UDK 666.597:620.179.11
Original scientific article/Izvirni znanstveni članek

ISSN 1580-2949
MTAEC9, 47(5)653(2013)

EVALUATION OF THE EFFECTS OF SURFACE TREATMENTS ON DIFFERENT DENTAL CERAMIC STRUCTURES

OCENA VPLIVA OBDELAVE POVRŠINE RAZLIČNIH DENTALNIH KERAMIK

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Prejem rokopisa – received: 2013-02-20; sprejem za objavo – accepted for publication: 2013-03-05

The surface treatments applied to porcelain materials can be different overglaze methods, chemical interactions and polishing techniques. The aims of these methods are the most durable restoration and the smoothest surface. The smoothness attained with these processes is important due to the following reasons: reduction of the bacteria remaining in the pores of a surface, improvement of gingival health and esthetic view, and prevention of an abrasion of the opposite canal.
The aim of this study is to assess different surface-finishing operations that are applied to widely used porcelains in prosthetic dentistry using SEM (a scanning electron microscope). In the experiments seven different surface finishing operations (sandpaper, rubber, Sof-Lex, HP paste, autoglaze, overglaze and ion exchange) were applied to four different commercial porcelains (IPS d. SIGN, Antagon, Ceramco 3, Vitadur Alpha). The effects of various surface-finishing operations on porcelain are micromorphologically evaluated (a SEM analysis). The results showed that the smoothest surfaces were obtained with the overglaze and autoglaze, followed by HP paste, rubber, Sof-Lex and sandpaper. In addition, the smoothness values of HP paste proved that it can be safely used in clinical surface-finishing operations.

Keywords: dental porcelain, SEM, surface finishing

Pri obdelavi površine porcelanskih materialov lahko uporabljamo različne metode: glaziranje v peči, kemijske interakcije in tehnike poliranja. Namen teh metod je največja zdržljivost, kot tudi najbolj gladka površina. Gladkost, dobljena pri teh postopkih, je pomembna zaradi naslednjih razlogov: zmanjšanje števila bakterij, ki ostajajo v porah na površini, izboljšanje zdravja obzobnega tkiva, boljši estetski videz, preprečevanje obrabe.
Namen te študije je oceniti površine pri različnih postopkih obdelave porcelana, ki se uporablja v protetičnem zobozdravstvu, z metodo SEM (vrstična elektronska mikroskopija). Pri eksperimentih je bilo uporabljeno sedem različnih operacij obdelave površine (brusni papir, guma, Sof-Lex, HP-pasta, samoglaziranje, preglaziranje in izmenjava ionov) pri štirih različnih komercialnih porcelanih (IPS d. SIGN, Antagon, Ceramco 3, Vitadur Alpha). Učinek različnih operacij obdelave površine na porcelanih je bil mikro-morfološko ocenjen s SEM-analizo. Rezultati so pokazali, da je bila najbolj gladka površina dosežena s prepoliranjem in z avtoglaziranjem, nato s HP-pasto, gumo, softlexom in brusnim papirjem. Dodatno je gladkost pri uporabi HP-paste pokazala njeno varno uporabo pri klinični obdelavi površine.

Ključne besede: dentalni porcelan, SEM, obdelava površine

1 INTRODUCTION

Dental porcelain restorations have two main disadvantages: these restorations have a brittle structure and they cause abrasion on the opposite teeth. Brittleness is mostly caused by the fractures that develop along the porcelain surface. These fractures are micro-fractures caused by porosity, oven heating or the process, with which the prosthesis is adapted to the patient. The existence of micro-fractures has the effect of accelerating the fractures by reducing the bending resistance under the chewing loads. It was concluded that the abrasion effect observed on the teeth of the opposite occlusion is proportional to the hardness and roughness of the porcelain surface. Therefore, when porcelain is preferred in dental restorations, aforementioned disadvantages should be minimized. For that purpose, certain measures are taken to strengthen the internal structure of the porcelain and various surface treatments are applied to solve this problem.[1–6]

The applied surface processes can be listed as follows: different overglaze techniques, chemical interactions and polishing techniques. With these methods we aim to achieve the most durable restoration and the smoothest surface possible. The smoothness attained with these processes are important due to the following reasons: reduction of the bacteria remaining in the pores of a surface, improvement of gingival health and esthetic view, and prevention of an abrasion of the opposite canal.[7–13]

A determination of the most suitable porcelain surface, in terms of the mechanical properties under the chewing loads and surface composition created via various surface-finishing operations, is a continuously researched and developed subject. The aim of this study is to assess different surface-finishing operations that are applied to widely used porcelains in prosthetic dentistry using SEM (a scanning electron microscope).

2 MATERIALS AND METHODS

In our study, three metal-supported commercial porcelains [IPS d. SIGN (Ivoclar Schaan, Liechtenstein), Antagon (Elephant Hoorn, Holland), Ceramco 3 (Degu-Dent GmbH, USA)] and a porcelain without any support [Vitadur Alpha (Vita, Germany)] were used.

Following the instructions of the producers, porcelain dough was mixed. The steel mould prepared to maintain the standards was placed on a vibrator device (Vibratör R2, Degussa, Germany). This step was repeated until the mould was full. For the condensation process, the vibration was provided by the vibrator.

For the production of the porcelain discs with a diameter of 7 mm and a thickness of 2 mm, later observed with SEM, a special cylindrical mould was used. The piston of the mould was pulled down by 3 mm and was fixed at this position. The porcelain dough, prepared in accordance with the producers' instructions, was put into the mould via a spatula. With the help of vibration, the condensation was carried out and the water that rose to the surface was taken away. Then, the porcelain discs were taken out by pushing the piston.

These porcelain-dough specimens were laid onto a 3 mm asbestos plate and placed in an oven following the instructions provided by the manufacturers. For any porcelain type of a given surface treatment 10 specimens were treated in the oven (**Table 1**).

The finishing of all of the porcelain blocks and discs were carried out using a handpiece at a speed of 15000 r/min and using a diamond-granule cylinder burr. The surfaces used for observing the discs and cylinders were ground for 30 min with the 220- and 360-grade abrasive papers. Porcelain discs were machined to the dimensions of 7 mm × 2 mm. Finally, an adequate smoothness and parallelism of the surfaces were maintained (**Figure 1**).

To one surface of all the specimens, 500-grade abrasive paper (waterproof silicon-carbide paper, England) was applied for 30 s. The opposite surfaces were marked. All the porcelain specimens were cleaned using an ultrasonic cleaning device (Euronda, Eurosonic Energy, Italy) and an ultrasonic cleaning solution (Sultan Chemist Inc., Englewood, USA). All the porcelain specimens were grouped with respect to their manufacturers. Then, ten porcelain blocks and ten discs were separated from each manufacturer group to form the following groups: sandpaper, rubber, Sof-Lex, paste, autoglaze, overglaze and ion-exchange.

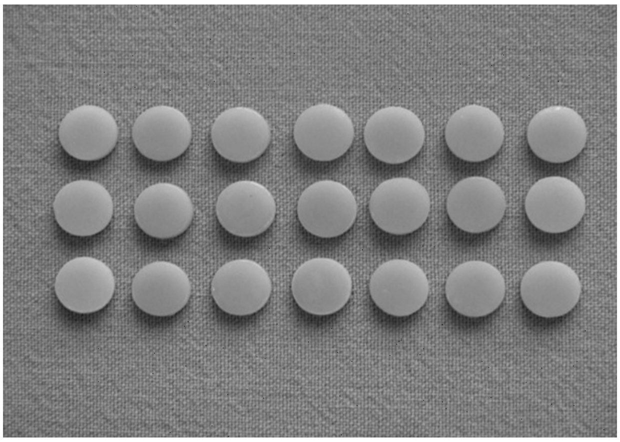

Figure 1: Specimens prepared for the SEM analysis
Slika 1: Vzorci, pripravljeni za SEM-analizo

1. **Sandpaper group:** After processing this group using the 500 grade for 30 s, no further steps were applied. The surface was being cleaned with steam bath and ultrasonic cleaners for 10 min.
2. **Rubber group:** The appropriate surfaces of the discs and cylinders of this group were ground at 15000 r/min for 20 s using Cerashine porcelain rubbers (Diatec, Switzerland). The rubber remnants were removed from the surface with a steam bath and ultrasonic cleaners.
3. **Sof-Lex group:** The Sof-Lex polishing rubber (3M ESPE, USA) was applied to the appropriate surfaces of the discs and cylinders of this group. 1982C, 1982M, 1982F and 1982SF grade discs were applied, respectively, for 10 s in accordance with the manufacturer's instructions.
4. **Paste group:** Using the HP paste (Heraeus Kulzer, Germany), the surfaces of the discs and blocks of this group were polished. In accordance with the manufacturer's instructions, this paste was applied using a bristle brush at the speed of 15000 r/min and for 20 s. After the completion of the process, the porcelain blocks and discs were cleaned under flowing water.

Table 1: Numbers of porcelain discs (D) used for different surface-finishing operations
Tabela 1: Porazdelitev števila (D) uporabljenih porcelanskih ploščic glede na obdelavo površine

	Sandpaper	Rubber	Sof-Lex	HP-paste	Autoglaze	Overglaze	Ion-exchange	Total
	D	D	D	D	D	D	D	D
IPS d. SIGN	10	10	10	10	10	10	10	70
ANTAGON	10	10	10	10	10	10	10	70
CERAMCO 3	10	10	10	10	10	10	10	70
VITADUR ALPHA	10	10	10	10	10	10	10	70
TOPLAM	40	40	40	40	40	40	40	280

Table 2: Time-temperature table for the autoglaze group
Tabela 2: Tabela čas-temperatura za skupino Autoglaze

Porcelain types	Initial temperature (°C)	Heating temperature (min.)	Temperature increasing rate (°C/min)	Highest temperature (°C)	Dwell duration (min)	Vacuum initiation (°C)
IPS d. SIGN	403	4	60	870	1	450
Antagon	500	3	60	895	1	–
Ceramco 3	650	3	45	920	1	–
Vitadur Alpha	600	3	60	940	1	–

Table 3: Time-temperature table for the overglaze group
Tabela 3: Tabela čas-temperatura za skupino Overglaze

Porcelain types	Initial temperature (°C)	Heating temperature (min)	Temperature increasing rate (°C/min)	Highest temperature (°C)	Dwell duration (min)	Vacuum initiation (°C)
IPS d. SIGN	403	4	60	830	1	450
Antagon	500	3	60	895	1	–
Ceramco 3	650	3	55	925	1	–
Vitadur Alpha	600	3	60	920	1	–

Then, they were being cleaned in the ultrasonic cleaner for 10 min.

5. **Autoglaze group:** According to the manufacturers' instructions, the cylinders and discs of this group were autoglazed according to the oven programs given in **Table 2**.
6. **Overglaze group:** For this group of porcelain discs and blocks, the glazing powders and liquids of the manufacturers were used. A glaze powder and liquid were mixed together and this mixture was applied using a grade-1 sable brush in such a way that it covered all the surface. At the end they were kept in the oven as described in the instructions provided by the manufacturer (**Table 3**).
7. **Ion-exchange group:** In order to use a dual ion exchange, 10 % mol LiCl and 90 % mol NaCl ion-exchange solution (Merck, Germany) was prepared. The surfaces of porcelain blocks and discs were covered with this ion-exchange solution using a spatula in such a way that it formed a 1 mm layer. The covered blocks were kept in the oven at 750 °C and for 30 min. For the second stage of the ion exchange, the temperature was reduced to 450 °C and kept in the oven for another 30 min. After being cooled at room temperature, these porcelain blocks and discs were being cleaned of the salt on the surface under flowing water and in the ultrasonic cleaner for 10 min. The porcelain blocks and discs,

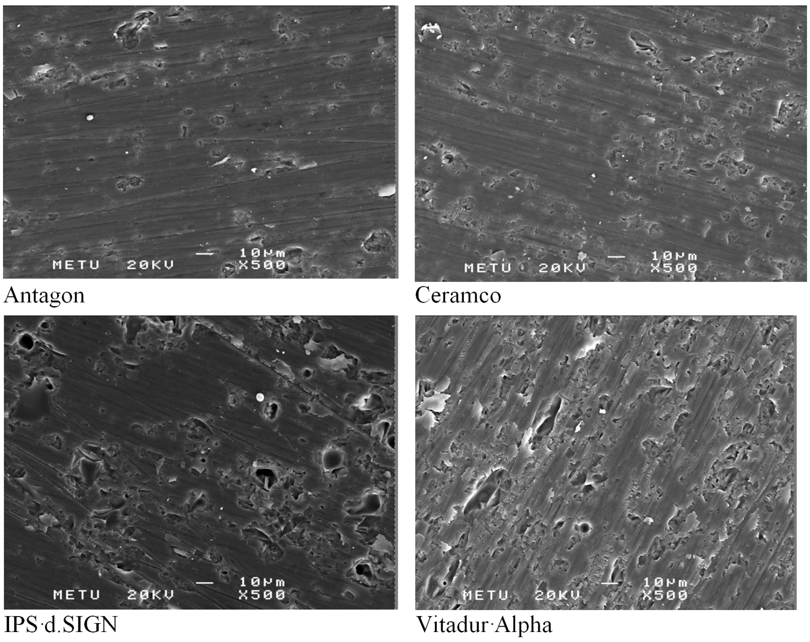

Figure 2: Surface views of sandpaper-finished specimens
Slika 2: Videz površine vzorcev, obdelanih z brusnim papirjem

whose surface processes were completed, were placed into plastic containers.

2.1 Evaluation of the surface-finishing operations on the test specimens with SEM

In order to qualitatively evaluate the surface operations of these porcelain discs, their single surfaces were covered with 250 Angstroms of gold using a gold-covering device (Hummer VII, Anatech Ltd., USA). The surface was scanned using an electron microscope (Jeol, JSM-6 6400, Japan). For all of the specimens, the voltage, inclination-angle and magnification values were kept constant. Each porcelain specimen was magnified 100, 500 and 2000 times.

3 RESULTS

The results of the SEM analysis are summarized under 7 headings.

a) Results of the specimens finished using sandpaper

All the porcelain specimens were prepared in accordance with the instructions provided by the manu-

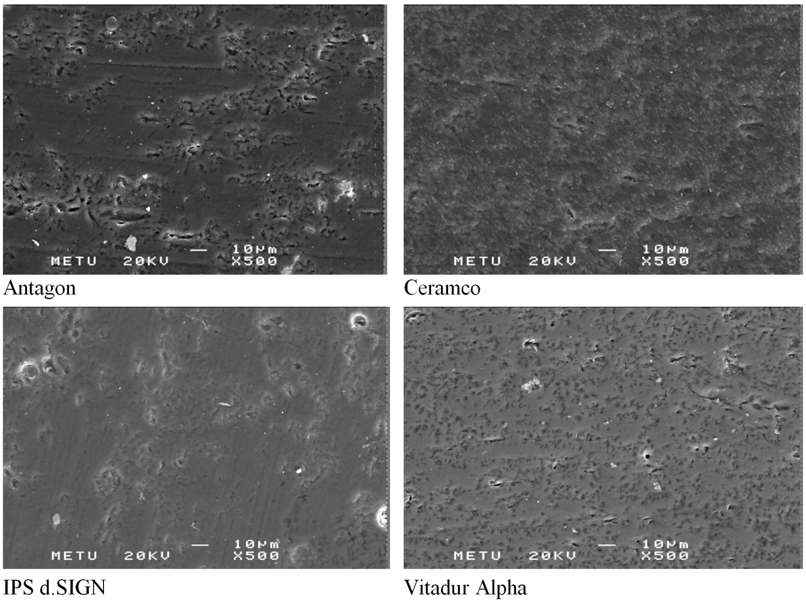

Figure 3: Surface views of rubber-finished specimens
Slika 3: Videz površine vzorcev, obdelanih z gumo

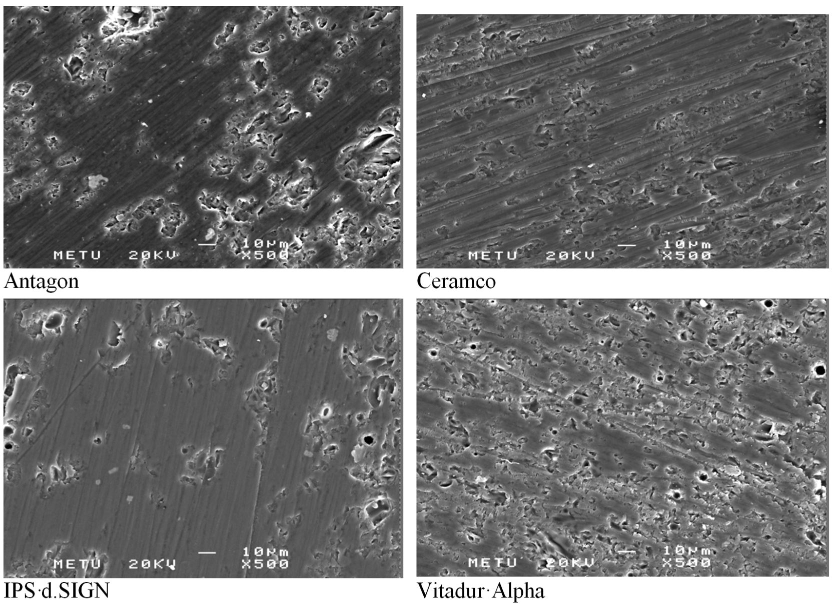

Figure 4: Surface views of Sof-Lex-finished specimens
Slika 4: Videz površine vzorcev, obdelanih s soflexom

facturers. These specimens were magnified 500 times and analyzed. It was found that a sandpapering operation can smooth the surface but it leaves deep scratches on the surface and cannot eliminate the porosity or fill in the gaps. In addition, no difference was observed between the porcelains of four manufacturers (**Figure 2**).

b) Results of the specimens finished using rubber

With the analysis it was found that the finishing operation carried out by using rubber could create smoother surfaces compared to sandpaper. However, it was not successful in removing the sandpaper and the finishing scratches. Moreover, it could not fill in the gaps that developed during the water vaporization (**Figure 3**).

c) Results of the specimens finished with Sof-Lex

After the examination of the Sof-Lex finished specimens, it was seen that the results were quite similar to the result obtained for the rubber-finished specimens. The Sof-Lex finished specimens were of a similar surface quality and this technique also failed to fill in the gaps that developed during the water evaporation (**Figure 4**).

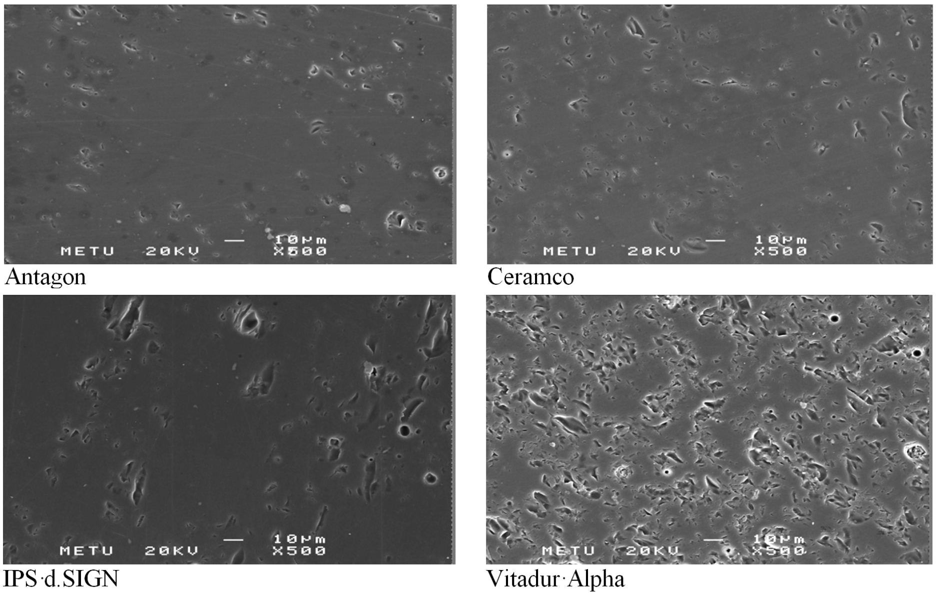

Figure 5: Surface views of HP-paste-finished specimens
Slika 5: Videz površine vzorcev, obdelanih s HP-pasto

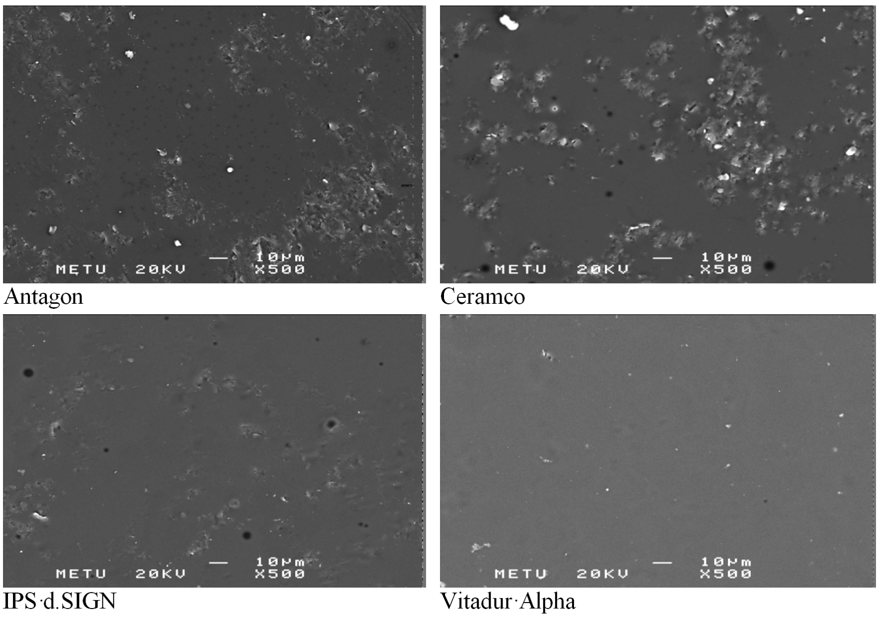

Figure 6: Surface views of autoglaze-finished specimens
Slika 6: Videz površine vzorcev, obdelanih s samoglaziranjem

d) Results of the specimens finished using HP paste

The examination of the HP-paste-finished specimens revealed that this finishing technique could eliminate the sandpaper and the finishing scratches but failed to fill in the gaps that developed during the water evaporation (**Figure 5**).

e) Results of the autoglaze-finished specimens

The autoglaze operation removed all of the scratches that emerged due to the finishing operations and filled in most of the gaps that developed during the water evaporation. In addition, it vitrified the surface and the structure of the porcelain specimens to some extent (**Figure 6**).

f) Results of the overglaze-finished specimens

The examination of the overglaze-finished porcelain specimens showed that all the finishing scratches and water-evaporation gaps were removed. In addition, this finishing process provided a perfect vitrification of both the surface and the structure. It was observed that, among all the groups, this surface-finishing process provided the best surface properties (**Figure 7**).

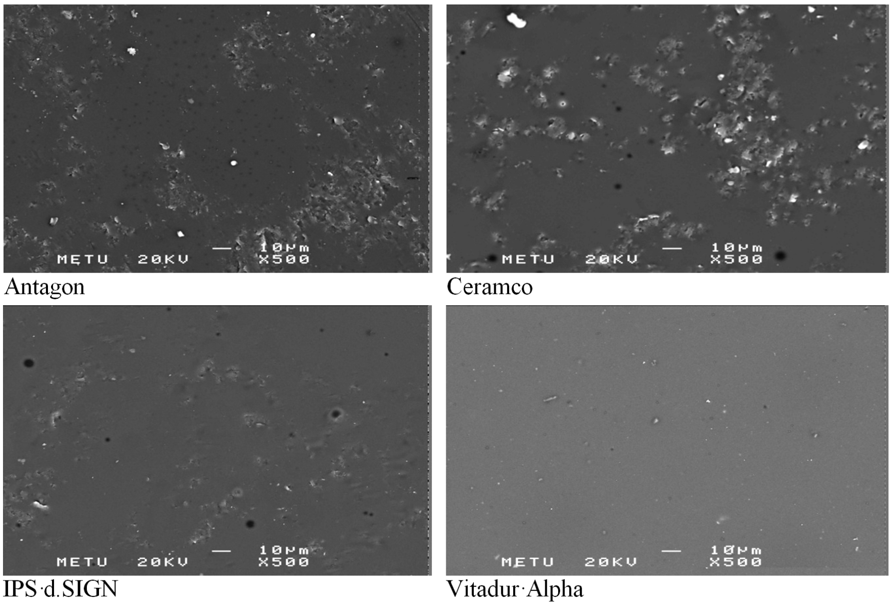

Figure 7: Surface views of overglaze-finished specimens
Slika 7: Videz površine vzorcev, obdelanih s preglaziranjem

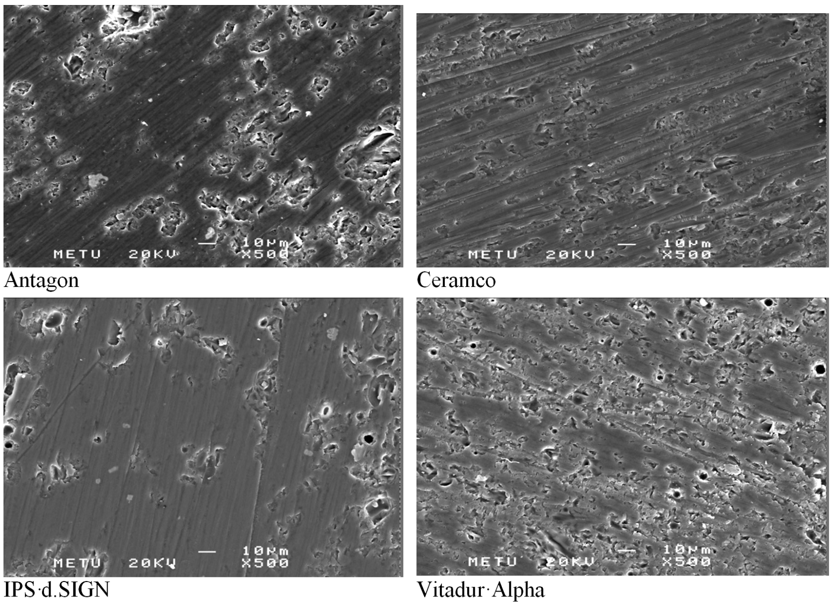

Figure 8: Surface views of ion-exchange-finished specimens
Slika 8: Videz površine vzorcev, obdelanih z izmenjavo ionov

g) Results of the ion-exchange finished specimens

The last group of the specimens was the ion-exchange group. The specimens of this group had the third best surface quality after the overglazed and autoglazed specimens. On the other hand, the ion-exchange application caused these specimens to deform and made some interior fractures to propagate to the surface (**Figure 8**).

4 DISCUSSION

Dental porcelains are the most preferred restorative materials thanks to their bio-compatible structures, perfect esthetic results and the capability of being used in various dental applications.[14] By implementing the appropriate surface-finishing operation needed for porcelain restorations, an aggregation of the agents that cause plaque and staining is prevented, the mechanical irritations of the surrounding soft tissue are eliminated and an abrasion on the contact surfaces of the neighboring and opposite teeth can be reduced.

Although porcelains are generally recognized as bio-compatible materials, they have a porous and brittle structure. In order to increase both strength and bio-compatibility of dental porcelains, many surface treatments are applied. These are the techniques of polishing, glazing and ion-exchange treatments. The aim of this study is to investigate the effects of these surface-finishing operations on dental porcelains and compare them with the results from the literature.

Various surface-finishing operations were investigated by many researchers.[15,16] Sof-Lex, rubber and autoglaze processes were examined[7,17] and the polishing methods and effects of the glazing techniques using the SEM method were studied.[18] The effectiveness of polishing using various grain-sized diamond burrs and diamond-grained pastes was studied.[19] In addition, diamond-added pastes and glazing treatments were also researched.[12] Some researchers investigated the polishing methods and autoglaze treatment.[20–22] They compared the porcelains, to which autoglaze was applied, using SEM.

Scientists tested the resistances of the porcelains that had undergone different surface treatments, employing the three-point bending test. In addition, they also evaluated these specimens' surface qualities and the fracture zones with a SEM analysis.

The SEM method was used in order to compare different surface treatments.[16] SEM was used to evaluate the effects of polishing using diamond-added pastes after machining with different-grained diamond burrs.[19]

In prosthetic restorations, shiny surfaces are one of the desired qualities along with the esthetics and functioning. While, for many dental materials, the polishing and finishing provide a sufficient surface shine, for dental porcelains that can only be obtained by employing the glazing techniques. Nowadays, in dentistry, many low-temperature porcelains and reduced-hardness porcelains are in use. Depending on the instructions of the manufacturers, the surface treatments of these porcelains may vary. For this reason, in our study, we examined different porcelains that are widely used in the Turkish dentistry.

In the surface-finishing operations of porcelain restorations, the sequences of the processes are quite important. By using the feldspathic porcelain, crack emergence was avoided on the polished and autoglazed surfaces.[23] However, microcracks occurred during the autoglaze treatment following the polishing. It was found that these microcracks may cause surface roughness and that a repetition of any surface treatment may result in a porous structure instead of a shiny surface. In our study, all the specimens were machined with the same burrs and sandpapered in the same manner. Then, the last required surface-finishing operation was carried out.

It was concluded that the autoglaze treatment provides a better surface than the polishing[15,17,21] but it was also stated that polishing creates a shinier surface than the autoglaze technique.[22] In our study, while the creation of the smoothest surface using the HP paste contradicts the findings of Campbell et al.[15] and Patterson et al.[17], it resembles the results from the study by Wright et al.[22] This contradiction might have been caused due to the difference between the methods of observation as, during the SEM analysis, the smoothest surfaces were observed on the autoglazed and overglazed specimens.

In the study, in which different polishing and glazing methods are compared,[18] it is reported that, according to the SEM-analysis results, the autoglaze treatment provided the smoothest surfaces. Similarly, in this study, it was concluded, on the basis of a SEM analysis, that the overglaze treatment provided the smoothest surfaces. The SEM analysis of our study is similar to their results.

Motro et al.[24] concluded that, when compared to the autoglaze, the polishing systems are also clinically acceptable. Wright et al.[22] and Patterson et al.[17] stated that the polishing techniques lead to smoother surfaces than the autoglaze techniques; however, they are not a substitute of the autoglaze. These results reveal that HP pastes can be used for restoring the porcelain, whose glaze structure was damaged. In spite of this, Campbell et al.[15] and Dalkiz et al.[21] reported that the autoglaze operations are more suitable for producing smoother surfaces. These results contradict what we found in our study.

It was observed that there is no significant difference between Sof-Lex and polishing rubbers in terms of surface smoothness.[25–28] It was determined that Sof-Lex discs are more suitable for creating smoother surfaces than the diamond-added pastes.[14] After using SEM, Giordano et al.[7] and Yilmaz et al.[20] found that the glaze treatments provide the smoothest surface, while Sof-Lex and rubber provide less smooth surfaces. In our study, with respect to the SEM findings, we found that Sof-Lex discs provide less smooth surfaces than the diamond-added HP paste and that our result contradicts the one of the above-mentioned scholars. This contradiction may be attributed to the use of different pastes of different manufacturers.

5 CONCLUSIONS

Dental porcelains are the most widely preferred restoration materials thanks to their desired properties, such as the optical properties, being esthetic restorative materials, bio-compatible, resisting chewing loads, etc. Surface-finishing operations are very important for porcelains because these treatments increase the tissue compatibility by reducing the abrasive effect of porcelains, eliminating staining and plaque aggregation. Hence, when the effects of different surface-finishing treatments are evaluated, the following conclusions can be made:

From a morphological point of view, the overglaze and then the autoglaze are the most appropriate techniques to create the smoothest surfaces. In descending order, HP paste, rubber, Sof-Lex and sandpaper are increasingly less favorable for a finishing operation on a porcelain surface.

From a micromorphological point of view, certain finishing techniques generate similar surface qualities on all the porcelains.

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