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# Effect of the abrasive blasting treatment on the quality of the pressed ceramics joint for a metal foundation

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## ABSTRACT

**Purpose:** Despite the increasing number of new advanced materials and constructions in prosthetics, ceramic crown and bridges with a metal foundation are still popular among patients. Facing ceramics can be applied on the metal foundation by the pressing or firing method. One of the more frequent damages is the chipping of the facing ceramics from the metal foundation. In order to improve the quality of the joint between the metal foundation and the facing ceramics, the metal surfaces usually undergo abrasive blasting treatment with the use of different treatment parameters, such as the working pressure and the grain size of the abrasive material.

**Design/methodology/approach:** The study presents the research of the effect of the working pressure during pressing on the quality of the metal-pressed ceramics joint. The selection of the abrasive blasting parameters was made based on the earlier studies of the strength of ceramics fired on metal. For the treatment, 110 μm grain and 0,2; 0,4; 0,6 Mpa pressures were applied. After the ceramics pressing process, the samples underwent shear strength tests.

**Findings:** The obtained results were much lower than in the case of a similar joint but with fired ceramics, and they did not meet the requirements of the respective standards. The applied treatment pressures did not affect the strength of the joint. Such results can be explained by the fact that the metal foundation exhibited insufficient roughness after the treatment. While, in the case of the fired ceramics, the gains size 110 μm was optimal, in the case of the pressed ceramics, of a higher viscosity, the ceramics flow did not sufficiently fill the surface irregularities, which caused a lower joint strength.

**Originality/value:** This results from the fact that the surface treatment parameters used before the ceramics firing process cannot be directly transferred to the case of the pressed ceramics.

**Keywords:** Abrasive blasting; Metal–ceramic joint; Strength

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## PROPERTIES

## 1. Introduction

Despite the increasing number of new advanced materials and constructions in prosthetics, ceramic crown and bridges with a metal foundation are still popular among patients. These prostheses provide a stable and strong construction as well as high esthetics [1]. Facing ceramics can be applied on the metal foundation by the pressing or firing method. Pressing of ceramics consists in providing the assigned shape at a high temperature by means of a proper pressure applied on the ceramic mass. Hot pressing reduces the risk of the occurrence of pores and results in an advantageous dispersion of the crystalline phase in the vitreous mass [2]. Ceramics assigned for pressing consists of leucite ceramics and lithium disilicate ceramics. The leucite ceramics contains 20-55% leucite crystals [3]. The microstructure of the pressed ceramics consists of leucite crystals of the size (1-5 μm), scattered in the viscous mass [2]. Its advantages include a twice as high bending strength in comparison to the traditional ceramics 109-153 MPa [4].

As prosthetic constructions are exposed to loads resulting from the chewing process in the oral cavity, their durability and exposition to damage is more and more often the subject of extensive research [5,6]. One of the more frequent damages is the chipping of the facing ceramics from the metal foundation. The strength of the ceramic-metal joint affects the quality of the prosthesis and thus, also, the level of satisfaction of both stomatologists and their patients. Research is being constantly performed on the improvement of the strength of these products and the prevention from a slow damage of the artificial tooth surface as well as its joint with the foundation.

The abrasive blasting treatment is applied in many production processes. The purpose of this process is to obtain the designed surface parameters. It is widely used in various stages of prosthetic element production. It aims at removing the mass residue from the metal surface, as well as it is an important stage in the process of preparing the surface for the application of facing ceramic or composite materials. The abrasive blasting treatment affects the state of the metal surface, the preparation of which is significant for the durability of the product at the stage of joining the construction elements of the prosthesis. That is why the main aim of the research is to improve the strength of the joint between them. To that end, it is important to remove the minor, weakly joined, surface structures, i.e. the remainder of the materials formed during the earlier treatment stages. The roughness of the surface is used to obtain a mechanical joint between two materials. The surface developed as a result of sand blasting also increases the area of a possible joint [7,8].

Another issue related to the abrasive blasting treatment is the possibility to drive the particles of the abrasive material into the metal structure during the treatment process. This results from the high kinetic energy obtained from the air stream [9]. The elements of the abrasive material driven into the surface are significant for the quality of the joint and the durability of the prosthetic restoration. They can constitute the areas of stress concentrations and cause the formation of cracks in the dental ceramics [10].

The state of the surface after the abrasive blasting treatment can be affected by many factors, such as: the granularity of the abrasive material used in the abrasive blasting treatment, the sand blasting angle, the pressure applied in the abrasive blasting treatment and the amount of the abrasive material driven into the metal structure. A strong joint is crucial. It is also obtained by way of an interaction of the ceramics with the metal oxides on the metal surface and by the roughness of the metal surface [2,11-13]. The state of the surface after the abrasive blasting treatment, resulting from the applied treatment parameters, affects the strength of the metal-ceramic joint. For the ceramics fired on the metal foundation, the best treatment parameters were: the grain size of 110 μm and the pressure of 0.4 MPa [14,15].

## 2. Research objective

The aim of the research was to determine the effect of the pressure applied in the abrasive blasting treatment on the quality of the joint between the pressed dental ceramics and the metal foundation.

## 3. Material and methods

For the tests, 39 metal cylinders were prepared, 15 mm and φ7 mm high, made of the Magnum Nitens alloy by Degudent. The chemical composition of the alloy obtained by the X-ray fluorescence spectrometry, with the use of the spectrometer SRS300 by SIEMENS is presented in Table 1.

The samples were divided into three groups, 13 samples each. The front surfaces of the cylinders from all the groups underwent the abrasive blasting treatment. Corundum ($Al_2O_3$) of the grain size 110 μm was used as the abrasive material. The samples from the first group were sand blasted with the stream pressure of 0.2 MPa, the ones from the second group – with 0.4 MPa, and the ones from the third group – with 0.6 MPa.

Table 1.
Chemical composition of the tested alloy

| Alloy element content, % wt. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Element | | Co | Cr | Mo | W | Si | Nb | Fe |
| Content % wt. | | Residue | 28.49 | 4.21 | 3.11 | 0.71 | 0.34 | 0.42 |

The distance of the operating nozzle from the treated surface equalled about 50 mm, whereas the angle between the treated surface and the nozzle axis was approximately 45°. After the abrasive blasting treatment, the samples were cleaned, with the use of a steam generator under pressure, of the abradant grains loosely joined with the surface, which had not been driven into the metal surface. Next, the samples were dried. The surfaces prepared in this way then underwent roughness tests. The following parameters were determined: Ra (mean arithmetic profile deviation), Rz (height of the roughness profile according to 10 points), Rt (total profile height), Rc (mean height of the profile element) and Rvo (renewable volume obligation), that is the volume of the liquid detention in the roughness profile. The selection of the first four parameters was justified by the fact that these roughness parameters are the ones usually applied, which provides the opportunity to compare the obtained results with the literature data [16]. What is more, in the study [17], a dependence was demonstrated between the parameters Rt and Rc and the strength of the ceramics fired onto the metal bases. In regard to the renewable oil obligation Rvo, it seems that this may be an important parameter as the strength of the metal-ceramic joint is mainly based on the ceramics being mechanically anchored in the metal surface irregularity, and, in order for this to happen, the liquid ceramics should be able to flow into these irregularities. The results of the roughness measurements are presented in Table 2. The next step was pressing the layers of the ceramics CERGO KISS by Degudent onto the treated surfaces. The pressing process lasted 45 min, and the pressing temperature was 950°C.

The samples prepared in this way underwent strength tests by way of technological shearing. The literature reports that metal-ceramic joints are mainly exposed to shearing loads and from the point of view of the durability of prosthetic restorations, the metal-ceramic joint's durability seems to be the most important, as one of the most frequent damages is the chipping of the ceramics from the metal foundation [2,14]. The strength tests were performed by means of the strength tester Zwick Roller 5000 with the feed rate of 2 mm/min. The results of these tests are presented in Table 1. In order to determine whether the obtained joint strength results differ statistically, NIR and Sheffe tests were conducted, and the results are compiled in Tables 3 and 4.

After the strength tests were performed, the obtained sample fractures underwent fractographic examinations. To that end, they were observed by means of a scanning electron microscope. The aim of the test was to determine the character of the fractures formed in the shearing process and the location of the cracking course. These examinations make it possible to point to the weakest area of the tested joint. Exemplary images of the samples sand-blasted with the 250 µm grain are shown in Fig. 1.

## 4. Results

The strength test results are included in Table 2, whereas Tables 3 and 5 present the results of the statistical analysis. Table 1 presents the results of the roughness measurements. Fig. 1 show the results of the fractographic tests on the samples treated with different pressures.

Table 2.
Roughness test results

| Parameter | Sand blasting pressure, MPa | | | | | |
|---|---|---|---|---|---|---|
| | 0.2 | | 0.4 | | 0.6 | |
| | mean | standard deviation | mean | standard deviation | mean | standard deviation |
| Ra, µm | 0.89 | 0.21 | 1.23 | 0.31 | 1.75 | 0.79 |
| Rz, µm | 8.69 | 3.11 | 12.21 | 3.74 | 14.97 | 6.25 |
| Rt, µm | 12.05 | 4.80 | 15.35 | 5.18 | 17.37 | 5.34 |
| Rc, µm | 4.51 | 1.13 | 6.19 | 1.34 | 6.93 | 2.67 |
| Rvo, µm³/µm² | 0.0015 | 0.0008 | 0.0019 | 0.0009 | 0.0028 | 0.0011 |

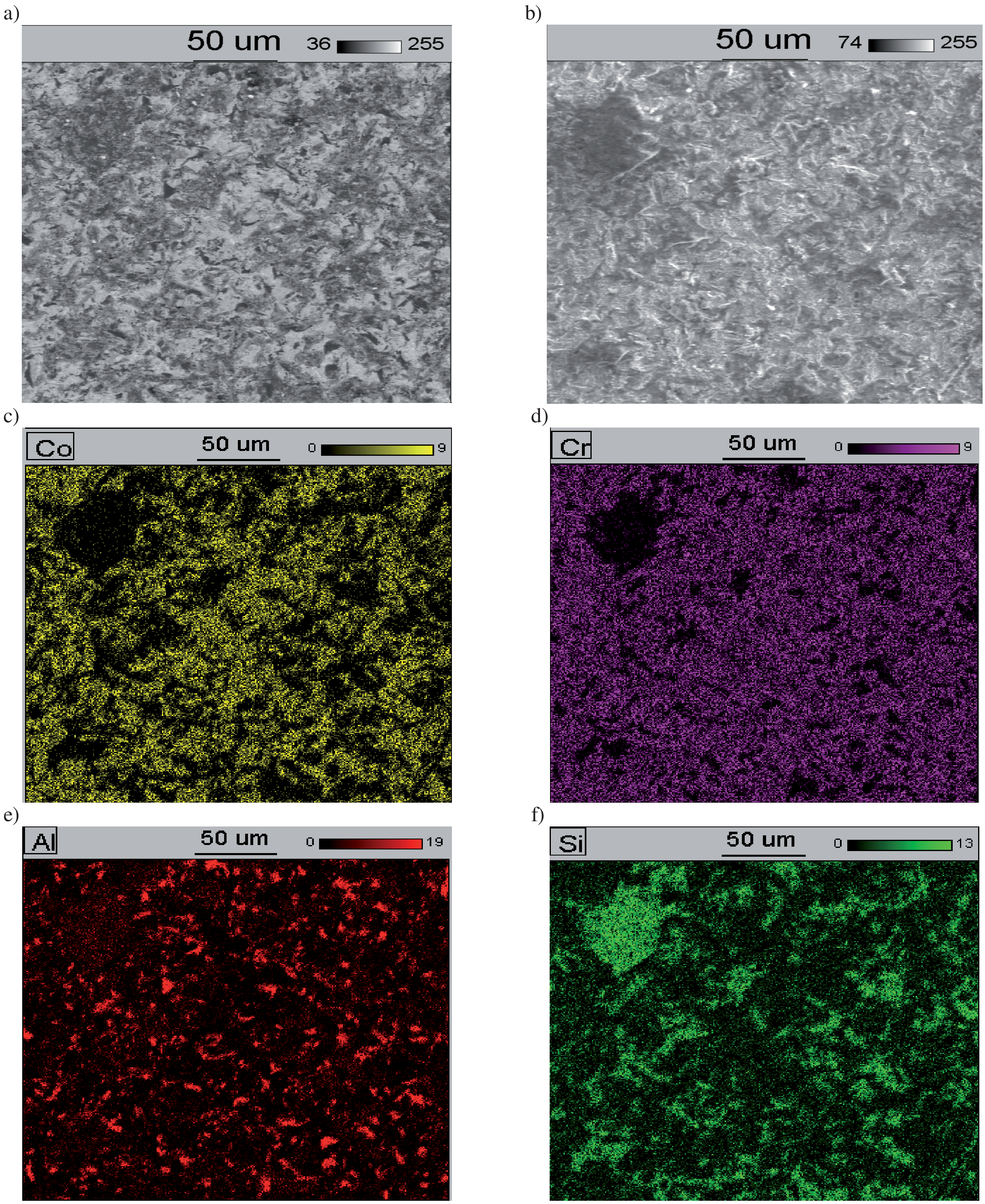


Fig. 1. Microscopic image and element surface distribution maps on the fracture of a sample treated with the pressure of 0.2 MPa, a) Back-scattered electron image, b) Secondary electron image, c) Surface distribution of Co, d) Surface distribution of Cr, e) Surface distribution of Al, f) Surface distribution of Si

Table 3.
Results of the strength tests on the metal-ceramic joint depending on the applied treatment pressure

| Pressure, MPa | Strength, MPa | Standard deviation |
|---|---|---|
| 0.2 | 7.44 | 1.78 |
| 0.4 | 7.43 | 1.85 |
| 0.6 | 7.08 | 1.39 |

Table 4.
NIR test of the significance of the strength result differences depending on the grain size

| Pressure | 0.2 MPa | 0.4 MPa | 0.6 MPa |
|---|---|---|---|
| 0.2 Mpa | – | 0.989 | 0.768 |
| 0.4 Mpa | 0.989 | – | 0.785 |
| 0.6 Mpa | 0.768 | 0.785 | – |

Table 5.
Sheffe test of the significance of the strength result differences depending on the grain size

| Pressure | 0.2 MPa | 0.4 MPa | 0.6 MPa |
|---|---|---|---|
| 0.2 Mpa | – | 0.477586 | 0.511871 |
| 0.4 Mpa | 0.477586 | – | 0.352950 |
| 0.6 Mpa | 0.511871 | 0.352950 | – |

## 5. Discussion of results

In all the treatment variants, the obtained shearing strength value was approximately 7 MPa. The statistical analysis did not show any differences between the particular groups. The value of this stress is significantly below the requirements for metal-ceramic joints in prostheses. The relevant standards and specifications state the required value as approximately 27 MPa, although the literature also provides much higher values, even up to 50 MPa [2,14,15]. While the presented results refer to fired ceramics, not ceramics pressed onto metal, the obtained values are too low and they do not ensure the proper functioning of the prosthetic elements made by this method. The performed fractographic tests showed that the joint cracking in all the groups mostly occurred on the metal-ceramics boundary, with a slight participation of the fracture within the ceramics. This is proven by the surface element distributions performed on the obtained fractures. The area occupied by cobalt and chromium, i.e. the alloy elements, in all the cases, is significantly smaller than the area occupied by the ceramics elements, i.e. silicon and aluminium. Considering the fact that, in the EDS method, the signals coming from silicon and tungsten (another alloy element) overlap and are difficult to separate regarding the presence of ceramics, the surface aluminium content should rather be analysed, while, as can be seen in Figs. 1e, 2e, 3e, only minor points proving the presence of this element are observed on the surface. The small sizes may also prove that some of them are the remains of the abradant grains driven into the surface during the abrasive blasting treatment. The above considerations confirm that the weakest link in the metal-pressed ceramics joint is its boundary. In the properly fired ceramics, the factures occur both at the joint boundary and through the metal and ceramics [2,15].

As it can be seen in the presented research, the proposed parameters of abrasive blasting treatments did not ensure the proper strength parameters of the metal-pressed ceramics joint. Considering the fact that the basic joint in this type of systems should be the mechanical joint resulting from the pressed ceramics flowing into the metal surface irregularities, we can conclude that this flow was insufficient. This is confirmed by the fractographic tests demonstrating a fracture on the metal-ceramic boundary. The selection of the abrasive blasting treatment parameters resulted from the analysis of the literature data, which suggested that the pressure of 0.4 MPa ensures the best strength of the joint [14,15]. However, those studies referred to ceramics fired onto a metal base. Considering the fact that ceramics is pressed at lower temperatures than it is fired, in the first case, it has a higher viscosity, and so, we observe problems connected with its flow and thorough filling of the irregularities in the treated metal surface. This results from the fact that the roughness parameters obtained after the abrasive blasting treatment can be too low to ensure a proper joint between the metal and the pressed ceramics.

## 6. Conclusions

1. The applied abrasive blasting treatment parameters do not ensure a proper metal-pressed ceramics joint.
2. It is not possible to apply the abrasive blasting treatment parameters used for fired ceramics in the process of surface treatment in the case of pressed ceramics.

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