

Effect of toothbrushing with different toothpastes at commercially pure titanium surface roughness

Efeito da escovação com diferentes dentífricos na rugosidade superficial do titânio comercialmente puro

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ABSTRACT

Objective

To evaluate the effect of brushing, using toothpastes with different fluoride concentrations, on the surface of commercially pure titanium (cp Ti).

Methods

Discs (13x4mm) made of cp Ti, embedded in PVC rings and metallographically polished have their surface roughness measured. Tooth brushing simulations (50,400 cycles) were performed: speed of 80mm/s, distance of 10mm distance, at 240 cycles/min. Three toothpastes were tested: Prevident 5000 (Colgate-Palmolive Ind. e Com. Ltda., São Paulo, Brazil), Colgate Total 12 (Colgate-Palmolive Ind. e Com. Ltda., São Paulo, Brazil) and Tandy (Colgate-Palmolive Ind. e Com. Ltda., São Paulo, Brazil), with 5000, 1300 and 500ppm fluoride concentrations, respectively. The brushings had 7.14g and 14.28g of toothpaste, both for 50mL of deionized water. The surface roughness was reevaluated and data were analyzed by two-way ANOVA and Tukey's test for the effect of brushing and toothpastes.

Results

At the beginning, no significant difference ($p=0.09$) of roughness was noted among the experimental groups (Prevident, Colgate-Palmolive Ind. e Com. Ltda., São Paulo, Brazil): 0.160 ± 0.019 ; Colgate Total 12 (Colgate-Palmolive Ind. e Com. Ltda., São Paulo, Brazil): 0.159 ± 0.030 ; Tandy (Colgate-Palmolive Ind. e Com. Ltda., São Paulo, Brazil): 0.157 ± 0.019) but roughness decreased after the 1st ($p<0.05$) (0.094 ± 0.010) and 2nd (0.089 ± 0.012) brushings ($p<0.05$) with Prevident 5000 (Colgate-Palmolive Ind. e Com. Ltda., São Paulo, Brazil), with no significant difference between the 1st and 2nd brushings ($p=0.16$). Discs brushed with Colgate Total 12 (Colgate-Palmolive Ind. e Com. Ltda., São Paulo, Brazil) presented surface roughness similar ($p=0.090$) at the beginning and after the 1st brushing (0.133 ± 0.029), and between the 1st and 2nd (0.113 ± 0.009) brushings ($p=0.402$); roughness after the 2nd brushing was statistically greater than at the beginning ($p<0.05$). Tandy (Colgate-Palmolive Ind. e Com. Ltda., São Paulo, Brazil) toothpaste caused a surface roughness significantly lower ($p<0.05$) after the 2nd brushing (0.113 ± 0.010), compared to the 1st (0.147 ± 0.020) and the starting point, which were statistically similar ($p=0.090$).

Conclusion

The results suggest that brushing using toothpastes with fluoride causes a decrease in the surface roughness of cp Ti, mainly when greater fluoride concentrations are present.

Indexing terms: Dentifrices. Fluorine. Titanium. Toothbrushing.

RESUMO

Objetivo

Avaliar o efeito da escovação com dentífricos contendo diferentes concentrações de flúor na superfície do titânio comercialmente puro (Ti cp).

Métodos

Discos (13x4mm) de Ti cp, embutidos em anéis de PVC e polidos metalograficamente, tiveram a rugosidade superficial avaliada. A simulação da escovação (50400 ciclos) teve velocidade de 80mm/s, curso de 10mm, com 240 ciclos/min. Foram testados três dentífricos: Prevident 5000, (Colgate-Palmolive Ind. e Com. Ltda., São Paulo, Brasil); Colgate Total 12 (Colgate-Palmolive Ind. e Com. Ltda., São Paulo, Brasil) e Tandy (Colgate-Palmolive Ind. e Com. Ltda., São Paulo, Brasil), com 5000, 1300 e 500ppm de flúor, respectivamente. As escovações tiveram 7,14g e 14,28g de dentífrico, ambas para 50ml de água deionizada. A rugosidade superficial foi reavaliada e os dados analisados por ANOVA - dois fatores e teste de Tukey quanto ao efeito da escovação e dos dentífricos.

Resultados

Inicialmente não houve diferença significativa ($p=0,09$) na rugosidade dos grupos experimentais Prevident, (Colgate-Palmolive Ind. e Com. Ltda., São Paulo, Brasil): $0,160\pm 0,019$; Colgate Total 12 (Colgate-Palmolive Ind. e Com. Ltda., São Paulo, Brasil): $0,159\pm 0,030$; Tandy (Colgate-Palmolive Ind. e Com. Ltda., São Paulo, Brasil): $0,157\pm 0,019$), mas houve diminuição da rugosidade após a 1ª ($0,094\pm 0,010$) ($p<0,05$) e 2ª ($0,089\pm 0,012$) escovações ($p<0,05$) com Prevident 5000 (Colgate-Palmolive Ind. e Com. Ltda., São Paulo, Brasil), sem diferença significativa entre as demais ($p=0,16$). Discos escovados com Colgate Total 12 (Colgate-Palmolive Ind. e Com. Ltda., São Paulo, Brasil) apresentaram rugosidade semelhante inicialmente ($p=0,090$) e após a 1ª escovação ($0,133\pm 0,029$), e entre a 1ª e a 2ª escovações ($0,113\pm 0,009$) ($p=0,402$); a rugosidade após a 2ª escovação foi significativamente maior que a inicial ($p<0,05$). O dentífrico Tandy (Colgate-Palmolive Ind. e Com. Ltda., São Paulo, Brasil) causou rugosidade superficial significativamente menor ($p<0,05$) após a 2ª escovação ($0,113\pm 0,010$), comparada à 1ª ($0,147\pm 0,020$) e a inicial, que foram semelhantes ($p=0,090$).

Conclusão

Os resultados sugerem que a escovação com dentífricos fluoretados diminui a rugosidade superficial do Ti cp, mais significativamente quanto maiores as concentrações de flúor presentes.

Termos de indexação: Dentífricos. Flúor. Titânio. Escovação dentária.

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INTRODUCTION

The increasing use of titanium in dentistry, with the frameworks of prostheses and implants, is a result of its good mechanical and biological properties¹⁻². To be able to manufacture, from titanium, the frameworks of partial, fixed and removable prostheses, casting machines and special investments have been developed in recent years³.

Titanium is a biocompatible material which is resistant to corrosion due to the formation of a protective layer on its surface⁴⁻⁵, composed of different oxides, of which TiO₂ is the most abundant⁵⁻⁷. A direct relationship can be noted between resistance to corrosion and biocompatibility, as corrosion leads to the release of metallic ions that could be distributed to the various tissues present in the oral cavity and systemically⁸⁻⁹. Therefore, the passive layer forming on the surface of the titanium is responsible for its biocompatibility as it prevents elements being released from the titanium surface to the medium in which the material is immersed¹⁰.

Nevertheless, when the titanium is in the oral medium, specifically when in a reduced pH, it can degrade quickly, mainly if it comes into contact with fluoridated solutions, as the incorporation of highly reactive fluoride ions into the layer of titanium oxides considerably reduces its protective properties^{4,7}.

As in dental practice the application of fluoridated solutions in different concentrations has been quite an effective way to control caries, the protective layer of the surface of the titanium becomes susceptible, leading to a consequent increase in surface roughness and the appearance of flaws on its surface, thus favoring the process of corrosion¹¹. In addition, oral hygiene includes the use of dentifrices that may contain different abrasive agents that help with the removal of the biofilm, the conditioning film and food debris. Consequently, grooves or polished areas may appear on the surface of the titanium due to the abrasiveness of the dentifrice¹². When combined with abrasive agents, dentifrices may present different concentrations of fluoride that could interfere with the passive layer forming on the surface of the titanium, and the texture and composition of the surface will be modified, mainly in an acid medium¹³⁻¹⁴.

It is also necessary to consider that during brushing, the chemical effect of the dentifrices will be combined with the mechanical effect arising from the presence of the abrasive particles and the toothbrush bristles which, according to some authors, are the items

mostly responsible for the deterioration of the titanium surface¹⁵. The deteriorated surface becomes susceptible to the buildup of biofilm and the greater release of metallic ions, having an impact on the toxicity of the material^{7,16}. As a result of this, various studies have researched the effect on the titanium surface^{10,12-15} of brushing with dentifrices of different viscosities, abrasiveness and fluoride concentrations.

The objective of this study was to evaluate the effect of brushing on the surface of commercially pure titanium, using a variety of dentifrices available commercially in Brazil, with different concentrations of fluoride.

METHODS

Wax models in the form of disks, with a diameter of 13mm and 4mm wide, were invested in Rematitan Plus phosphate investment (Dentaurum, Pforzheim, Germany) and cast in commercially pure titanium (cp Ti) grade I (Tritan Dentaurum, Pforzheim, Germany) in the Discovery Plasma casting machine (EDG Equipamentos e Controles Ltda., São Paulo, Brazil), which cast using a voltaic arc in an inert atmosphere of argon, with an injection of the metal into the mold by vacuum pressure.

After casting, the discs are divested and blasted with aluminum oxide particles (80psi=5.62kgf/cm²), polished using wet sandpaper with grits of 320, 400, 600, 1200, 1500 and 2000 (Norton, Saint-Gobain Abrasivos Ltda., Igarassú, Brazil), and the final polishing was carried out using a special titanium polishing cloth (Fortel, São Paulo, Brazil) and a colloidal silica based solution (OPS, Struers A/S, Denmark) + H₂O₂ 30%.

Before and after the brushing simulation test, the discs were washed in an ultrasonic bath, immersed for 10 minutes in isopropyl alcohol and then immersed twice in distilled water, for 10 minutes. The average surface roughness of the samples was then measured (Ra) using a roughness tester (Mitutoyo SJ201-P, precision of 300µm, speed of 0.5mm/s and cut-offs of 0.8mm). Three readings were taken for each test specimen and the mean value was then calculated.

For the brushing simulation tests, the test specimens and the Colgate Professional toothbrushes (Colgate-Palmolive Ind. e Com. Ltda., São Paulo, Brazil), whose bristles were soft, straight and of equal height, were embedded in PVC rings using self-polymerizing acrylic resin so that they could be encased in the equipment. The samples

were numbered and divided randomly into three groups, varying the dentifrice with different fluoride concentrations: Colgate Total 12 (Colgate-Palmolive Ind. e Com. Ltda., São Paulo, Brazil) (0.32% NaF; 1,300 ppm fluoride, Colgate-Palmolive Ind. e Com. Ltda., São Paulo, Brazil), Tandy (Colgate-Palmolive Ind. e Com. Ltda., São Paulo, Brazil) (~0.16% NaF; 500 ppm fluoride, Colgate-Palmolive Ind. e Com. Ltda., São Paulo, Brazil) and Prevident 5000 (Colgate-Palmolive Ind. e Com. Ltda., São Paulo, Brazil) (1.1% NaF; 5,000 ppm fluoride, Colgate-Palmolive Ind. e Com. Ltda., São Paulo, Brazil). The test specimens were subjected to two brushing simulation tests, varying the concentration of the dentifrice used. For the first brushing simulation test, the solution containing dentifrice was prepared by adding 7.14g of dentifrice to 50ml of deionized water; and for the second test, 14.28g of dentifrice was added to 50ml of deionized water, the test specimens being polished again between the first and second brushing simulation test. This concentration was used for each test specimen individually.

The brushing simulation test was conducted on equipment developed within the Department of Dental Materials and Prostheses at the Faculty of Dentistry in Ribeirão Preto, University of São Paulo¹⁷ and carried out via repeated gliding using a load of approximately 5N at a frequency of 4.4Hz (265 cycles per minute, and a distance of 10mm). A total of 50,400 cycles were carried out over a period of 180 minutes, corresponding to 4.7 months of brushing, assuming two brushing sessions of two minutes each, twice a day¹⁸.

The data obtained were tabulated and submitted for statistical analysis using the software SPSS 12.0 (SPSS Inc., USA). Once the normality of the sample distribution was found, a two-way analysis of variance was performed as well as a Tukey HSD test, to evaluate the effect of the brushing and the dentifrices on the surface roughness of the cp Ti.

RESULTS

The results of the surface roughness of the test specimens, before and after brushing with the different dentifrices evaluated, are shown in Figure 1 and in Table 1. Table 1 shows the statistical differences between the groups, taking into account the variation factors brushing, dentifrice and interaction of these two factors. The variation factors brushing, dentifrice and interaction of the two factors were significant in terms of the surface roughness of the cp Ti.

Initially, there was no statistically significant difference ($p=0.09$) between roughness in the three experimental groups Prevident (Colgate-Palmolive Ind. e Com. Ltda., São Paulo, Brazil); Colgate Total 12 (Colgate-Palmolive Ind. e Com. Ltda., São Paulo, Brazil); and Tandy (Colgate-Palmolive Ind. e Com. Ltda., São Paulo, Brazil), but there was a reduction in roughness after the 1st ($p<0.05$) and 2nd brushings ($p<0.05$) when the dentifrice Prevident (Colgate-Palmolive Ind. e Com. Ltda., São Paulo, Brazil) 5000 was used, with no significant difference between the 1st and 2nd brushings ($p=0.16$). The discs brushed with the dentifrice Colgate Total 12 (Colgate-Palmolive Ind. e Com. Ltda., São Paulo, Brazil) showed statistically similar roughness ($p=0.402$) at the start and after the 1st brushing, but the roughness after the 2nd brushing was statistically lower than at the start ($p<0.05$), though no different from the roughness after the 1st brushing ($p=0.402$). As for the dentifrice Tandy (Colgate-Palmolive Ind. e Com. Ltda., São Paulo, Brazil), this showed significantly lower roughness ($p<0.05$) only after the 2nd brushing, compared with the 1st brushing and at the start, which were statistically similar ($p=0.09$).

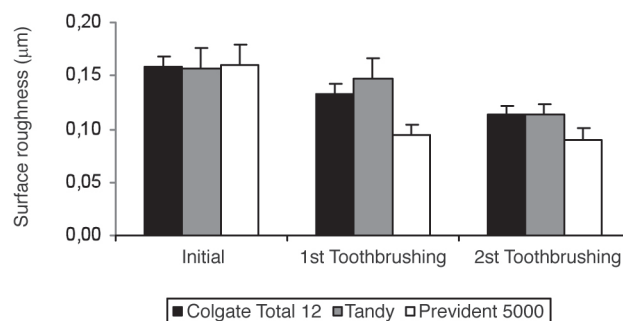


Figure 1. Surface roughness (μm) of the test specimens at the start and after the brushing simulation with the different dentifrices.

Table 1. Results of mean surface roughness (μm) of the test specimens at the start and after the brushing simulation with the different dentifrices. The results are presented as averages (standard deviation).

	Start	1 st Brushing	2 nd Brushing
Colgate Total 12	0.159 (0.030) ^a	0.133 (0.029) ^{ab}	0.113 (0.009) ^{bc}
Tandy	0.157 (0.019) ^a	0.147 (0.020) ^a	0.113 (0.010) ^{bc}
Prevident 5000	0.160 (0.019) ^a	0.094 (0.010) ^c	0.089 (0.012) ^c

* The different letters represent statistically significant differences ($p<0.05$).

DISCUSSION

In this study, a machine which simulates brushing was used to evaluate the effect of brushing, with a variety of dentifrices, on the surface of the cp Ti, simulating a period of approximately 4.7 months of brushing, based on the estimated time of each brushing and on the number

of times the teeth are brushed each day¹⁸. Even though it is necessary to take into consideration that brushing, in practice, is performed in single sessions of 2 to 3 minutes, followed by a long period of recovery of the metallic surface, which is subject to variations in temperature, pH, humidity and bacterial activity in the oral medium⁸⁻⁹, it is necessary to understand the difficulty of simulating these factors in *in vitro* simulation tests. Although the results of the *in vitro* simulation tests have their limitations, such as intermittent brushing of the surface and they cannot be transported directly to the clinic, these are useful tools in predicting the clinical behavior of the materials.

In the knowledge that surface roughness is one of the characteristics affected by brushing, this study evaluated the surface roughness of cp Ti by using different dentifrices in two separate concentrations. Although there are accounts in the literature of increased surface roughness after brushing^{12,16}, in this study the reduction in roughness was observed after brushing, and after the first brushing, where the lower concentration of dentifrice in the solution was used, only the dentifrice Prevident 5000 (Colgate-Palmolive Ind. e Com. Ltda., São Paulo, Brazil), whose fluoride concentration is higher, led to a significant reduction in surface roughness. Nevertheless, the other dentifrices also led to a significant reduction in surface roughness after the second brushing, when higher concentrations of dentifrice were used in the solution. These results are in agreement with those reported in another study, which corroborates the reduction in surface roughness after brushing¹⁹.

Despite the titanium surface alteration being attributed to the chemical composition of the dentifrices, their abrasive agents and mainly to the toothbrush bristles¹⁵, this study standardized the toothbrushes used in order to evaluate only the effect of the different dentifrices on the surface of the cp Ti. The different dentifrices behaved differently after brushing, with dentifrice Prevident 5000 (Colgate-Palmolive Ind. e Com. Ltda., São Paulo, Brazil) showing a reduction in surface roughness even when a smaller concentration of dentifrice was used in the solution. With regard to the dentifrices Colgate Total 12 (Colgate-Palmolive Ind. e Com. Ltda., São Paulo, Brazil) and Tandy (Colgate-Palmolive Ind. e Com. Ltda., São Paulo, Brazil), these only showed a significant difference in surface roughness when a higher concentration of dentifrice was used for brushing. These results may be attributed to the concentration of fluoride present in the dentifrices, since Colgate Total 12 (Colgate-Palmolive Ind. e Com. Ltda., São Paulo, Brazil) and Tandy (Colgate-Palmolive Ind. e Com.

Ltda., São Paulo, Brazil) exhibited 1,300ppm and 500ppm respectively, while the dentifrice Prevident (Colgate-Palmolive Ind. e Com. Ltda., São Paulo, Brazil) exhibited 5,000ppm.

The effect of the concentration of fluoride on the surface of the titanium was evaluated in another study¹⁵ which, on immersing the cp Ti discs into solutions of topical fluoride, reported having had greater corrosion when a solution with a high concentration of fluoride was used, but the authors reported that this corrosion was superficial and temporary, since the protective layer of oxides on the surface of the titanium is quickly restored, arguing that the controlled use of these substances did not promote a marked degradation on the surface of this material. Although in the present study the effect of the dentifrices containing different concentrations of fluoride may have been evaluated using surface roughness after brushing, significant changes in surface roughness also seem to be dependent on the fluoride concentration.

However, in spite of the various studies having demonstrated a concern over the use of fluoridated compounds on the surface of the cp Ti because the dissolution of the titanium, after undergoing the corrosive process, would lead to the occurrence of a totally rough surface, which would consequently lead to a greater buildup of biofilm^{7,16}, in the present study, a reduction in surface roughness was observed after the brushing simulation test. It is possible that this alteration in surface roughness may have been affected by the abrasiveness of the dentifrice. Nevertheless, although the morphology of the abrasive particles and the abrasiveness of the dentifrice have not been covered in this study, all the dentifrices used contained silica as the abrasive particle and are considered to be dentifrices of low abrasion¹. According to a study that evaluated the surface of the titanium after brushing with dentifrices with different abrasive particles, the silica based dentifrices were the ones that produced less roughness after the brushing simulation¹², and this is perhaps one of the reasons for the results found, which are different from others reported in the literature. According to the manufacturer¹, the dentifrice Tandy (Colgate-Palmolive Ind. e Com. Ltda., São Paulo, Brazil) is 20% less abrasive than the other dentifrices studied, but the morphology of the abrasive particles and the percentage of abrasive agents cannot be revealed as they constitute an industrial secret. Considering that the abrasiveness of the dentifrices Colgate Total 12 (Colgate-Palmolive Ind. e Com. Ltda., São Paulo, Brazil) and Prevident 5000 (Colgate-Palmolive Ind. e Com. Ltda., São Paulo, Brazil) is identical, and the surface roughness of the discs brushed with Colgate Total

12 (Colgate-Palmolive Ind. e Com. Ltda., São Paulo, Brazil) only presents a significant reduction after the 2nd brushing, while the discs brushed with Prevident 5000 (Colgate-Palmolive Ind. e Com. Ltda., São Paulo, Brazil) showed a significant reduction after the 1st brushing, where a lower concentration of dentifrice was used, this difference may be attributed to the concentration of fluoride present in the two dentifrices. Surface roughness of the discs brushed with the dentifrices Tandy (Colgate-Palmolive Ind. e Com. Ltda., São Paulo, Brazil) and Colgate Total 12 (Colgate-Palmolive Ind. e Com. Ltda., São Paulo, Brazil) was statistically similar after the 1st and 2nd brushing, but there was a reduction in roughness after the 2nd brushing when compared with the starting point. Although the dentifrice Tandy (Colgate-Palmolive Ind. e Com. Ltda., São Paulo, Brazil) is 20% less abrasive and has a lower concentration of fluoride than Colgate Total 12 (Colgate-Palmolive Ind. e Com. Ltda., São Paulo, Brazil), this difference did not interfere with the surface roughness of the samples.

Additionally, some studies have reported the effect of the pH on the interactions between the titanium surface, the fluoridated compounds and the abrasive agents^{10,14}. When studying the effect of the dentifrices with no fluoride and different pH on the surface of the titanium, some authors reported that the brushing carried out in a solution of alkaline or neutral pH gave rise to a rougher surface than in a solution of acidic pH¹⁰. As for Nakagawa et al.¹⁴, they reported that the corrosion process occurring with the titanium, at the moment the fluoride ions are present, was dependent both on the concentration of these ions in the medium and on the pH of the solution, noting that the titanium suffered corrosion even when there was a low fluoride concentration, provided that the solution's pH was low. Similarly, the titanium also exhibited corrosion with high pH, provided that the fluoride ion concentration was high. The authors concluded that the

higher the concentration and the lower the pH, the greater the corrosion suffered by the titanium on its surface.

It is necessary to take into consideration that, due to limitations encountered in the performance of the tests, it was not possible to control the pH of the solution used, thereby preventing an evaluation of the dentifrices with different concentrations of fluoride on the surface of the cp Ti, knowing the pH of the solution. The need remains, therefore, for new information to be collected to evaluate the effect of abrasive particles and the solution's pH on the surface of the cp Ti, evaluating the interaction of the solution's pH factors, abrasive agent and concentration of fluoride at the surface of the cp Ti after brushing. Therefore, other studies are required to find out the surface characteristics of these materials, given the different dentifrices, to enable a better use of dentifrices in clinical practice, when cp Ti frames are present in the oral cavity.

CONCLUSION

The results of this study suggest that silica based dentifrices lead to a reduction in the surface roughness of cp Ti, and this reduction is more significant when higher concentrations of fluoride are present.

Collaborators

RCS RODRIGUES, ACL FARIA, PD FRIGHETTO, MGC MATTOS e RF RIBEIRO all participated in the preparation and performance of the tests, the analysis of results and the composition of the article for publication.

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