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The effect of different metal surface grindings in the metal-ceramic bond strength

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Abstract

Purpose: This study aims to compare the bond strength of Ni-Cr alloys to ceramic after different types of grindings.
Materials and Methods: 20 specimens made of Ni-Cr alloys were divided into two groups. The first group of specimens was grinded with a carbide bur (EL5, SS White Burs Inc, Lakewood, NJ, USA) in one direction and the second group of the specimens was grinded in multiple directions. After sandblasting and steam cleaning, 2 mm ceramic (Ceramico II, Ceramco Inc, Burlington, NJ-USA) was fused to Ni-Cr alloy. A tensile bond strength test was used and the data was analyzed by one-way statistically analysis of variance (ANOVA) and Student's t-test. Surface characterizations of Ni-Cr alloys are also examined on scanning-electron microscopy (SEM) after debonding.
Results: Grinding alloys in multiple directions prior to the application of the ceramic, demonstrates significantly higher bond strength with ceramic than grinding in one direction ($p<0.05$).
Conclusion: Within the limitation of this study, metal grinding in multiple directions with light hand pressure maybe an advantage in increasing metal-ceramic bond strength.

INTRODUCTION

The failure of the ceramic-to-metal interface instigates a discomfited situation for both patients and dentists. Even though dental ceramic is a brittle, it is still one of the most biocompatible materials for the restoration of teeth. New investigations attempt to bring high-quality mechanical properties to ceramic which is why full ceramic restorations are very much admired these days. However, these are generally not used for they are expensive and not experienced for long and posterior bridges. Conventional metal-ceramic restorations are nevertheless most preferred indications in most cases. Metal has a good mechanical strength than ceramic which is why this combination makes the restoration more resistant to the chewing forces. Although it is very common, metal and ceramic has bonding problems to work with [1,2,3,4,5].

The metal and ceramic have some bonding mechanisms. These are Van der Waal s forces, mechanical retention, compression bonding and direct chemical bonding [6]. The perception of these hypothetical skills is equally important as understanding the technical skills required for ceramic application, when considering a successful metal ceramic restoration. [6, 7, 8].

The use of the word ‘bond' demands that the link between dental ceramic and metal is simply a chemical one. Indeed, the function of chemical bonds throughout the bonding process is crucial and assumes considerable importance. Besides, it is perceived that a number of non-chemical mechanisms take part in the bonding of dental ceramic and its core metal substructure. [7,9].

The porcelain-bearing area of a metal casting contains many microscopic irregularities into which opaque porcelain may flow when fired. Air abrading the metal with aluminum oxide is assumed to improve mechanical retention further by eradicating surface irregularities (stress concentrations) while increasing the overall surfaces area available for bonding [7].

Despite its existence, mechanical retention's input to bonding may be moderately limited. Dental ceramic does not require a roughened area to bond to metal, it is believed that ceramic will fuse to a well-polished surface [10], but some surface roughness is effective in increasing bonding forces [7]. After the cast of the metal for metal-ceramic restorations, technicians prepare Ni-Cr alloy before the bonding of the ceramic. Grinding the surface of metal increases roughness, aiding the retention of the ceramic to the metal by micromechanical interlocking [11, 12]. Care is needed when grinding the veneering surfaces to avoid dragging the metal over itself, which would entrap air, and grinding debris. Finishing of the surface in one direction is recommended [7]. Many authors believe that this will avoid trapping debris between folds of the metal, a particular problem when using metals with high elongation values [6, 7].

Grinding in multiple directions is also believed that may be the reason of the failure of metal and ceramic connection because grinding in multiple directions may cause some debris on the surface of the alloy. This may affect the bonding to the ceramic [11, 13]. But in most cases, it is very difficult to use carbide burs in one direction. After the surface smoothed, it should be air-abraded with aluminum oxide according to the manufacturer's instructions. This will create a satin finish on the veneering surface that is readily wettable by the ceramic slurry [6, 7, 13, 14, 15]. The aim of this preliminary study is to compare the different types of grindings for bond strength of Ni-Cr alloys to ceramic. Surface characterization of Ni-Cr alloys were also aimed to be examined on Scanning Electron Microscope after debonding.

MATERIAL AND METHODS

This study was performed on 20 specimens made of Ni-Cr alloys (20*5*0.5 mm). 20 wax patterns were prepared, and then they were invested in a phosphate-bonded investment.

The specimens were cast using an alloy, (Kera N, Germany) with a metal content as follows: %62 Ni, %25 Cr, % 10.62 Mo, %1.4 Si, % 0.01 Mn, %0. 02 C. After the cast of Ni-Cr alloys, all investment was removed with an ultrasonic cleaner. Also hydrofluoric acid was used to dissolve the refractory silica material of the investment. Sharp angles and pits on the veneering surface of the metal frame were eliminated and convex, rounded contours were created to make a smooth surface and avoid internal stresses. The specimens were divided into two groups. The first group of specimens was grinded with a carbide bur (EL5, SS White Burs Inc, Lakewood, NJ, USA) in one direction and the second group of the specimens was grinded in multiple directions. Same technician made all the grindings by using light hand pressure. Then they were air-abraded with aluminum oxide particles (Korox 50 µm grain size aluminum-oxide, Bego, Bremen, Germany) then cleaned in distilled water. Following the steam cleaning, 2 mm ceramic (Ceramico II, Ceramco Inc, Burlington, NJ-USA) was fused to metal alloy. Firing was carried out in a commercial ceramic furnace, which was programmed to follow the firing schedule recommended by the ceramic manufacturer. Then they were mounted in a universal testing machine (Lloyd, LRX, England) with a 2500N load cell and 1mm/min crosshead speed. The number of cycles was determined for both groups of specimens at set values of dynamic loading until cracks between the ceramic and metal base occurred.

A one-way statistically analysis of variance (ANOVA) was performed to analyze the differences in load at fracture between the two groups. Then fracture loads of the two groups were compared. Individual result comparisons were also undertaken using a Student's t-test. After the separation the metal surfaces were evaluated first with stereomicroscope (Leica MZ12, Heerburg, Switzerland) then one sample from the each group on SEM (Jeol Electron Microscope, Tokyo, Japan).

RESULTS

There was a statistically significant difference between the fracture strengths of two groups. The mean value of the loading forces for the fracture of the samples which were grinded in multiple directions was higher than the other group. The mean value of the group which was grinded in one direction was 57.7N; the mean value of the other group was 73.6N (Table 1).

Figure 1

Table 1: Experimental Groups and Bond Strengths (N)

Group	Mean	Std. Deviation	Median	Minimum	Maximum
One Direction Grinding	57.66N	10.14	56.42N	40.78N	76.24N
Multiple Direction Grinding	73.60N	13.53	79.12N	47.91N	86.16N

Table 1 shows the data for Student's t-test. Statistical Analysis shows that Ni-Cr alloys which were grinded in multiple directions have higher bond strengths to porcelain than the group which were prepared in one direction.

SEM AND STEREOMICROSCOPIC EVALUATION

There wasn't a clean separation between alloy and ceramic surfaces. Oxide layers were seen most on both parts of the pieces. This showed a cohesive failure between oxides layers itself. Especially, the specimens which were grinded with multiple directions have also some partial ceramic remains on the surfaces. This group also showed cohesive failure between ceramic itself and adhesive failure between oxide layer and ceramic. But samples which were grinded with one direction had mostly cohesive failure between ceramic and alloy within the oxide layer.

Figure 1 shows the sample, which was grinded in one direction, has little caves on the surface of the alloy and these caves are also not deep. This sample has a smoother surface than the other group. Figure 2 shows the sample, which were grinded in multiple directions, has more micro roughness than the sample, which were grinded in one direction. This sample has more and also larger caves than the other sample.

Figure 2

Figure 1: SEM photograph of the one way grinded metal alloy after debonding. There are less deposits on the surface (originally magnification: 750X).

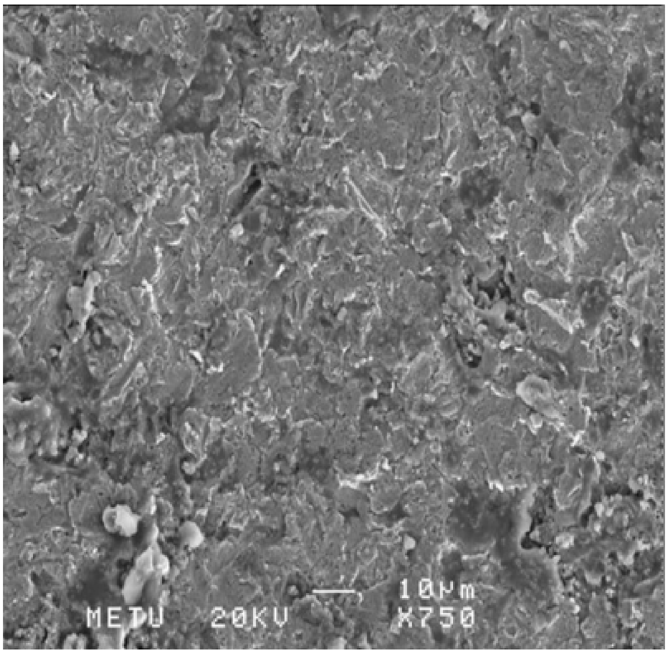
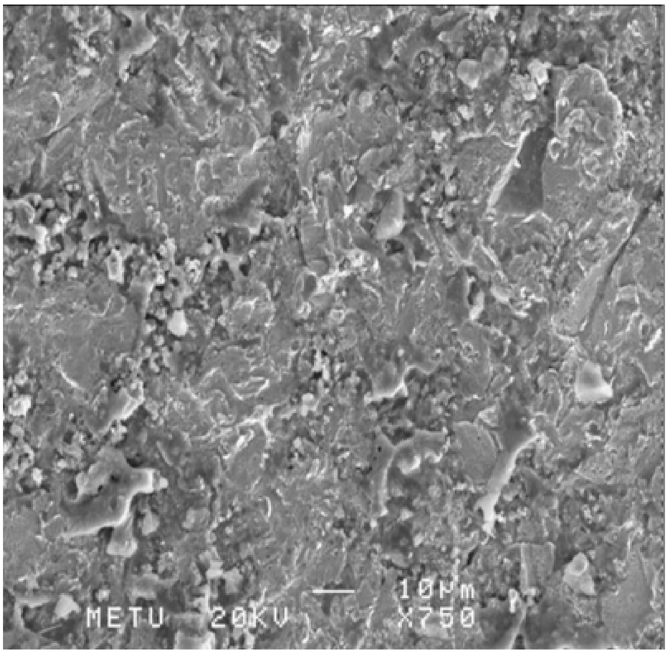


Figure 3

Figure 2: SEM photograph of the multiple grinded metal alloy after debonding. The surface roughness is increased on the surface. Surface porosities and some deposits are seen (originally magnification: 750X).



DISCUSSION

The result indicated that grinding Ni-Cr alloy with multiple directions may be an advantage to increase the bond strength between metal and ceramic. SEM Evaluation after grinding in multiple directions showed an increase on the surface roughness.

Several methods of preparing the metal surface prior to porcelain application have been reported in the literature. Wagner et al [16] found that the greater the roughness of metal surface, the greater the bond strengths. Similar findings were reported by Lavin and Custer [17] Murakami and Schulman [18] observed a reduction in contact angle between ceramic and metal as the surface roughness increased, promoting better adhesion. Mclean and Sced [19] reported that excessive roughening could result in the introduction of stress concentrations. This study also supports that the increase of the roughness of metal surface may be an advantage for the bonding to the ceramic

Airbone particle abrasion with aluminum oxide is routinely performed on the alloy casting to create surface irregularities and to provide mechanical interlocking with the opaque dental porcelain, which has sufficiently low viscosity in the firing temperature range to flow into these microscopic openings. After grinding the dental alloys, in order to obtain a satin finish, air abrading the veneering surface with a fine grit alumina is recommended. [6] In the current study Ni-Cr alloys were also sandblasted with 50 µm alumina-oxide particles. Sandblasting increased the surface area of the metal.

Grinding the surface of the Ni-Cr alloy also increases roughness, aiding the retention of the ceramic to the metal by micromechanical interlocking [11, 12]. Naylor [13] and Van Noort [11] indicated that grinding in many directions can trap debris and air in surface irregularities, which may decompose on firing and result in the presence of gas bubbles at the interface between the metal and ceramic; these bubbles cause a reduction in bond strength. Naylor [13] recommends finishing the metal in one direction only as it leaves the metal smooth and debris free. Various methods have been recommended for cleaning the metal surface prior to porcelain application: electrolytic degassing with soda [15] steam cleaning [13, 15, 20, 21]organic solvents in an ultrasonic cleaner[11], rinsing under running water [22, 23] or boiling in hydrochloric acid followed by distilled water[23]. In these experimental groups, the metal surfaces were grinded in one way or in multiple directions. The risk of metal debris maybe mostly due to using carbide burs with heavy hand pressure or the anticipated limits of remnants might be removed by sandblasting and steam cleaning.

De-gasing, the formation of an oxide layer by heat treatment in a porcelain furnace in air or a partial vacuum, is recommended to improve bonding. It allows metallic elements in the alloy to migrate to the surface to form the oxide layer; during firing the ceramic is taken above its glass transition temperature, allowing the ceramic to flow and fuse with the oxide on the metal and length of firing [11].Thick oxide layers are said to weaken bond strength [15, 24]; therefore short firing cycles [15] or removal of the oxide layer by means of sandblasting after de-gasing is recommended [24]. Graham JD et all [25] concluded that de-gassing the alloy prior to porcelain application increased the bond strength and excess surface grinding of the alloy reduced bond strength; steam cleaning the alloy surface prior to de-gassing and porcelain application also significantly reduced the bond strength. In the current study, common failure mode was cohesive in the oxide layer, this might be the reason of thick oxide layer formed. Removal of the oxide layer by means of sandblasting after de-gasing could be a useful technique to increase the bond strength between alloy and porcelain. Even the steam cleaning has been performed in the both groups; multiple grinding did not decrease the bond strength between alloy and porcelain. Maybe not the direction but the excess surface grinding is the responsible of decreasing bond strength as described previously.

Essential to the formation of strong interfacial bond is complete wetting of the ceramic on the alloy surface so the interface will be free of pores and voids. Pores are potential sites for crack nucleation. [19] Multiple grinding is believed to be the reason of pores and metal debris but if the metal frames are grinded with light hand pressure and metal surface for porcelain is set as ordered (sandblasting, steam cleaning), on the contrary there might be more retentive surface for interlocking but still debris and gas free.

Within the limitation of this preliminary study, grinding in multiple directions with light hand pressure seems to make the surface more retentive for bonding. After grinding in multiple directions, the surface of the metal frame was larger than the other sample. Air abrading the porcelain - bearing surfaces with aluminum oxide and steam cleaning might remove surface contaminants but leaves a matte finish for improved porcelain bonding. This result was also supported with microscopic and SEM evaluations. The future studies should involve different dental alloys and different porcelains to compare the effect of grinding on the metal ceramic bond strength and the surface structure and content of the dental alloys' surfaces should be reevaluated after different kinds of grindings.

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