The Effect of Bleaching Agents on the Surface Topography of Ceramometal Dental Alloys

Cherif A. Mohsen, BDS, MDSc, DDSc

Associate Professor, Vice Dean, and Chairman, Department of Fixed Prosthodontics, Faculty of Dentistry, Minia University, Giza, Egypt

Keywords
Surface roughness; gold alloys; Ni-Cr alloys; Co-Cr-Ti alloys.

Correspondence
Cherif A. Mohsen, 4 El Tharrir St., Dokki, Giza, Egypt. E-mail: cherif.mohsen@gmail.com

Accepted December 5, 2008

doi: 10.1111/j.1532-849X.2009.00519.x

Abstract

Purpose: To study the effect of bleaching agents on the surface topography of ceramometal alloys.
Materials and Methods: Three types of ceramometal alloys were used (gold, Ni-Cr, Co-Cr-Ti), and two types of bleaching agents (an agent intended for home use, one intended for use in the dental office) were studied. Forty-five specimens were constructed and divided according to the alloy type into three main groups, 15 specimens per group. Each group was further subdivided into three subgroups according to the type of bleaching agent used. The first subgroup (five specimens) was not subjected to any bleaching agent. The second and third subgroups were subjected to home and in-office bleaching agents, respectively.
Results: Au alloy showed the least surface roughness when subjected to either of the two bleaching agents. Ni-Cr alloys showed the highest surface roughness for both the control and home bleached subgroups, and Co-Cr-Ti alloy showed the highest surface roughness in the in-office bleached subgroup. No statistically significant difference was found between the control subgroup and the home-bleached subgroup for either the Au alloy or the Co-Cr-Ti alloy. For the two alloys, both the control and home-bleached subgroups were statistically different from the in-office bleached subgroups. There was a statistically significant difference between the Ni-Cr control subgroup and the other two bleached subgroups, while there was no difference between the two bleached subgroups. Results also showed that increasing the concentration of bleaching agents increased the surface roughness of all the tested alloys. There was a statistical difference between the Ni-Cr alloy and the other two alloys in all tested subgroups except the in-office bleached subgroup, for which no difference between the surface roughness of the Ni-Cr alloy and the Co-Cr-Ti alloy was found. Scanning electron microscopic examination revealed surface deteriorations in the two bleached subgroups for all tested ceramometallic alloys.
Conclusion: Surface topographic alterations occurred as a result of the application of bleaching agents. These alterations increased with the increase of the carbamide peroxide concentration.

Tooth bleaching was reported in the literature as an esthetic treatment option as early as 1898.[1] Bleaching has been described as "lightening and whitening of discolored vital or nonvital teeth, by using oxidizing materials such as hydrogen peroxide, carbamide peroxide, and sodium perborate."[2] Newer bleaching systems are based primarily on hydrogen peroxide or one of its precursors, notably carbamide peroxide. They are applied externally to the teeth (vital bleaching), or internally within the pulp chamber (nonvital bleaching). These two techniques aim to bleach the chromogens within the dentin, thereby changing the body color of the tooth.[3–6] Recently, ozone has been used as a fast, effective, and harmless method of whitening teeth.[7]

Many treatment methods, materials, and concentrations are available for tooth bleaching, ranging from specially formulated toothpastes, chewing gums, and strips for home bleaching, to solutions and gels applied either directly or in night guards for in-office or home bleaching.[8–15] The fact that the bleaching agent is held in intimate contact with the teeth and potentially any associated restorations raises the possibility that this agent may cause undesirable changes, such as softening and degradation of the teeth and filling materials. If the bleaching process weakens any of the surfaces, then wear caused by subsequent tooth brushing may be increased.[16,17]

Several investigations have reported that bleaching agents alter the surface topography of teeth and restorative dental materials including their chemical and physical properties. At the same time, other studies have shown that bleaching agents have no effect on restorative dental materials.[18-23]

Canay et al[24] evaluated the effect of 10% carbamide peroxide on the electrochemical corrosion of dental alloys (Au-Pd, Au-Ag, Cr-Co, Ni-Cr, polished amalgam, and nonpolished amalgam). They reported that the bleaching agent affected the corrosion rate of the tested alloys. Oshida et al,[11] in an in vitro study, evaluated and compared chemical and electrochemical corrosion behavior of four metallic dental materials (pure Ti, Ni-Co-Mo alloy, type IV gold alloy, amalgam) subjected to 10% carbamide peroxide. They concluded that these bleaching treatments were proven to be contraindicated for dental metallic materials.

Surface roughness is defined as relatively finely spaced surface imperfections whose height, width, and directions establish a predominant surface pattern.[25] Preserving the surface smoothness of dental cast restorations is of a great importance in preventing retention of microorganisms, reducing plaque accumulation, and increasing alloy resistance to corrosion.[26-28] Mohsen and Amer[28] reported that increasing surface roughness leads to an increase of bacterial accumulation.

The aim of this investigation was to study surface alterations on three dental ceramometal alloys resulting from application of two types of bleaching agents, one intended for home use and the other intended for use in the dental office.

Materials and methods

Specimen construction

A split copper mold with five openings, each 10 mm in diameter and 3 mm in thickness, was used for construction of the specimens. A separating medium was painted on the internal surfaces of the mold to facilitate removal of the wax pattern, and a molten blue inlay wax was poured into the mold. After wax hardening, the mold was disassembled, and the patterns were removed. The specimens were then sprued using a standard ready-made wax sprue former (gauge 3 mm). Each set of five sprued specimens was attached vertically to a circular horizontal feeder sprue former (gauge 10 mm), which was then connected to a main thicker wax sprue former by two oblique ones (gauge 8 mm). All previously assembled wax patterns were attached to a rubber crucible former. The wax patterns were sprayed with wax wetting agent before being invested in suitable size glass casting rings. The casting ring was then placed over a rubber crucible former and lined with ring liner. The casting ring containing the patterns was placed over a vibrator. Investment was first painted on the surfaces of each pattern using a soft brush. Then the ring was filled with the investment.

Each casting ring was kept at room temperature for 15 minutes for setting of the investment. The rubber crucible former and glass ring were removed, and the investment on the free end of the ring was trimmed to remove the glazed surface, exposing a porous surface to ensure later escape of gases. Each ringless investment was placed in the muffle of a burnout furnace with the base of the ring facing downward. The temperature was raised from room temperature, and the wax patterns were eliminated. Then the ringless mold was filled with molten alloy. Finally, the specimens were finished and polished. To simulate the laboratory procedures carried out during porcelain application, all specimens were subjected to the same firing cycles as Vita VMK 95 porcelain.

Specimen groupings

Forty-five specimens were fabricated from three types of ceramometal alloys: Au alloy (IPSd.SIGN 91, Ivoclar, Schaan, Liechtenstein), Ni-Cr alloy (Wiron 99, Bego, Germany), and Co-Cr-Ti alloy (Experimental alloy: Co 61%, Cr 26%, Mo 7%, W 3%, Si 1.5%, Fe 0.5%, Ce 0.5%, C 0.02%, Ti 0.5%). The 45 specimens were divided into three groups according to type of ceramometal alloy (15 specimens each). Each group was further subdivided into three subgroups (five specimens each) according to the type of bleaching agent used. The first subgroup was not subjected to any bleaching agent and served as the control. The second and third subgroups were subjected to the home and in-office bleaching agents, respectively.

Bleaching agent application

The specimens in the second subgroup were subjected to 14 applications of a home bleaching agent (Opalescence PF, Ultradent, South Jordan, UT). The active ingredient of this bleaching agent is 10% carbamide peroxide and has a pH of 6.5. Each application extended for 8 hours. Specimens in the third subgroup were subjected to four applications of an office-bleaching agent (Opalescence Quick, Ultradent). This bleaching agent has 35% carbamide peroxide as its active ingredient and a pH of 6.0. The duration of each application was 2 hours. The specimens were washed and brushed under running water after each application and then stored in distilled water.

Surface topography assessment

Surface roughness was measured with a Zygo Maxim-GP, .200 prolifometer (Zygo, Middlefield, CT). This apparatus measures the microstructure and topography of surfaces in three dimensions, using computerized phase-measuring interferometry. Zygo Metropro software analyzes areas as well as profiles and provides roughness results. The Zygo Maxim-GP 200 measures without contact, using filtered white light interferometry. Surface roughness of the tested specimens was measured in microns. Two parameters were calculated: Average roughness (Ra) and Root-mean-square roughness (Rq)

$$R_a = \frac{1}{L}\int_0^L |r(x)|\,\mathrm{d}x. \quad R_q = \sqrt{\frac{1}{L}\int_0^L r^2(x)\,\mathrm{d}x}.$$

Scanning electron microscopic (SEM) examination

SEM examination of randomly selected specimens was performed (JEOL JX-840 A, Electron Probe Microanalyzer,

Table 1 Means and standard deviations of surface roughness (in microns) of the tested specimens

Type of alloy bleaching agents	Au Ra	Au Rq	Ni-Cr Ra	Ni-Cr Rq	Co-Cr-Ti Ra	Co-Cr-Ti Rq
No bleaching	0.14 (0.05)	0.18 (0.02)	0.48 (0.18)	0.63 (0.08)	0.22 (0.08)	0.30 (0.01)
Home bleaching	0.26 (0.07)	0.34 (0.05)	0.69 (0.09)	0.92 (0.07)	0.33 (0.06)	0.45 (0.04)
Office bleaching	0.58 (0.08)	0.72 (0.09)	0.79 (0.09)	0.99 (0.09)	0.87 (0.09)	1.13 (0.20)

Sollentuna, Sweden). The specimens were examined and photographed.

Statistical tests

Surface roughness records were tabulated and statistically analyzed using two-way ANOVA and Fisher's LSD test.

Results

Surface topography assessment

The means and standard deviations of surface roughness of the tested materials due to bleaching agent application (home and in-office) are shown in Table 1. Comparison between the means is also represented in Figure 1. Surface profiles of tested alloys are shown in Figures 2–10. One-way ANOVA was carried out to determine the statistically significant differences between the tested groups ($p < 0.05$). Fisher's LSD test at $p < 0.05$ was carried out following two-way ANOVA (Table 2). Results showed that all Au subgroups exhibited less surface roughness when compared to their corresponding subgroups of the other two tested alloys. Ni-Cr alloys showed the highest surface roughness in both the control and home-bleached subgroups, while the Co-Cr-Ti alloy showed the highest surface roughness in the office-bleached subgroup. The results also showed no statistically significant difference between the control subgroup and the home-bleached subgroup for the Au and Co-Cr-Ti alloys. For the two alloys, the two subgroups (control and home-bleached) were statistically different from the office-bleached subgroups. The results with the Ni-Cr alloys showed a statistical difference between the control subgroup and the two bleached subgroups, but there was no difference between the two bleached subgroups. The results also showed that increasing the concentration of the bleaching agents resulted in an increase in the surface roughness of the tested alloys. The results showed no statistically significant difference between the Au alloy and the Co-Cr-Ti alloy, except in the office-bleached subgroup. A statistical difference was found between these two alloys and the Ni-Cr alloy in all tested subgroups except the office-bleached subgroup. With that group, there was no difference between the surface roughness of the Ni-Cr alloy and the Co-Cr-Ti alloy.

SEM examination

Scanning electron micrographs of the Au subgroups are shown in Figures 11–13. These micrographs clearly show pores on the specimens of the two bleached subgroups. The micrographs of the home-bleached subgroups show pitting of the alloy surface; however, more pitting and grooves on the alloy surface with slight attacks at the grain boundaries can be seen in the micrographs of the office-bleached subgroup.

Figures 14–16 represent the SEMs of the three Ni-Cr alloy subgroups. These micrographs reveal the same findings that can be seen for Au alloys, but the effect is more pronounced, with extensive pitting and grooves on the alloy surface. In addition, attacks around grain boundaries can be detected. The micrographs of the office-bleached subgroup show deeper pits and grooves on the alloy surface, with more extensive attacks at the grain boundaries.

The micrographs of Co-Cr-Ti alloy are shown in Figures 17–19. Pitting and grooves can be observed on the alloy surface of the home-bleached subgroup. Micrographs of the in-office subgroup show more surface topographic deterioration due to deeper pits and grooves and more extensive attacks at the grain boundaries.

Discussion

Surface topography alteration of three ceramometallic dental alloys due to application of bleaching agents was studied.

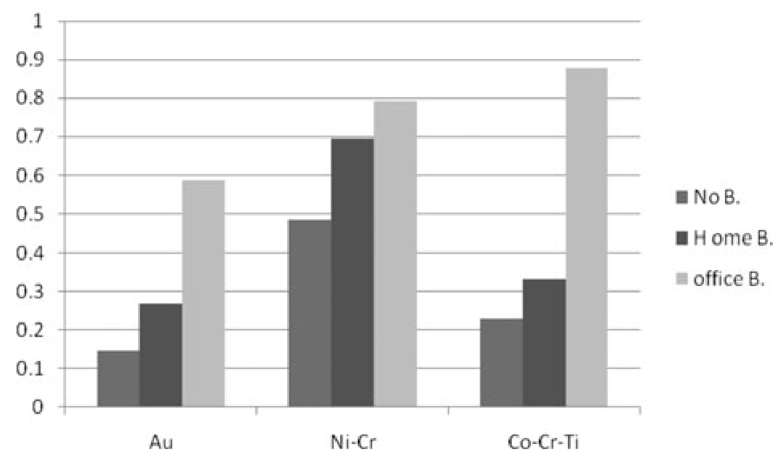

Figure 1 Comparison between the means of the tested alloys (B = bleaching).

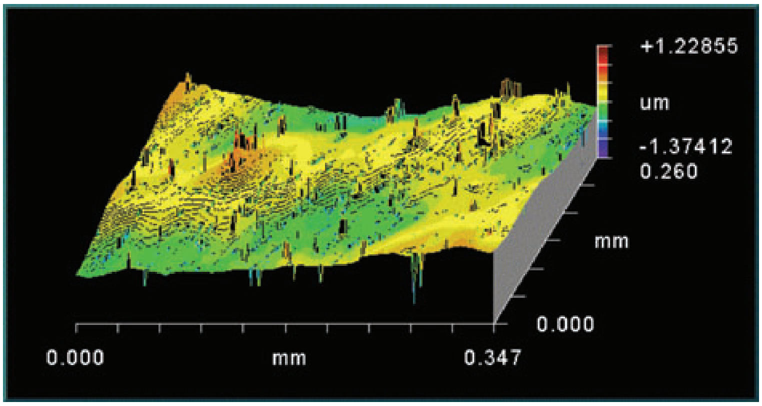

Figure 2 Surface profiles of Au alloy.

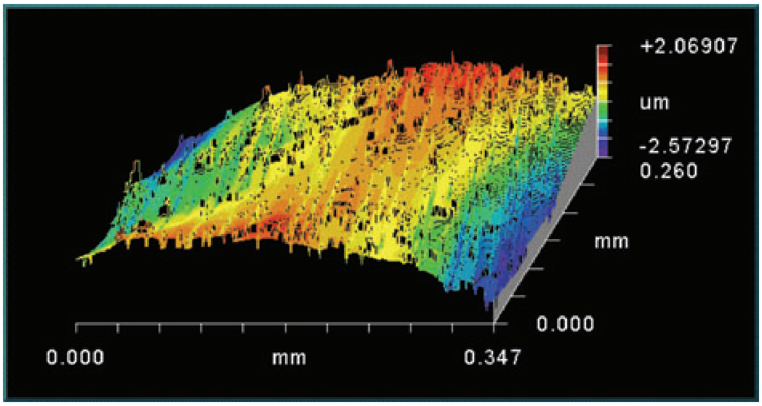

Figure 3 Surface profiles of home-bleached Au alloy.

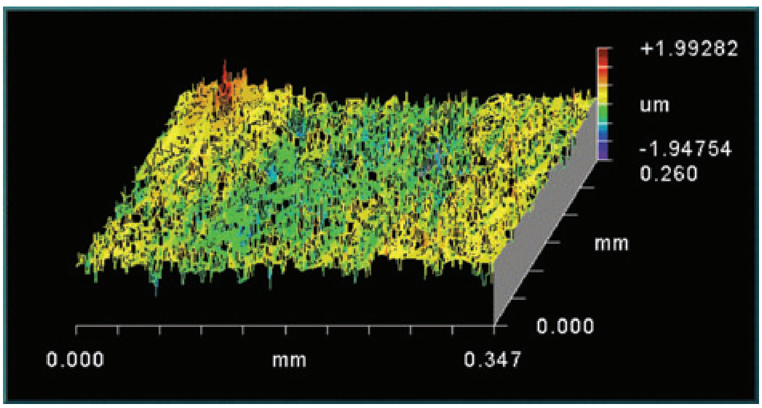

Figure 4 Surface profiles of office-bleached Au alloy.

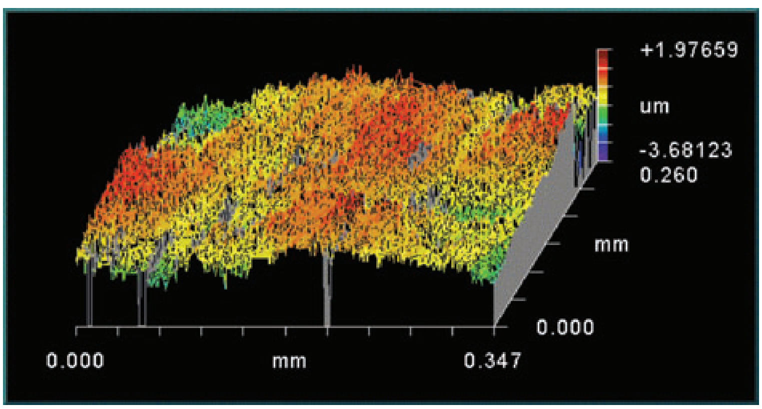

Figure 5 Surface profiles of Ni-Cr alloy.

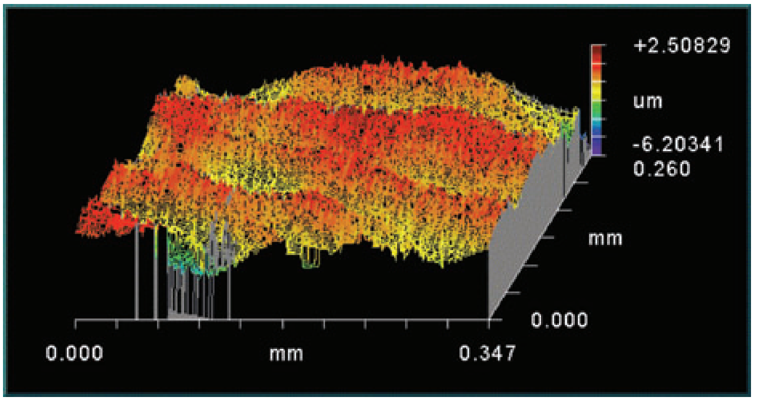

Figure 6 Surface profiles of home-bleached Ni-Cr alloy.

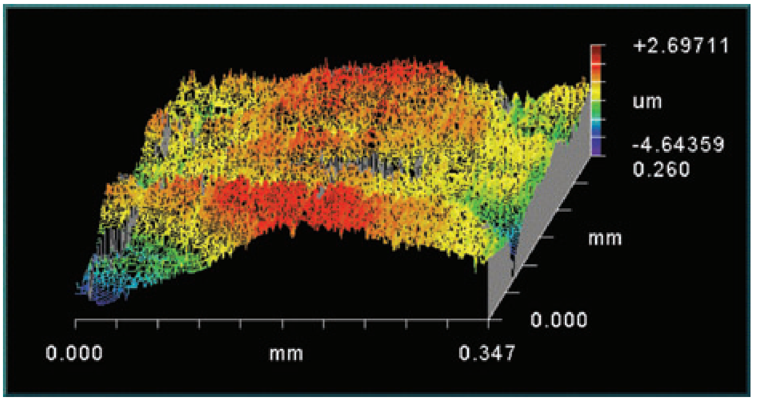

Figure 7 Surface profiles of office-bleached Ni-Cr alloy.

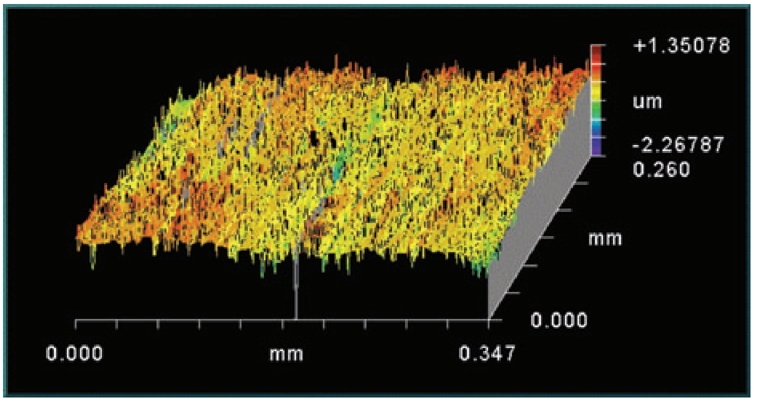

Figure 8 Surface profiles of Co-Cr-Ti alloy.

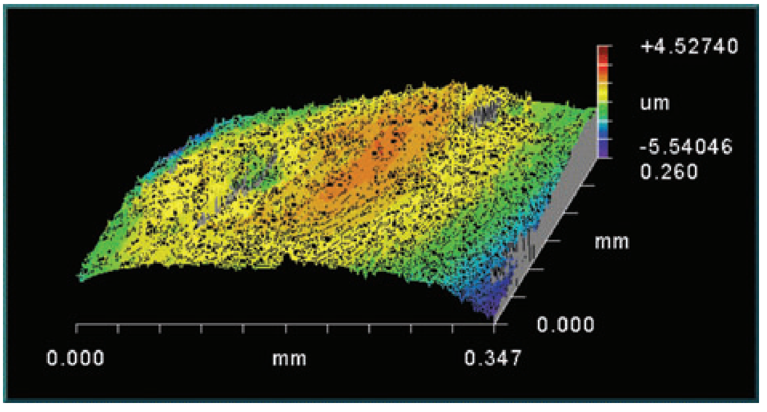

Figure 9 Surface profiles of home-bleached Co-Cr-Ti alloy.

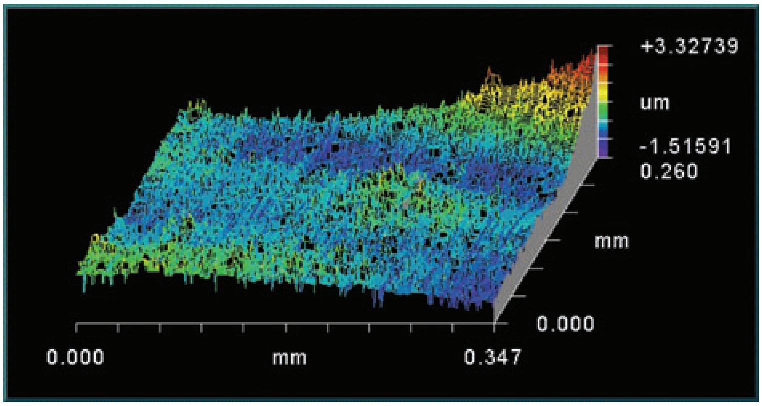

Figure 10 Surface profiles of office-bleached Co-Cr-Ti alloy.

Although the literature is rich with studies on the effect of different concentrations and compositions of bleaching agents on tooth structure and esthetic restorative materials,[18-23] few researchers have studied the effect of bleaching on ceramometallic dental alloys; however, the majority of these researchers studied the effect of bleaching on the corrosion behavior of dental alloys.[29] This study focused on surface topography due to the major role played by surface roughness in allowing plaque accumulation and microorganism deposition.[26-28] Two parameters for surface roughness were calculated: average roughness (Ra), which is the arithmetic mean of the departure of the roughness profile from the profile center line; and root-mean-square roughness (Rq), which is the average of the measured height deviations taken within the evaluation length or area, measured from the mean linear surface.[30]

Three types of ceramometallic dental alloys were studied (Au alloy, Ni-Cr alloy, Co-Cr-Ti alloy). The gold-based metal casting alloys achieved corrosion resistance due to the inherent nobility of gold, which does not form stable oxides at room temperature and has good biocompatibility.[31] For eco-

Table 2 Two-way ANOVA

Source	S.S.	df	M.S.	F	P
Total	3.1091	44	–	–	–
Column factor	0.7899	2	0.3950	41.1458	<.05
Raw factor	1.6866	2	0.8433	87.8438	<.05
Between cells	2.7629	–	–	–	–
Interaction	0.2864	4	0.0716	7.4583	<.05
Error	0.3462	36	0.0096	–	–

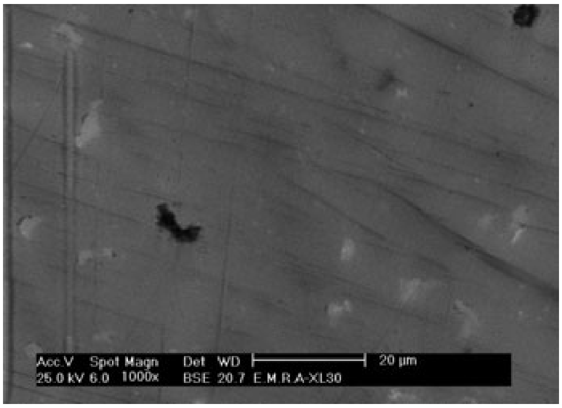

Figure 12 SEM of home-bleached Au alloy.

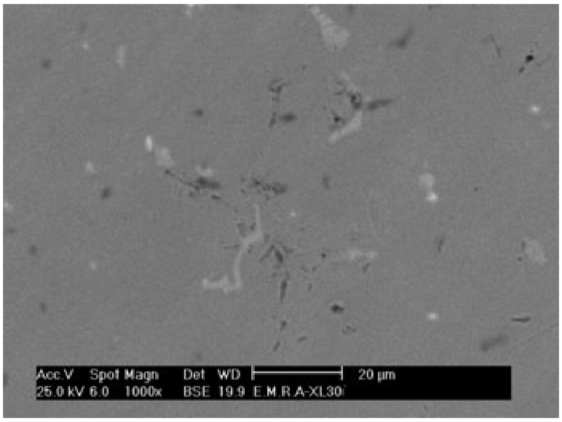

Figure 11 SEM of Au alloy.

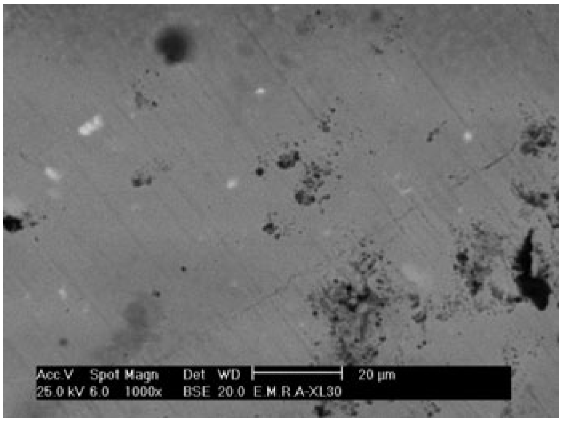

Figure 13 SEM of office-bleached Au alloy.

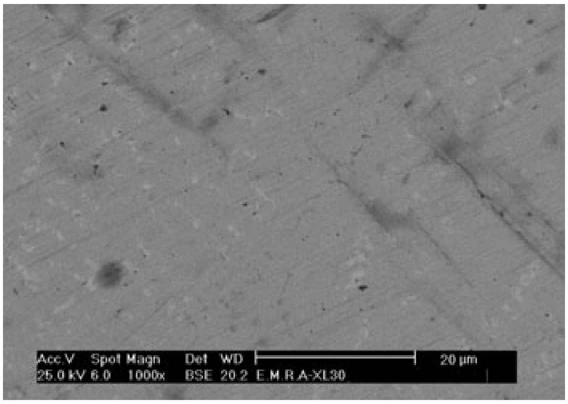

Figure 14 SEM of Ni-Cr alloy.

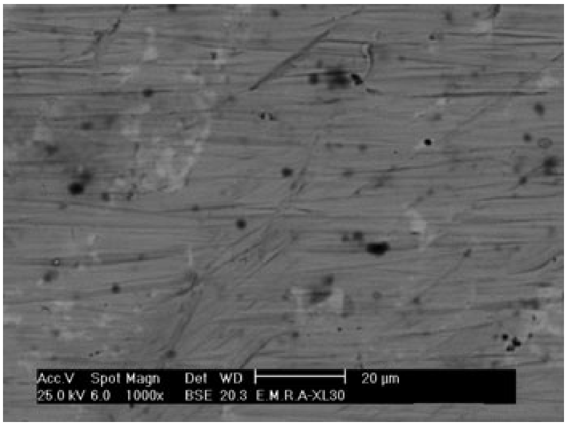

Figure 15 SEM of home-bleached Ni-Cr alloy.

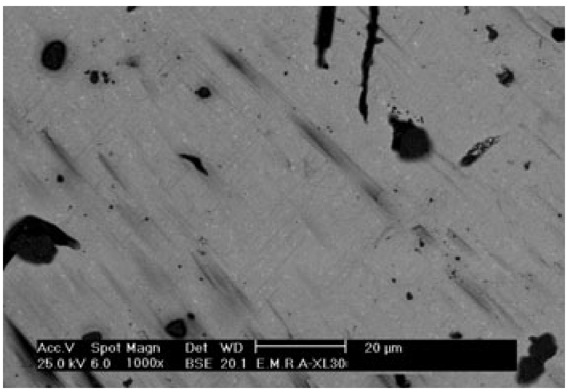

Figure 16 SEM of office-bleached Ni-Cr alloy.

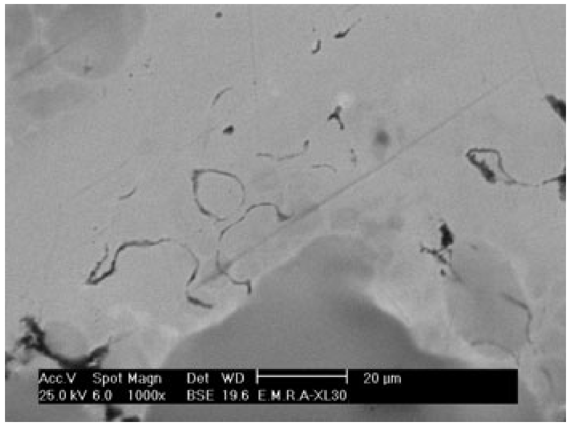

Figure 17 SEM of Co-Cr-Ti alloy.

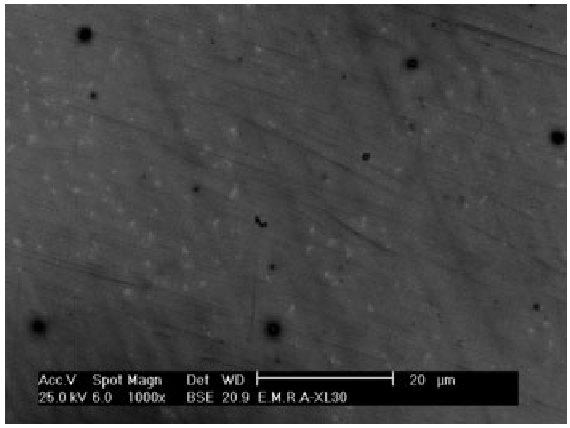

Figure 18 SEM of home-bleached Co-Cr-Ti alloy.

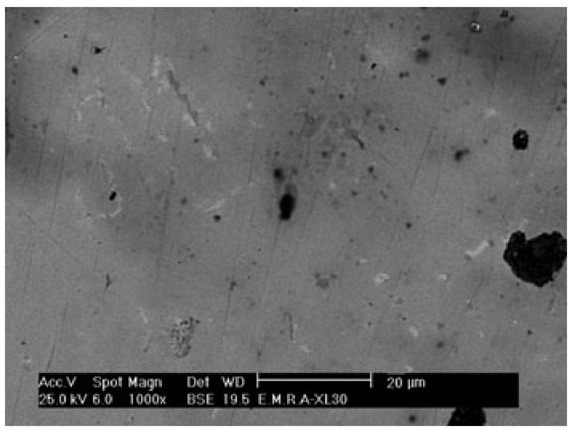

Figure 19 SEM of office-bleached Co-Cr-Ti alloy.

nomic reasons, the search for alternative alloys other than conventional gold has been pursued for many decades. Base metal alloys (Ni-Cr, Co-Cr) have been developed and widely used in dentistry.[32] Recently, Co-Cr-Ti alloys have been developed to incorporate the advantages of both Co-Cr alloy and Ti.[33] Co-Cr base metal alloys can be generally described as nonmagnetic and wear-, corrosion-, heat-, and body-fluid-resistant. Many properties of the alloy originate from the crystallographic nature of Co, the solid solution strengthening effect of Cr and alloying elements, the formation of extremely hard carbides, and the corrosion resistance imparted by Cr. At the same time, Ti has many important properties, including low weight, adequate strength, good corrosion resistance, and excellent biocompatibility. Therefore, the addition of Ti to Co-Cr alloy can improve the properties of Co-Cr alloy.[25]

To simulate a real-life scenario, the specimens of the three investigated ceramometallic dental alloys were subjected to the porcelain firing cycles used in porcelain-fused-to-metal restorations. This simulation was important, as some studies have reported a change in the chemical composition and corrosion behavior for ceramometallic alloys after the melting, casting, and porcelain firing cycle processes.[34-35]

Two types of bleaching agents representing products intended for home and in-office use were examined in this research. The number and duration of applications represented the maximum use of the material as recommended by the manufacturer. These were 14 applications, 8 hours each for home-bleaching agent, which is the equivalent of 2 weeks nighttime use. For the in-office bleaching agent, four applications of 2 hours each were applied.

Although the SEM examination revealed some surface changes, in the form of pitting, in the home-bleached subgroups, results demonstrated no statistical difference in surface roughness between the control subgroups of both Au alloy and Co-Cr-Ti alloy and their home-bleached subgroups. Pitting is considered to be a type of corrosion. Pitting in this case may be due to the low concentration of the home-bleaching active ingredient (10% carbamide peroxide) and the excellent corrosion resistance of the Au alloy. In addition, the Co-Cr-Ti alloy is composed of Co-Cr, which has good corrosion resistance, and Ti, which possesses an excellent corrosion resistance. Surface roughness of both alloys (Au and Co-Cr-Ti) showed a statistical difference between the home-bleached subgroups and the office-bleached subgroups. This may be related to the higher carbamide peroxide concentration in the in-office (35%) groups than in the home-bleaching (10%) groups. This assumption is in accordance with the findings of other investigators, who have reported that the detrimental effect of bleaching agents is directly proportional to their concentrations.[14,36] On the other hand, there was a significant difference between the office-bleached Au alloy and the Co-Cr-Ti alloy. This may be attributed to the fact that Au has more corrosion resistance than Co-Cr-Ti alloy. Au is a noble element with a more advanced place in the electromotive series than any element in Co-Cr-Ti alloy.[25]

A significant difference in surface roughness was found between the control subgroup and the two bleached Ni-Cr alloy subgroups. SEM examination revealed extensive pitting and grooves on the alloy surface and attacks around grain boundaries of the bleached subgroups. This may be because Ni-Cr possesses low corrosion resistance.[37] Comparing the two bleached subgroups (home, in-office), no statistical difference was found, although the office-bleached subgroup recorded higher surface roughness (0.79, 0.99 μm) than the home-bleached subgroup (0.69, 0.92 μm). In addition, the SEM examination revealed a more pronounced effect. This may be because the base metal casting alloys, in which Ni is the principal element, oxidize rapidly to form a passivating chromium oxide surface layer that blocks the diffusion of oxygen to the underlying metal.[31]

Comparing the Au alloy and the Co-Cr-Ti alloy on one side and the Ni-Cr alloy on the other revealed a statistical difference between them in all subgroups, except for the office-bleached Ni-Cr and the Co-Cr-Ti alloy subgroups. This may be related to the fact that both subgroups suffered a marked surface deterioration due to the high concentration of the bleaching agent. Surface roughness means for the nonbleached Ni-Cr alloy were 0.48 (Ra) and 0.63 (Rq) and were 0.79 (Ra) and 0.99 (Rz) μm for the Ni-Cr office-bleached group. Surface roughness means for the nonbleached Co-Cr-Ti alloy were 0.22 (Ra) and 0.30 (Rq) and were 0.87 (Ra) and 1.13 (Rz) μm for the Co-Cr-Ti office-bleached group.[14,36]

Conclusions

Based on the results obtained in this study, the following can be concluded:

1. Bleaching agents have a negative effect on the surface topography of dental ceramometallic alloys, increasing surface roughness and pitting.
2. Increasing the concentration of the bleaching agents resulted in increasing the surface topography deterioration of the alloys tested.
3. No statistical difference was found between the control subgroup and the home-bleached subgroup for the Au alloy or the Co-Cr-Ti alloy.
4. Office bleaching has a significant effect on the Au alloy and Co-Cr-Ti alloys, increasing the surface roughness.
5. Ni-Cr alloys showed the highest surface topography alteration in all subgroups, but no statistical difference was found between the office-bleached subgroups of the Ni-Cr and the Co-Cr-Ti alloys.

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