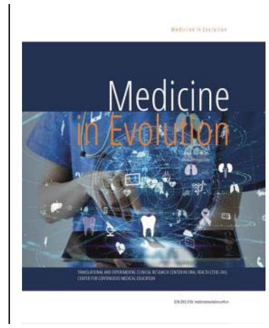
The Influence of Metals Processing Technologies on Metal-Ceramic Interface



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Abstract

Aim and objectives

The aim of this study is evaluation of metal-ceramic prostheses interface. The metallic frameworks were made with two technologies.

Material and methods

For samples manufacturing, was used the NeWay Open Technology Scanner. On the virtual cast, was designed the metallic framework with EXOCAD program for SLS. The patterns for the melting-pouring technology were milled in wax using the Zenotec Select Hybrid. The veneering of Co-Cr metallic frameworks was made with IPS d-SIGN (Ivoclar Vivadent) ceramic. The samples were cut and investigated with the optical microscope.

Results

Optical Microscopy revealed inclusions and dehiscence on metal-ceramic interface of pour-melted frameworks. The interface of ceramic and sintered framework had dehiscence and the veneering ceramic showed spherical inclusions.

Conclusions

The errors of detaching the veneered ceramic are reduced in case of SLS due to the adherence of ceramic which is higher for SLS metallic infrastructures.

Keywords: metal framework, SLS, metal-ceramic interface

INTRODUCTION

The patients demandes on the aesthetic results of the prosthodontic restorations have increased significantly due to the concept of "metal-free dentistry" (1). Melting-casting still remains the most used technological option for obtaining metallic frameworks, although multiple errors occur and require a lot of working time (2). The options of making computer-assisted dental prostheses (CAD/CAM) using subtractive or additive technologies have become very popular due to high accuracy (3, 4).

The subtractive method of milling the metallic disc is considered a waste of material. Pre prior studies, 90% of raw material is lost in manufacturing (4, 5).

In order to eliminate the disadvantages represented by the material loss and pollution in case of dry milling (3), the use of addition methods like rapid prototyping technology is now an option that allows the making of metal frameworks for fixed prosthetic restorations. Selective Laser Sintering (SLS) was introduced in dentistry to make the frameworks of fixed and partial prostheses (3, 4). Selective laser melting has as a principle the addition of successive layers of metal powder followed by melting and rapid solidification. Through this process is obtained a fine and homogeneous microstructure, while in the stages of conventional casting there is always the risk of overheating and segregation (5, 6).

SLS is an additive technique that allows the generation of a complex three-dimensional structure to be consolidated by successive selection of metal powder. The prostheses are built through layers, using the thermal energy provided by a computer-focused laser beam (7).

Aim and objectives

The aim of this study is evaluation with the Optical Microscope the metal ceramic interface of metal-ceramic prostheses. The metallic frameworks were made with Selective Laser Sintering (SLS) technology and compared with the ones made through melting-pouring classic technique.

MATERIAL AND METHODS

For this study were made 12 samples, of full physiognomic metal-ceramic crowns. Two groups were created, six samples for each group of prosthetic restorations. For the first group the metal frameworks were obtained by the classic melting technology with alternative protocol regarding the wax models and for the second group, SLS technology was used. Selective Laser Sintering is replacing the conventional casting of the metal alloys. In both situations, Co-Cr metal alloy is use for the design of metallic infrastructure.

The scanning of the working cast was done using the NeWay Open Technology Scanner. The scan was followed by the "Order from" file in which the dental abutments were selected, the type of restoration (fixed partial prosthetic restorations), the type of material (wax pattern respectively Co-Cr). This was followed by scanning the entire cast at a low resolution, to obtain an overview image and the scanning of each abutment.

The steps of making the design with the EXOCAD software were as following: first was marked the insertion axis of the future restoration and was drawn the limit of the preparation. The design of the frameworks had the purpose to define the internal surface, this stage is being called "interface". Depending on the material used for the infrastructure, was selected the appropriate thickness of the space for the cement film. This cement film comprises 3 areas: "cement gap" - it is applied at a distance of 1 mm from the marginal limit to "extra cement gap" - which is found on the entire surface of the dental abutment. The transition from "cement gap" to " extra cement gap” is given by “smooth distance”. The values of these cement areas are: "cement gap" - 0.080 mm; "extra cement gap" - 0.100 mm.

By similarity, the program also draws the outer surface of the framework. The thickness is given depending on the type of processed material, sintered or milled (Co-Cr alloy, wax). The design of the metal framework and the design of the wax pattern of the future metal framework is accessed by the "frame design". The virtual wax knife can be used to adjust the occlusal surface, according to requirements, so that both the thickness of the metal frameworks and the thickness of the wax pattern frameworks are 0.50 mm. In the stage called "finalize", the last touches are made and the data file obtained is saved, so the FPR design is stored and can be transmitted to the CAM module (Fig. 1).

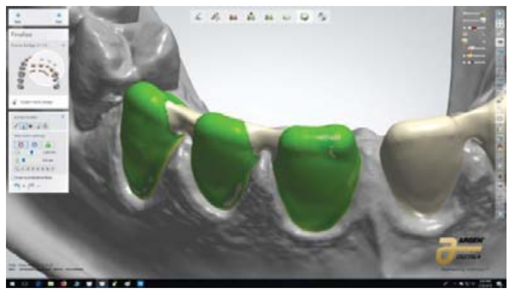


Figure 1. The creation of the metallic framework design in "Frame design"

The strategy and stages of manufacturing the sintered frameworks were preceded by several geometric decisions regarding the position of the frameworks on the disk during the sintering process. Firstly, the framework is positioned upside down to ensure well-finished plans, and secondly, the frame is left tilted to reduce the effect of scale and the volume of any supporting structures. The.stl data file was transmitted to the Phenix PXS 3D laser sintering device, and a specially Cr-Co alloy (Starbond CoS 16 Powder from Scheftner Dental Alloys) was used for sintering.

The sintering process takes about 6 hours. The disc on which the prosthetic frameworks are located is placed in a preheating oven, which is rises to a temperature of 240˚C, 10˚C per minute. At this temperature is kept for 35 minutes. Next, the temperature is rising to 820˚C, with 20˚C per minute and is maintained at this temperature for 45 minutes. After the 45 minutes, the oven temperature is gradually decreasing to 600˚C and during this time the disc is inside the oven. At this point, it can be removed from the oven and allowed to cool gradually. Due to the high precision of the SLS machine, to verify the adaptation of the prostheses was easy, thus it was demonstrated that no major processing was required.

The polishing of the surfaces was made using tungsten carbide burrs, which are suitable for Co-Cr alloys. The network of metallic rods was removed with a disc, then with rotary tools, respectively hard burrs. The metallic component was processed and adapted, followed by the blasting and final cleaning of the metal surface with the steamer.

The strategy and manufacturing stages of the milled wax pattern, used the Zenotec select hybrid system, which combines a CNC (computer numerical control) milling system that offers a state-of-the-art technology (simultaneous 5-axis milling) with the advantage of very compact external dimensions. It is chosen the wax block for the milling, the bar code is scanned and then the wax-pattern is positioned on the wax block. The computer automatically generates the clamping rods. The milling of 3-elements wax pattern takes 12 minutes.

The patterns are easily removed from the wax block with a scalpel. Further, are chosen and applied the casting rods with a diameter of 2 mm and 3 mm, respectively, and the wax pattern were prepared for investing and casting. After the investing, the assembly was preheated at 8000C for 60 minutes followed by a rise of temperature to 9500C. At this temperature, takes place the melting at pouring of the Co-Cr alloy. The technological process ends with the removal of investment material and finishing.

The next step was to apply IPS d-SIGN ceramic (produced by Ivoclar Vivadent) on the frameworks in several stages. The thermal treatment of the ceramic was made at the sintering temperature recommended by the manufacturer with the programmed P300 oven from Ivoclar Vivadent.

The fix partial prostheses were analysed using optical microscopy. The metal-ceramic interface was evaluated by an invasive technique. With the help of a diamond disk mounted on the rotary instrument using cooling with air and water. The samples were sectioned in the areas of interest: the structures on the retainer element and the rigid connectors. Buccal -oral sections were made for all the samples (Fig.2).

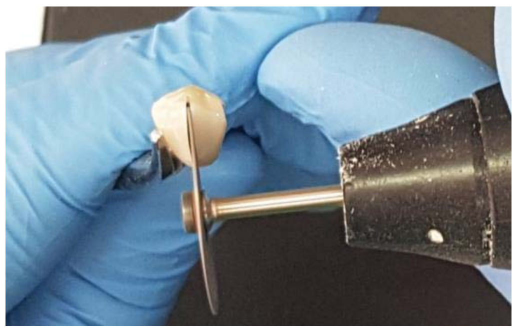


Figure 2. Sectioning on the retainer element with cast metallic framework

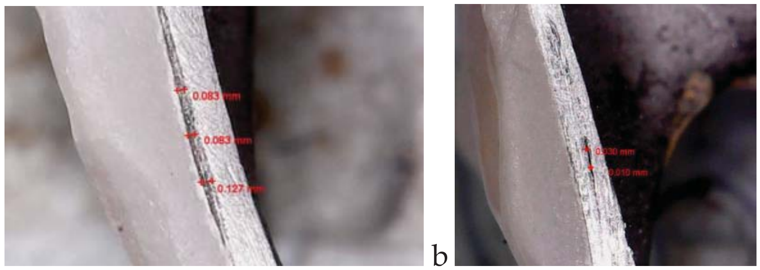
The sectioned samples were cleaned with the steamer and polished with Klingspor abrasive paper with different granulation size in descending order: 220 microns, 360 microns, 800 microns and 1200 microns.

RESULTS

After preparing the samples, they were analyzed under an optical microscope. To analyze the metal-ceramic interface, it was used the TM-M200 digital microscope from JINGOU, which has the following technical characteristics: -Video capture resolution: 160x120, 320x340, 640x480, 1280x1024, 1600x1200, Still Image Capture Resolution: 160x120, 320x340, 640x480, 1280x1024, 1600x1200, -Light Source In built White LED x 8 PCS, Snapshot Software and Hardware.

The microscopic evaluation of the samples revealed the presence of defects, inclusions and dehiscence at the interface between the metal and the ceramic material. It was detected a defect in the metal-ceramic interface on the buccal-oral section of the mesial retainer element.

The characteristics of the interface defects are: dehiscence between the cast alloy and the sintered ceramics of 0.083 mm - 0.127mm (Fig.3a). It was detected at the level of the metallic component of the prosthesis with the cast framework in the buccal-oral section, a casting defect in the mass of the material (Fig.3b). The evaluation in the area of the connector for the prosthetic restoration with metal cast framework revealed the existence of gaps at the interface and the existence of inclusions in the sintered ceramics (Fig.4).

a 

b

Figure 3. a. The aspect of the metal-ceramic interface with the defects. b. The aspect of the defect in the cast metal framework.0.010mm-0.030mm

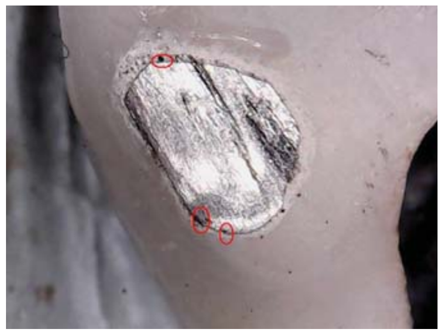
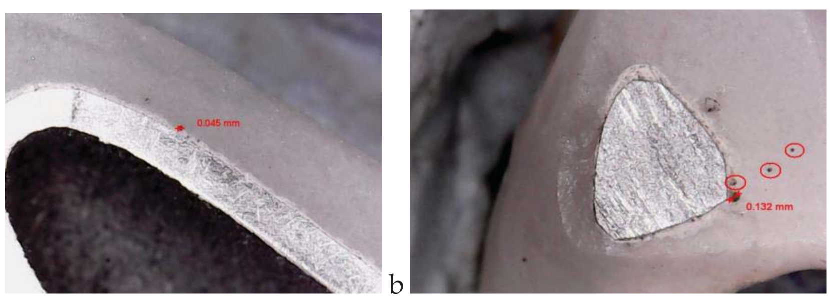


Figure 4. Image with the connector section – the cast framework visible

a 

b

Figure 5. a. The aspect of the metal-ceramic interface for the prosthetic restoration with the sintered framework, buccal-oral section. b. Inclusions in the ceramic mass. Section aspect of the connector - sintered framework

When evaluating the aspect of the metal-ceramic interface for the restorations with sintered framework, in the buccal-oral section an area without dehiscence was highlighted, but in the ceramics was observed the existence of spherical inclusions (Fig.5). At the evaluation in the area of the connectors, inclusions in the ceramic mass were found.

DISCUSSIONS

The processing performance of metal frameworks obtained by the SLS technique depends on several parameters which include laser beam size focus, laser power, sintering speed, average particle size of the base powder, layer thickness, layer overlap and atmospheric processing conditions (8, 9).

The researchers found that the internal adaptation, the marginal adaptation, the precision of laser sintered metal restoration are better than those obtained by traditional casting techniques. In the study comparing the marginal adaptations, the smallest marginal discrepancies were obtained at the level of the laser sintered metal frameworks 51,78µm, while in the case of the conventional method of obtaining the metal framework, the marginal discrepancies of the framework was 80,39 µm (9, 10).

The strength of the metal-ceramic bond of the SLM samples and that of the conventional metal cast after 3, 5 and 7 burnings did not accentuate major differences according to the test results. On the other way, after more extensive analyzes, the metal framework obtained by melting-casting, after 3, 5 and 7 burns, showed a significantly lower adhesion to the ceramic mass compared to that of the metal made by SLM (8).

The different manufacturing techniques influence the morphology and the surface thickness of the Co-Cr dental alloys. Thus, the adhesion strength of the groups exceeds the minimum acceptable value, recommended by ISO 9693, of 25 MPa (11,12,13). Thereby, the frameworks from Co-Cr alloy prepared with SLM techniques could be a promising option for metal-ceramic restoration (13).

The high costs and environmental pollution due to metal dust are the consequences of computer-assisted milling, as a subtractive manufacturing method. In comparison, the SLM technique is an additive manufacturing method. It consists of a high power laser that is used to melt the Co-Cr powder layer. This melting leads to the formation of metal substrates that provide structures with up to 100% density without porosity and material waste (13, 14).

The advantages of SLS technology, in terms of reducing human errors while maintaining a constant quality of restorations recommends this process.

CONCLUSIONS

By making the metal components using the SLS technology, having a smaller number of working steps, the sources of errors encountered in melting-casting are eliminated. The metal frameworks made by SLS technology has fewer structural defects compared to that obtained by traditional technology.

The metal-ceramic interface in the case of SLS structures showed a lower number of defects. The incidence of ceramic detachment, due to failure, can be reduced by using SLS technology in the manufacture of the metal component.

The metallic components obtained by SLS, compared to those made by melting-casting, contain less porosities and inclusions.

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