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Evaluation of Interactions of Surface Fluorides on Nickel–chromium and Casted Titanium Alloys: An *In Vitro* Study

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ABSTRACT

Aim: The present study was conducted to assess the effects of topical fluoride on casted Titanium and nickel chromium using Scanning Electron Microscope.

Materials and methods : This *in vitro* study comprised of 45 specimens of Titanium and 45 specimens of nickel-chromium of same dimensions. They were divided into three groups of 15 each. GroupI specimens were immersed in 2% neutral sodium fluoride (NaF) solution for 16 minutes. Group II specimens were placed in 1.23% acidulated phosphate fluoride (APF) gel for eight minutes. Group III specimens were placed in distilled water for 8 minutes. All specimens were evaluated for surface roughness using a scanning electron microscope.

Results: Data thus obtained were subjected to statistical analysis including post-hoc test and analysis variance (ANOVA). There was no significant increase in surface roughness of nickel- chromium specimens in group I, II and III ($p > 0.05$) whereas Titanium specimens in group II showed a substantial increase in surface roughness ($p < 0.05$). There was surface corrosion of Titanium specimens and slight pitting of nickel-chromium specimens in group II.

Conclusion: The studied preparation (1.23%) of acidulated phosphate fluoride has shown to affect the surface roughness of Titanium and nickel-chromium specimens whereas 2% neutral sodium fluoride and distilled water has no noticeable effect, therefore, providing some logical clinical correlations.

Clinical significance: Clinicians must be well known about the logical usages of topical fluorides in dentistry. Different fluoride concentrations and preparations are capable of producing prosthesis's surface roughness of various degrees. Surface roughness is acting as potent areas of bacterial adhesion, plaque retention, calculus retention and microcrack formation with poor esthetics and therefore it significantly affect long-term prosthesis success. Thus, the operator must be very critically monitoring and managing the harmful effects of acidic fluoridated on prosthesis made up of casted Titanium and nickel-chromium.

Keywords: Fluorides, Scanning Electron Microscope, Surface roughness, Titanium.

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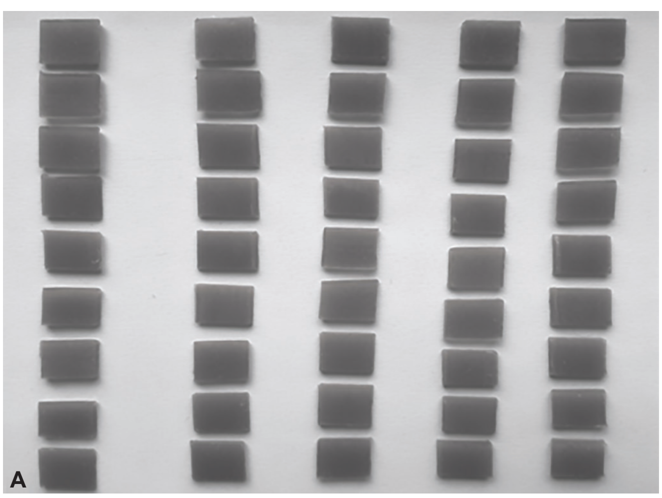
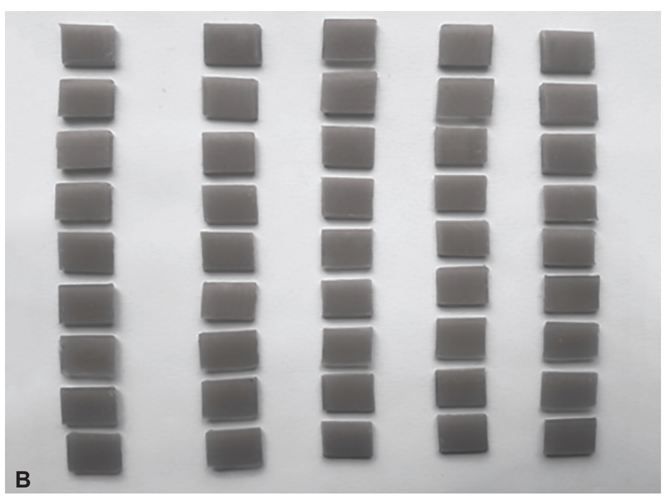
INTRODUCTION

In dentistry, the clinical application of casted Titanium has increased dramatically in the past few years still it has not been adequately discussed in the literature. Interest in the casting of Titanium for dental applications developed because of its favorable properties like excellent biocompatibility and low cost compared to gold. The overall strength and low thermal conductivity are other advantages of titanium based dental prostheses. In modern trends, casted titanium is typically used for single and multiple unit crown and bridge prostheses, implant superstructures and partial or full denture bases.[1] In orthodontic, casted titanium can be used successfully to replace nickel and chromium alloys where patients are assumed to develop hypersensitivity to nickel and chromium alloys.[2] Moreover, titanium is significantly used because of its properties of high strength and rigidity, low density and low weight, ability to withstand high temperatures and corrosion resistance. Titanium exhibits passivation where it quickly forms a stable oxide layer when exposed to air, preventing further oxidation. This protective layer usually is very resistant to the action of strong acids however if it is jeopardized then metal can react with localized environment unexpectedly. Corrosion processes caused by certain acidic phenomenon are known to temper this layer that can further affect the long-term success of the concern prosthesis . Therefore, corrosion in titanium is still a subject of matter of consideration particularly when titanium prosthesis is exposed to the rapidly changing oral environment in different therapeutic and preventive procedures. On the contra ry, nickel-chromium is being used since 1970 in bridges and crowns. They also possess corrosion resistance. They are most widely used in casting procedures of crown and bridges. However, ultimately they are to be maintained unaffected in the intraoral environment so as to possess optimum desirable properties. Dental fluorides are well known preventive agents extensively used in dental offices as well as at home by patients. They are typically used in topical forms such as 2% NaF and 1.23% APF gel. Dental fluorides are available in solutions, gels, pastes, varnishes and other preparations. Various studies have shown that fluorides prevent progression of dental caries by creating fluorapatite which is more resistant to acid attack. This is how it makes a protective sheet over teeth thus helps in the prevention of dental caries. Additionally, fluorides aid in the re -mineralization process as a defense mechanism of the tooth.[3] Therefore it is imperative to explore the fundamental interactions of Dental fluorides on Nickel- chromium and casted titanium hence authors have genuinely attempted to assess the effect of topical fluoride on casted titanium and nickel chromium using scanning electron microscope.

MATERIALS AND METHODS

The present study was conducted in the Department of Prosthodontics. The sole aim of the study was to evaluate the effects of topical fluoride on prosthetic materials like nickel chromium and casted Titanium those used for fabricating crown and bridge prostheses, implant superstructures and partial or full denture bases. It comprised of 45 titanium and 45 nickel-chromium test specimens. Ethical clearance was taken prior to the execution of the study. The 90 wax patterns were made by flowing molten casting inlay wax into the mold space of 10 mm × 8 mm × 2 mm with the help of a thermostat (Thermo-mat, Dentaurum GMBH and Co., Ulm, Germany). All wax patterns were of rectangular in shape. The 45 wax patterns were used for preparing cast Titanium samples (Schuler–Dental GmbH and Co., Ulm, Germany) and 45 wax patterns were used for preparing cast nickel-chromium samples (MeAlloy, Dentsply, India). All ninety samples were thoroughly checked for casting defects (both internal and external) by manual and roentgenographic methods (Fig. 1). Castings with defects were re-fabricated instead of repairing to avoid any error in result compilations and interpretations. Titanium samples were freed from superficial coatings using Titanium finishing bur (Dentaurum, Germany). While nickel-chromium specimens were freed from all surface defects by regular tungsten carbide burs (Dentsply, India). To maintain strict standardization, all samples were finished by the solo operator for 7 minutes using very light unidirectional force. To avoid any manual fatigue stress or error that could produce biased results, only five samples were finished per day. All samples were finally uncontaminated in an ultrasonic bath for 8 minutes and air dried. Three groups were made of 15 samples each. Group 1 consisted of 15 samples each of Titanium and nickel- chromium which were immersed in 2% neutral sodium fluoride (NaF) solution for 16 minutes. Group II comprised of 15 samples each of titanium and nickel- chromium which was immersed in 1.23% acidulated phosphate fluoride





Figs 1A and B: (A) Finished casting samples of Titanium (n = 45); (B) Finished casting samples of nickel-chromium (n = 45)

(APF) gel for 8 minutes. Group III had 15 samples each of Titanium and nickel-chromium which were placed in distilled water for 8 minutes. All samples were assessed for surface roughness under scanning electron microscope at 500X magnification with a resolution of 10 µm and the accelerating voltage of 20 kV. Results thus obtained were subjected to basic statistics including ANOVA test and post-hoc comparison. A p-value of less than 0.05 was considered significant.

RESULTS

All the observational findings were compiled and sent for statistical evaluation using statistical software Statistical Package for the Social Sciences (SPSS) version 21 (IBM Inc., Armonk, New York, USA). The scanning electron microscopic evaluation revealed exceptionally noticeable changes on the surface of Titanium samples. All macroscopic color changes were seen as dark lined stains. However, it could be possibly due to initiation of corrosion and other oxidative reactions. On contrary nickel-chromium, surfaces showed numerous areas of corrosions and crystalline by products on metal surfaces. It could be explained by the fact that nickel-chromium show extensive pitting corrosion when subjected to acidic medium (acidulated phosphate fluoride). SEM evaluation of Group I samples showed few tiny areas of corrosion while Group II samples showed multiple growing areas of linear corrosion (Figs 2 and 3). All samples those immersed in distilled water showed insignificant changes in surface topography. Only the microscopic markings and irregularities those produced during finishing and polishing was revealed. Table 1 shows that surface roughness (mean ± SD) of Titanium in group I before treatment was 4.84 ± 0.53 µm and after treatment was 4.92 ± 0.52 µm. The difference was nonsignificant ($p > 0.05$). In group II, it was 4.91 ± 0.50 µm and 6.72 ± 0.53 µm before and after treatment respectively. The difference was highly significant ($p < 0.05$). In group III, it was 5.04 ± 0.37 µm and 5.05 ± 0.38 µm before and after treatment respectively. The difference was non- significant ($p > 0.05$). Table 2 shows that surface roughness (mean± S.D) of nickel- chromium in group I was 4.47 ± 0.45 µm and 4.49 ± 0.43 µm before and after treatment respectively. In group II, it was 3.65 ± 0.67 µm and 4.72 ± 0.68 µm before and after treatment respectively. The difference was significant ($p < 0.05$). In group III, it was 4.57 ± 0.51 µm and 4.58 ± 0.52 µm before and after treatment respectively. The difference was non-significant ($p > 0.05$) (Table 2).

Fig. 2: Scanning electron microscopic (SEM) evaluation of Group I samples: Titanium (A) and nickel-chromium (B)

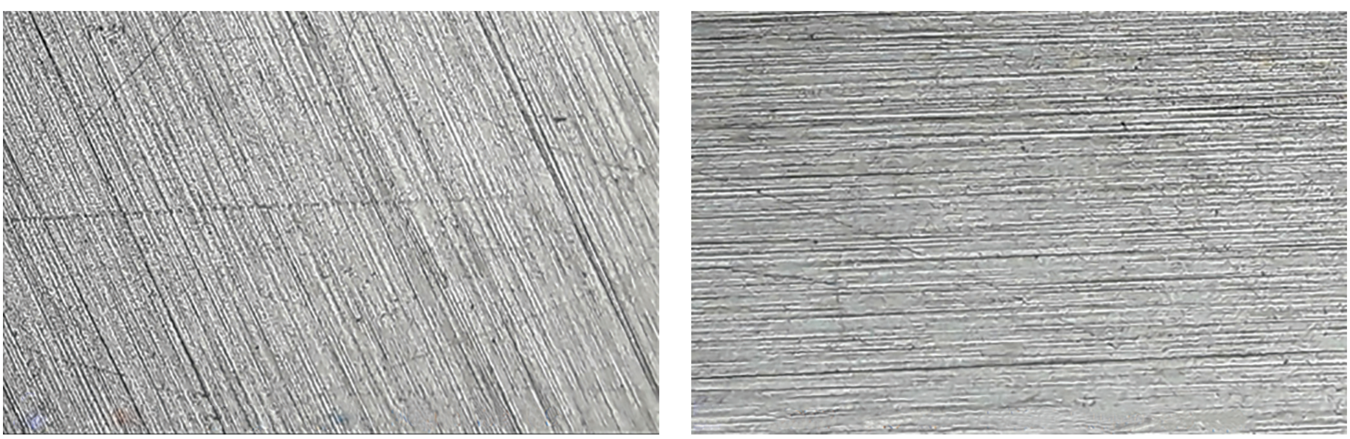


Fig. 3: Scanning electron microscopic (SEM) evaluation of Group II samples: Titanium (A) and nickel-chromium (B)

Table 1: Surface roughness of titanium in all groups (Values in μm)

Groups	*Before Mean ± S.D*	*After Mean ± S.D*	*p-value*
Group I	4.84 ± 0.53	4.92 ± 0.52	0.5
Group II	4.91 ± 0.50	6.72 ± 0.53	0.001*
Group III	5.04 ± 0.37	5.05 ± 0.38	0.71

*p < 0.05 significant

Table 2: Surface roughness of nickel-chromium in all groups (Values in μm)

Groups	*Before Mean ± S.D*	*After Mean± S.D*	*p-value*
Group I	4.47 ± 0.45	4.49± 0.43	0.1
Group II	3.65 ± 0.67	4.72± 0.68	0.04*
Group III	4.57 ± 0.51	4.58± 0.52	0.12

*p < 0.05 significant

Table 3: Comparison between the three respective groups of Titanium and nickel-chromium (post-hoc comparison)

Groups	*Tested samples*		*Mean difference*	*Standard error*	*p-value*
Group I	Titanium	Nickel-chromium	0.054	0.081	0.456
Group II	Titanium	Nickel-chromium	1.542	0.081	0.020*
Group III	Titanium	Nickel-chromium	0.045	0.081	0.360

*p < 0.05 significant

DISCUSSION

Titanium is well tolerated in a salivary environment that makes it popular amongst all metals. It is said to be extremely reactive and when comes in contact with air, it forms titanium oxide which hampers its further oxidation. Moreover, its capability to withstand strong acids in the oral cavity makes it quite popular amongst general dental practitioners. One of the major causes of titanium prosthesis failure is its corrosion titanium. Corrosion is usually seen after tarnish but in cases of titanium, corrosion processes directly and creating surface roughness. The surface roughness of the prosthesis usually acts as areas of bacterial adhesion, plaque retention, and microcrack formation. In corrosion, there is actual surface degradation rather than just surface discoloration. An acidic salivary environment can augment the relative risk of cracking and discoloration that ultimately leads to prosthetic failure. Conversely, nickel-chromium is the metal of choices for crowns, bridges and cast partial denture.[4] Hayes et al. in their study showed that its chromium in a nickel-chromium alloy that increases the corrosion resistance against acidic environment of the oral cavity.[5] Literature has well substantiated that dental fluorides are mostly used in developing as well as developed countries for routine dental preventive measures.[3] As we know that topical fluoride therapy is easy to perform and can be done by the patient at home. Fluoride therapy has become compulsory for those undergoing orthodontic treatment as there is a lack of appropriate oral hygiene in such patients. However, it's being applied as a prophylactic agent in patients with dentine hypersensitivity and dry mouth.[6] The present study was conducted to determine the effect of topical application of fluorides such as NaF and APF on titanium and nickel-chromium.

In the present study, we included 45 samples each of Titanium and nickel- chromium which was treated with 2% NaF in group 1, 1.23% acidulated phosphate fluoride (APF) gel in group II and distilled water in group III. In each group, mean surface roughness was analyzed before and after application of fluoride. Scanning electron microscopic evaluation clearly illustrated different patterns of corrosions seen in two tested materials. Titanium and nickel- chromium samples mainly showed the patterns of pitting, intra-granular and linear corrosions. We found that there was a non-significant change in mean surface roughness of Titanium with NaF and distilled water. However, the value was significantly affected with APF gel (Table 3). The results were comparable with those presented by Boere el al.[7] They stated that titanium is affected by the acidic environment in the presence of fluoride. Travaglini et al. also showed that the corrosion resistance of titanium is due to the formation of titanium oxide in the mouth.[8] The study conducted by Toniollo et al. was as imperative in these perspectives as they also explored the similar objectives. They classified titanium specimens into five groups of 10 each.[9] Group 1 specimens were kept in distilled water, group II specimens were also kept in distilled water, and they were immersed in 0.05% NaF for 3 minutes daily. They processed Group 3 samples by immersing them into distilled water and were subjected to 0.2% NaF for 3 minutes daily. Group 4 samples were kept in distilled water along with 0.05% NaF fortnightly for 3 minutes, and group 5 samples were kept in distilled water and stored in 0.2% NaF fortnightly for 3 minutes. Unlike our study parameters, they had attempted to find the combined effects of the immersion medium on metal surfaces. However, results were not identical and not exactly in accordance to the present study. They noticed non- significant change in surface roughness value before and after the application of fluorides in any concentration on Titanium. In the present study, we found that there was non- significant change in surface roughness value in all groups with nickel-chromium specimens. This shows that fluorides had no effect on nickel-chromium and can be safely used. Nevertheless, there was slight corrosive pitting with APF gel. Laiza et al. conducted a 10 years long-term study to estimate the relative effects of fluoridated and non-fluoridated toothpaste on titanium. Their study results were in accordance with the present study results as they also concluded that fluoridated toothpaste changed the surface topography of these restorations to some extent. However, the difference what they drew was non-significant.[10] Yoshinari and co-workers also explored the similar effects by conducting a study on fluorides and acid producing Streptococcus mutans with pure titanium. They concluded that less than 500 ppm fluorides in the presence of *Streptococcus mutans* affect the corrosion resistance of titanium alloys.[11] Takemoto et al. in their study found that 1.23% sodium fluoride has a deleterious effect on Titanium dental implants.[12] Ana Lucia et al. performed a study to find out the relative strength of Titanium implants in the presence of topical fluorides. They had noticed the effects of surface changes on strength. Similar to our results they also summarized that long-term usage of fluorides produces a detrimental effect on the surface topography of titanium dental implants.[13] Siirila and Kononen in their study assessed the surface of titanium dental implants on the application of topical fluorides found that prolong the abrasive action of brushing is very harmful to titanium dental implants.[14] Tatsumi and colleagues aimed to see the effects of the fluoride-containing solution and peroxide solution on dissolution and discoloration of titanium. Similar to our results they also intimated that commercially pure Titanium showed both dissolution and discoloration with fluoride-containing solution and peroxide solution.[15] Nakagawa and co-workers noticed that the passive film on Titanium surface was damaged under conditions where 30 ppm or more hydrofluoric acid was produced by dissociation of sodium fluoride.[16] However, few other pioneer workers observed that sodium fluoride in the concentration of 0.5% or higher may be sufficient in causing corrosion of Titanium.[17-19] They noticed that fluorides are significantly causing discoloration of titanium. Our results also exhibited quite similar outcomes wherein we found corrosion effects of acidulated phosphate fluoride in titanium and nickel-chromium. Hence care should be taken while applying a topical application of fluorides in patients with titanium or nickel-chromium prosthesis. Also, it must be taken into account that routine laboratory processes like sandblasting, finishing and polishing might have incorporated little variation in surface roughness. They must also be considered in the studies for precise and genuine results. In clinical circumstances, the real exposure time would be possibly longer as the patients are directed not to rinse for 30 minutes after topical fluoride application. Therefore, it is the need of the hour to conduct some additional researches using different topical fluorides with variable concentrations and exposure times.

CONCLUSION

Titanium is frequently used materials for the different dental prosthesis and similarly, nickel-chromium is widely used for fabricating crowns and bridges. Routinely practiced topical fluorides those producing acidic pH may affect the surface topography of both titanium and nickel-chromium. In the present study, 1.23% acidulated phosphate fluoride has been shown to affect the surface roughness of Titanium and nickel-chromium specimens. After immersion into 1.23% acidulated phosphate fluoride, Titanium and nickel-chromium showed an increase in surface roughness by 1.81 ± 0.51 µm and 1.07 ± 0.67 µm respectively. The corrosive effects of this acidic environment were more significant in Titanium as compared to nickel-chromium. However, immersion into 2% neutral sodium fluoride and distilled water has no significant corrosive effects. Our study results could be treated as suggestive for predicting clinical outcomes for prone situations. Though we expect other large-scale, long-term studies to be conducted that could further establish certain concrete guidelines in this field.

CLINICAL SIGNIFICANCE

Clinicians should be cautiou s with the right usages of topical fluorides in different clinical circumstances. Different concentrations and preparations could be capable of producing the surface roughness of various degrees. Any corrosive metallic surface is very prone to be attacked by plaque and calculus thereby. Therefore while using acidic fluoridated preparations in patients with Titanium/nickel-chromium restorations, a clinician must be very careful as it may diminish the overall performances of the prosthesis in their long-term usage.

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