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A Study of the Surface Topography and Roughness of Glazed and Unglazed Feldspathic Ceramics

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ABSTRACT

The aim of this study was to obtain the 3-D qualitative and quantitative nanoscale data of the surface topography and surface roughness of glazed and unglazed feldspathic ceramics. Twelve samples composed of Ni-Cr alloy (Wiron 99, Bego Germany) and feldspathic ceramics (IPS Classic, Ivoclar-Vivadent, Schaan, Liechtenstein) were prepared, and divided into two groups, dependent of the surface final finishing; 6 unglazed and 6 glazed samples. The surface of the samples was recorded and analysed by atomic force microscopy (AFM, Veeco Instruments, Santa Barbara, CA, USA). According to the results of this study, unglazed ceramic surface is significantly rougher than the glazed one, showing significantly higher root mean square (RMS), mean roughness (Ra) and maximum height (Z range values) ($p<0.01$), higher crystallites with sharper peaks and deeper pores. The roughness parameters of the unglazed samples were almost twice or even more higher than of the glazed samples. Exposed unglazed ceramic surfaces can therefore promote antagonistic tooth wear.

Key words: *feldspathic ceramics, glazed, unglazed, AFM, surface roughness*

Introduction

Wear of any solid material is the net result of a number of fundamental processes: abrasion, adhesive effects, fatigue and corrosion effects[1,2]. In the case of a dental restorative material, abrasion is the main cause of its wear[3,4]. It is also thought that abrasion of a dental restorative material is more related to the roughness of its surface and fracture resistance than to the hardness of the material[5]. Moreover, some micro and nano structural factors of the material, such as its porosity and grain size are of importance in its wear as well[6]. The size and shape of the contact area between a restoration and the opposing tooth as well as the friction between them are the factors that should also be taken into account in analyzing their wear.

Ceramic materials are of special importance in dentistry because they have a fairly large number of desirable properties, e.g. ease of fabrication of complex shapes, superior chemical stability in comparison with other biomaterials in oral environment[1] as well as appropriate aesthetic appearance. However, ceramic materials also have shortcomings, e.g. brittleness, lack of resistance to fracture, and the promotion of antagonistic teeth wear[2,3]. To wit, natural teeth show increased wear when opposed to a ceramic restoration in comparison with a gold one[4].

It is a standard clinical practice first to adjust occlusaly the surface of an unglazed ceramic restoration by grinding and then to glaze the restoration before the final cementation[7]. While all occlusal adjustments prior to glazing may be made with the greatest care, very often after the glazed restoration has been permanently cemented additional surface modifications are necessary in order to correct minor occlusal interferences. These addi-

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tional adjustments of the glazed ceramic surface lead to the removal of glaze and to the exposure of unglazed surface of the restoration[8]. Clearly, in practice the surface of the glazed ceramic restoration consists of glazed and unglazed parts. Owing to all the aforesaid reasons, it is justifiable and desirable to examine in detail the surface topography and surface roughness of glazed and unglazed feldspathic ceramic samples in order to obtain a deeper insight into the actual surface of a feldspathic ceramic restorations.

Materials and Methods

Sample preparation

Twelve metal-ceramic plates (9.0 mm long × 9.0 mm wide × 1.2 mm thick) composed of Ni-Cr alloy (Winron 99, Bego Germany) and feldspathic ceramics (IPS Classic, Ivoclar-Vivadent Schaan, Lichtenstein) were prepared according to the manufacturer's recommendations. Six out of these samples were glazed according to the manufacturer's recommendations.

Sample cleaning

Prior to the AFM analysis the surfaces of the samples were cleaned with alcohol, then rinsed with ultrapure water and finally sonicated for 10 minutes in ultrapure water. The samples were then dried in a stream of nitrogen and stored in a plastic Petry dish.

AFM imaging and analysis

The 3-D images of the surfaces of the samples were obtained using the contact mode operation of the MultiMode AFM with NanoScope IIIa controller (Veeco Instruments, Santa Barbara, CA, USA) under ambient conditions. Regions of interest (ROIs) at the surfaces of the samples were located by means of an optical camera (Sony high resolution CCD camera, Japan). The AFM scanner (model JV) had maximum range of 125 μm on the xy axes and the vertical (z) range of 5 μm. The V-shaped cantilevers (nominal spring constant of 0.32 N/m) with square pyramidal silicon-nitride tips (NP-20, Veeco) were used to record images of ROIs. The ROIs had dimensions: 10×10 μm, 50×50 μm, and 100×100 μm. The images were recorded at the highest possible resolution of 512×512 pixels *per* image. Image browsing, roughness analysis, and section analysis of the profiles of ROIs were made off-line using the AFM NanoScope Control software version V614r1m (Veeco Instruments, Santa Barbara, CA). The surface roughness was assessed by the following parameters: (i) the root mean square (RMS) roughness (R_q), which gives the root mean square average of the height deviations taken from the mean data plane within a given area; (ii) the mean roughness (R_a) being the arithmetic average of the absolute values of the surface height deviations measured from the mean plane; and (iii) the maximum height (R_t or Z value), which is the vertical distance between the highest and the lowest data points of the image.

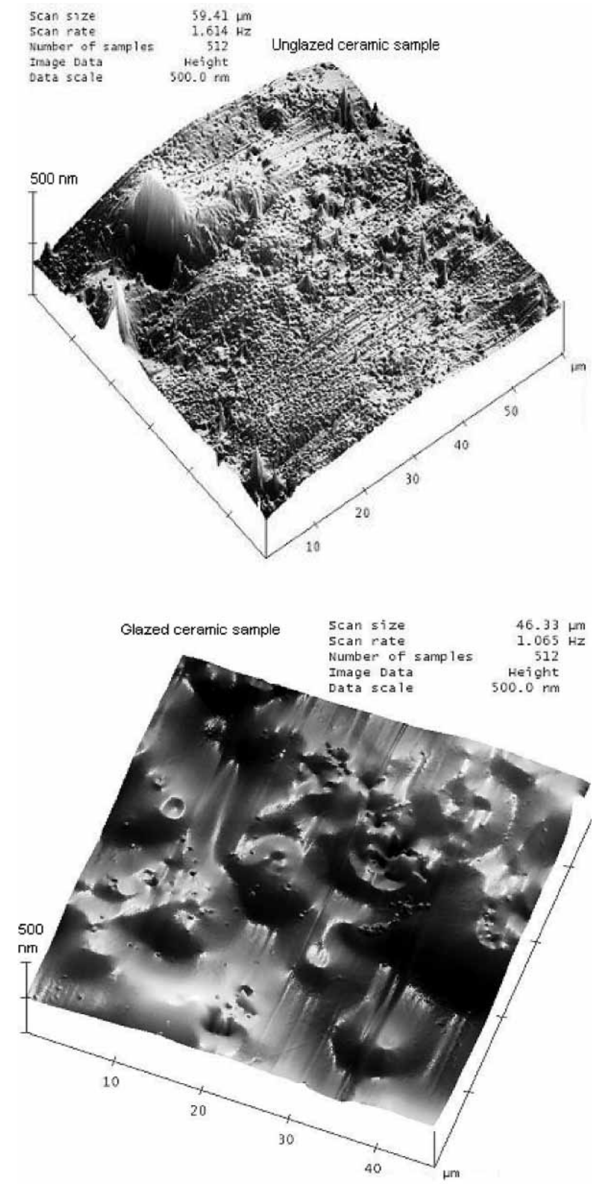

Fig. 1. Typical 3-D topography of the unglazed and glazed ceramic samples obtained by AFM (50×50 μm).

The statistical analysis was carried out using the SPSS 14 for Windows (Chicago, Illinois, USA). Descriptive statistics were calculated for RMS, R_a, and Z-range values. The significance of the difference between the glazed and unglazed surfaces was tested using the independent t-test. The level of probability was set at 0.01.

Results

The typical 3-D topography of the glazed and unglazed feldspathic ceramics samples is shown in Figure1. The arithmetic means and standard deviations of the RMS and R_a values for the unglazed and the glazed ceramics samples are presented in Figure 2. The arithmetic means

TABLE 1
SIGNIFICANCE OF THE DIFFERENCES BETWEEN MEAN RMS, RA AND Z VALUES OF THE UNGLAZED AND THE GLAZED CERAMIC SAMPLES

Variable	t	df	p
RMS	3.755	10	0.004**
Ra	3.865	10	0.003**
Z	4.547	10	0.001**

** p<0.01

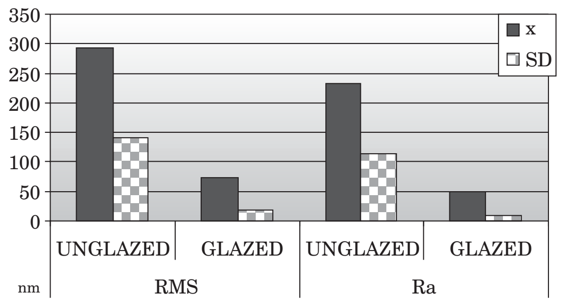

Fig. 2. Mean values and standard deviations of RMS and R_a values of the unglazed and the glazed ceramic samples.

and standard deviations of Z (R_t), values for the unglazed and glazed ceramics samples are shown in Figure 3.

Levene's test revealed the equality of variances ($p>0.01$). The significance of the difference between the arithmetic means of RMS, R_a, and Z values of the unglazed and glazed ceramics samples (Student's test for independent samples) is shown in Table 1.

Discussion

Occlusal adjustment is a procedure to be performed at a dental office for almost every fixed partial denture (FPD), sometimes even after permanent cementation. Final adjustments may result in a loss of ceramic glaze in ceramic FPDs[9]. The purpose of this study was to evaluate surface roughness and surface topography of the glazed and the unglazed ceramic surfaces. The material investigated in this research was feldspathic ceramics, as it is generally used in dental offices. Feldspathic ceramic materials are composed of feldspathic glass matrix with different volume fractions of crystalline phases, such as undissolved feldspar, leucite crystals and alumina particles[10,11]. In ceramic materials with comparable crystalline content, factors such as porosity, grain size, shape and grain orientation are important to determine mechanical properties[12].

The Atomic Force Microscope (AFM) has become a useful tool for examining material structure at both the micron and nanometre scale. The optical micrographs or SEM images allow only a two-dimensional view[13]. To obtain the 3-D view and to assess the surface topography of the glazed and the unglazed feldspathic ceramics at

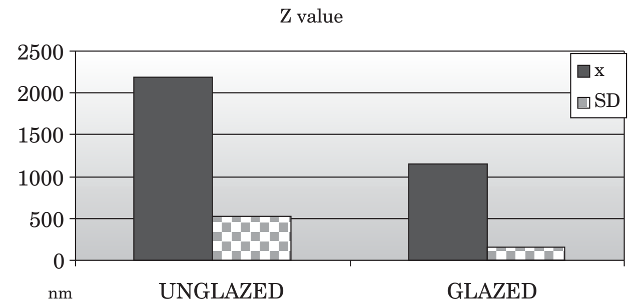

Fig. 3. Mean values and standard deviations of Z (R_t) values of the unglazed and the glazed ceramic samples.

nanometre scale we browsed the surfaces by means of AFM.

The typical 3-D surfaces of the unglazed and the glazed samples, obtained by the AFM imaging in this study (Figure 1) reveal rougher surface of the unglazed sample with several higher crystallites with pointed peaks emerging perpendicularly from the surface. Moreover, deeper pores can be observed compared to the glazed sample. It is known that glaze seals cracks and pores within the ceramic material[14]. It is obvious that sharp edges have been smoothed by glaze, which is clearly demonstrated in the 3-D image of the glazed sample (Figure 1). Statistical analysis also revealed that RMS values, Ra values and Z range were significantly ($p<0.01$) higher in the unglazed samples.

This study clearly demonstrates that additional occlusal adjustments, which reveal unglazed ceramic surface increase surface roughness. Glazing of ceramic restorations, except for sealing the flaws in material and strengthening it, also reduces the possibility of wearing the opposite teeth by covering hard elements like crystals and pores of the surface of the ceramic materials[15]. The findings of this study are in agreement with the study which also confirmed that surface treatments significantly affect roughness values but had no effect on colour of the surface[16].

According to the results of this study, unglazed ceramic surface is significantly rougher than the glazed one, showing significantly higher Z range values (Figure 3, Table 1), higher crystallites and deeper pores (Figure 1). Higher crystallite peaks and rougher surface of the unglazed parts of any ceramic restoration may promote antagonistic teeth wear, compared to the glazed, smoother surfaces. Unglazed ceramic shows sharper peaks and deeper cracks than the glazed. Due to the cyclic loading and fatigue cracks propagation is deeper, and thus the possibility of fracture in ceramic material. Therefore, it is certainly necessary to avoid further grinding ceramic of fixed partial denture in clinical work. However, exposed unglazed ceramic surface may be additionally polished in a dental office by different rotating instruments, like rubber cups. Some authors have even recommended such polishing techniques as alternatives to glazing[17,18], but it will be the object of further study.

Conclusion

The surface roughness of the glazed ceramic material is significantly lower than of the unglazed one. The crystallites of the unglazed ceramic surfaces are significantly higher and the pores are significantly deeper compared to the glazed samples. The unglazed ceramic surfaces can promote antagonistic teeth wear.

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IZGLED I HRAPAVOST POVRŠINE GLAZIRANE I NEGLAZIRANE GLINIČNE KERAMIKE

SAŽETAK

Svrha ovog rada bila je dobiti trodimenzionalne kvalitativne i kvantitativne podatke na nano skali o topografiji i hrapavosti površine glazirane i neglazirane glinične keramike. Pripravljeno je 12 uzoraka koji su se sastojali od metalne pločice (Ni-Cr legura, Wiron 99, Bego Germany) na koju je napečena glinična keramika (IPS Classic, Ivoclar-Vivadent, Schaan, Liechtenstein). Uzorci su podijeljeni u dvije skupine, ovisno o završnoj obradi njihove površine (6 neglaziranih i 6 glaziranih uzoraka). Površine uzoraka snimljene su i analizirane pomoću mikroskopa atomskih sila (AFM, Veeco Instruments, Santa Barbara, CA, USA). Dobiveni rezultati pokazuju da je površina neglazirane keramike značajno hrapavija od površine glazirane keramike. sa značajno višim drugim korijenom srednjeg kvadrata hrapavosti (RMS), srednjom hrapavosti (R_a) i rasponom hrapavosti (Z vrijednostima) ($p<0{,}01$). Parametri koji opisuju hrapavost površine bili su više nego dvostruko veći kod neglaziranih uzoraka. Stoga je zaključeno da neglazirana keramika može pospješiti trošenje antagonističkih zuba.