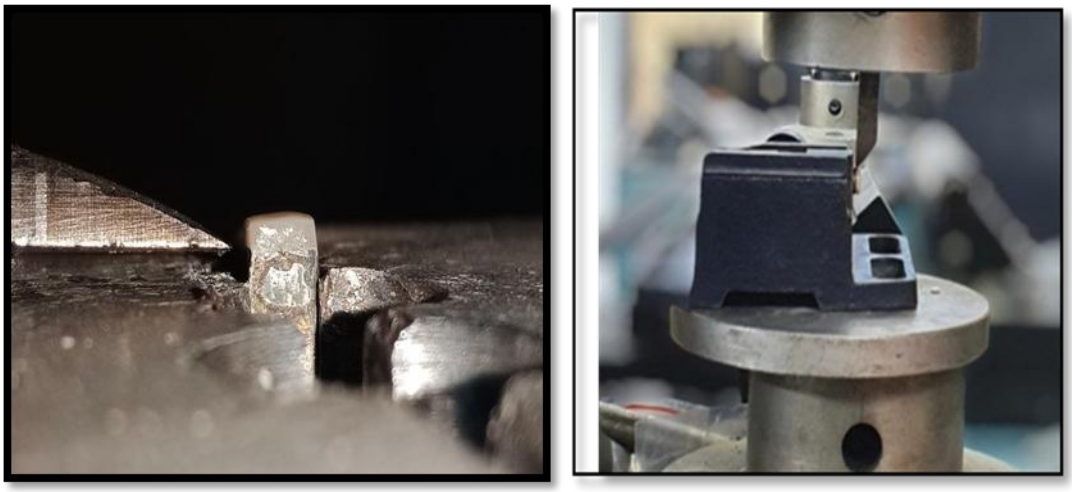

Fig. 1: Universal testing machine


Fig. 2: demonstrates the specimens' CO-CR surface following their de-bonding from the ceramic during the shear bond strength test.

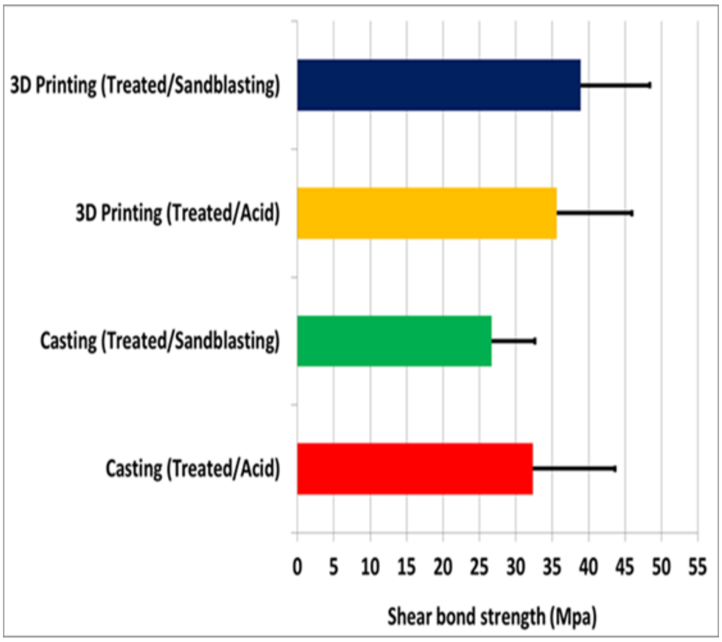


Fig. 3: Bar graph displaying the study groups' mean distribution of shear bond strength (SBS)

Table 1: Group and material specifications for this study

| **Firing process** | **Preach eating temperature ( c )** | **Drying time ( min )** | **Raise of temperature ( c / min )** | **Vacuum** | **Final temperature** | **Holding time ( min )** | **Total time** |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| **Oxidation** | 500 | 0 | 100 | Yes | 980 | 5 | 9:48 |
| **Bonding agent** | 600 | 6 | 60 | Yes | 960 | 1 | 13 |
| **Opaque 1** | 500 | 2 | 79 | Yes | 950 | 1 | 8:38 |
| **Opaquer2** | 500 | 2 | 79 | Yes | 950 | 1 | 8:38 |
| **Dentin1** | 500 | 6 | 55 | Yes | 935 | 1 | 15:54 |
| **Dentin2** | 500 | 6 | 55 | Yes | 920 | 1 | 15:38 |

Table 2: Descriptive statistic of the shear bond strength for two different process techniques of studied groups

| Groups | Mean | Std. Deviation | N |
|---|---|---|---|
| Casting (Treated/Acid) | 32.3590 | 11.86964 | 10 |
| Casting (Treated/Sandblasting) | 26.6930 | 6.23171 | 10 |
| 3D- Printed (Treated/Acid) | 35.6410 | 10.83051 | 10 |
| 3D-Printed (Treated/Sandblasting) | 38.8712 | 10.04211 | 10 |
| Total | 33.3911 | 10.61088 | 40 |

Table 3: Descriptive statistic of the shear bond strength for two different process techniques of studied groups

| Source | Type III Sum of Squares | Df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Corrected Model | 810.239[a] | 3 | 270.080 | 2.715 | .059 |
| Intercept | 44598.522 | 1 | 44598.522 | 448.377 | .000 |
| Groups | 810.239 | 3 | 270.080 | 2.715 | .059 |
| Error | 3580.799 | 36 | 99.467 | | |
| Total | 48989.560 | 40 | | | |
| Corrected Total | 4391.038 | 39 | | | |

Table 4: Using the Least Significant Difference (LSD) test for statistical analysis

| (I) Groups | (J) Groups | Mean deference | Std. Error | p-value | Sign | 95% Confidence Interval | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound |
| Casting (Treated/Acid) | Casting (Treated/Sandblasting) | 5.6660 | 4.46019 | .587 | NS | -6.3463 -15.2943 | 17.6783 |
| | 3D Printing (Treated/Acid) | -3.2820 | 4.46019 | .882 | NS | -18.5246 | 8.7303 |
| | 3D Printing (Treated/Sandblasting) | -6.5122 | 4.46019 | .471 | NS | | 5.5001 |
| Casting (Treated/Sandblasting) | 3D Printing (Treated/Acid) | 4.46019 | 4.46019 | .205 | NS | -20.9603 -24.1906 | 3.0643 |
| | 3D Printing (Treated/Sandblasting) | 4.46019 | 4.46019 | .046 | S | | -.1659 |
| 3D Printing (Treated/Acid) | 3D Printing (Treated/Sandblasting) | -3.2303 | 4.46019 | .887 | NS | -15.2426 | 8.7821 |

Table 5: Failure mode analysis outcomes

| | Groups | cohesive | | adhesive | | Mixed | |
|---|---|---|---|---|---|---|---|
| | NO % | No | % | NO | % | | |
| 1 | casting (sandblasting) | 30 | 3 | 40 | 4 | 30 | 3 |
| 2 | casting (acid etch) | 30 | 3 | 50 | 5 | 20 | 2 |
| 3 | 3D printing (sandblasting) | 20 | 2 | 50 | 5 | 50 | 5 |
| 4 | 3D printed (acid etch) | 20 | 2 | 30 | 3 | 50 | 5 |

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