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Surface examination of a dental CoCrMo alloy after different surface treatments

Bruno Henriques, Filipe Silva and Delfim Soares
Centre for Mechanical and Materials Technologies
E-mail: brunohenriques@dem.uminho.pt

KEYWORDS

CoCrMo alloy, alumina, oxidation, grit-blasting

ABSTRACT: INTRODUCTION

This work was designed with the purpose to investigate the mechanical and chemical modifications produced by grit-blasting treatment in different stages of CoCrMo alloy's surface preparation for metal-ceramic bonding in dental restorations.

Porcelain-fused-to-metal (PFM) is a widely used technique in dental restoration. It combines the strength of a metal substrate with the aesthetic of feldspathic porcelain veneer. Noble based alloys started to being replaced by base metal alloys, such as NiCr and CoCr alloys, due to their lower price and excellent mechanical properties. Allergenic problems have raised some barriers in the use of Ni containing alloys. CoCr alloys are regarded to be more biocompatible and therefore, more adequate for PFM in dental restorations.

Base metal alloys are formed by elements that are able to be oxidized, especially chromium. They form a surface oxide layer during the "degassing" treatment, which is responsible for developing a bond with porcelain. One of the challenges in this type of alloys is controlling the excessive formation of chromium oxide that results in lower bond strength between metal and porcelain. The oxides formed on dental PFM alloys must be adherent to its metal in order to produce a suitable metal-ceramic bond strength.

The adhesion mechanism that plays a major role is the mechanical interlocking. This effect is generally produced by grit-blasting surface treatments , resulting in substancially rough surfaces that are filled by fused porcelain, creating this way a mechanical retention. Grit-blasting is commonly made by alumina particles in the divesting stage and after preoxidation heat treatment. In the latter case, it is performed a light grit-blasting.

MATERIALS AND METHODS

In this work was used a CoCrMo dental alloy (Nobil 4000, Nobilmetal, Villafranca d'Asti, Italy) which chemical composition, as supplied by the manufacturer, is exhibited in Table 1.

Table 1: Base Alloy Composition [wt%]

Co	Cr	Mo	Si	Fe, Mn, W
62	31	4	2.2	Trace

Metal specimens were obtained by lost wax process casting, in an arc melting furnace, (Degumat 2033, Degussa, Germany) which produced metal rods of approximately 4.5 mm of diameter and 40 mm length. After divesting, several specimens were then obtained by cutting 4mm height metal substrates in a precision cut-off machine (Minitom, Struers). All substrates were ground and polished with 2400-grit SiC sand-paper. Then, some were alumina blasted with Ø110μm-alumina grit at a pressure of 3bar. All of them were ultrasonically cleaned in an alcohol bath for 10 min and rinsed in distilled water for another 10 min to remove contaminants. Then they were dried with adsorbent paper towels.

The preoxidation heat treatment was performed in the polished samples at 1200ºC for 10 min in air, after which, the oxide layer formed on the metal's surface was removed by two route: light grinding (2400-grit SiC sandpaper) and alumina blasting (Ø110μm; 0.5bar).

It was performed a SEM-EDS analysis (Nova 200, FEI, Oregon, USA) on the following metal's conditions: (1) non-preoxidized; (2) preoxidized and (3) preoxidized followed by alumina blasting (Ø110μm; 0.5bar).

The surface mechanical analysis was performed by the means of microhardness tests (Microhardness tested, type M, Shimadzu, Japan) and roughness tests, Ra, (Perfilometer Mahr S5P, Germany) in polished (2400-grit SiC sandpaper) and sandblasted (Ø110μm; 3bar) non-preoxidized specimens.

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RESULTS AND DISCUSSION

Three types of surface conditions were chemically analyzed: Type 1- non-preoxidized polished surface; Type 2 - preoxidized polished surface; Type 3 – alumina blasted surface after preoxidation (Figure 1). As expected, it was observed an oxygen concentration increase, on the metal's surface, after preoxidation heat treatment. The greater oxygen level had origin in oxides formed on the surface during heat treatment especially CrO_2 and Cr_2O_3. At the same time, it was also registered a significant reduction of carbon content after preoxidation.

Surface's chemical analysis showed that sandblasting does not remove the oxides from the metal surface in a great extent. The amount of oxygen in the surface remains in a high level (Type 3), which means that instead of removing the oxide layer from the surface alumina blasting is retaining part of it.

It was also found Al traces on the sandblasted surface that have its origin in alumina powders retained after sandblasting once no Al was detected in any previous chemical analysis of the alloy.

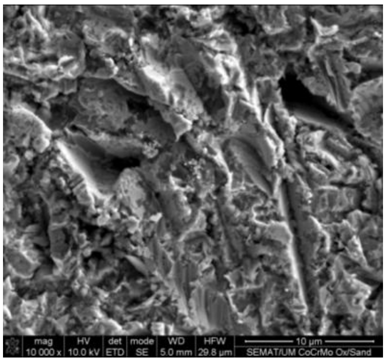

Figure 1: Grit-blasted Surface After Preoxidation

The finding of alumina contamination in sandblasted metal surfaces was already reported by other authors and some studies point alumina as producing positive effects on metal-ceramic bond strength.

The microhardness and roughness tests performed on CoCrMo sandblasted surfaces allowed to characterize the hardening mechanisms and topography modifications produced by sandblasting on metal's surface. Alumina blasting treatment produced an approximately ten times rougher surface relatively to polished one, Ra=0.58±0.07µm and Ra=0.05±0.07µm, respectively (Figure 2).

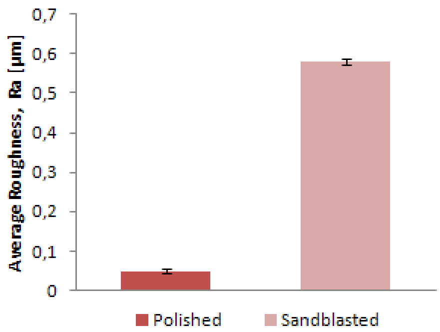

Figure 2: Average Roughness for Different Surface Treatments

It not only produced a roughening effect but also introduced considerable cold work into the surface layer of the metal. The microhardness analysis of metal's surface, before performing the preoxidation treatment, revealed an 84% increase in surface's hardness, for sandblasted specimens, relatively to the polished specimens, 614±62HV/1 and 334±31HV/1, respectively (Figure 3).

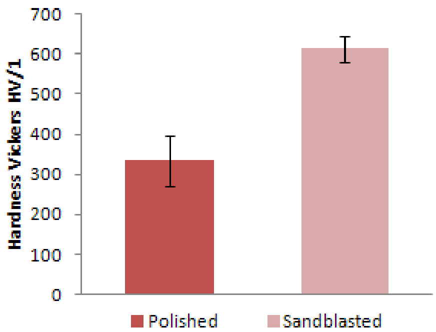

Figure 3: Hardness Vickers (HV/1) for Different Surface Treatments

CONCLUSIONS

Sandblasting treatment does not entirely remove the oxide layer formed during preoxidation heat treatment. It rather disrupts and embeds part of it in the deformed metal surface.

Alumina blasting of CoCrMo surfaces leaves contaminants on surface, thus altering the chemical composition of metal's surface.

Alumina sandblasting proved to produce both mechanical and chemical effect on preoxidized metal's surface, resulting in two complementary effects for metal-ceramic bond strength enhancement.