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Original Research Article

Microbial corrosion of orthodontic wires

Gitanjali Yadav[1], Vipul Kumar Sharma[2,*], TP Chaturvedi[1], SN Upadhyay[1], Ragini Tilak[1]

[1]*Banaras Hindu University, Varanasi, Uttar Pradesh, India*
[2]*Institute of Medical Sciences BHU, Varanasi, Uttar Pradesh, India*

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ABSTRACT

Objective: To evaluate microbial corrosion by weight loss, microbial corrosion and elemental analysis of NiTi and stainless wires after period of 2 months in streptococcus mutans containing media.
Results: Percentage change in weight after 2 months is 1.7% and 0.8% in NiTi & SS respectively. Elemental analysis of NiTi wire in streptococcus containing media showed decrease in Ni by 2.9% by weight and Ti decreased 3.07% by weight due to leaching of Ni and Ti from the surface of wires. In stainless steel wire, there was decrease in Fe by 8.82% and Cr 1.39% by weight.
Conclusion: Significant microbial corrosion was observed in NiTi wires as compared with SS wires may be attributed to the surface roughness of NiTi wires. However, the role of biofilm is dual and remained controversial due to being protective and corrosive.

1. Introduction

Microbial corrosion refers to influence of microorganism adhering onto the surface on the kinetics of corrosion process of metals and alloys. Prerequisite to occur microbial corrosion arepresence of microorganism, presence of energy source, electron donor, electron acceptor, and medium in which reaction will occur.[1] All these requisites are present in oral cavity. Hence, orthodontic materials or alloys get deteriorated by the corrosion process. But the phenomenon is less appreciated, due to slowness of process and there is paucity of analytical techniques to identify, localize, control corrosion reaction on metal surfaces.[2] The corrosion of metallic dental materials in presence of Streptococcus mutans and their growth by-products is quite significant. Improper tooth-brushing habits, saline food, and attachment of microbes on the metal might disturb the passivity of metallic aids. The formation of organic acids from sugars by bacteria during glycolysis may reduce pH. A low pH provides a favourable environment for aerobic bacteria to proliferate and influence corrosion.[3] Intraoral aging of Ni-Ti and stainless-steel wires alters topography and structure of alloy surface through surface attack in form of pitting, crevice or galvanic corrosion and formation of integuments. Eliades et al[4] performed an in-vivo study on the surface characterization of retrieved Ni-Ti orthodontic arch wires using optical microscopy, micro multiple internal reflection Fourier transform-infrared spectroscopy (MIR FT-IR) and scanning electron microscope (SEM). The results showed that the intra-oral exposure of Ni-Ti wires altered the topography and structure of the alloy surface through surface attack in the form of pitting or crevice corrosion or formation of integuments. The large surface area provided by the teeth surface along with the orthodontic wire and accumulation of food debris provide favourable condition for growth of the biofilm.[5] Chaturvedi et al[6–8]

* *Corresponding author*.
E-mail address: dr.vipul2010@gmail.com (V. K. Sharma).

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discussed thoroughly the degradation of orthodontic alloys and metals in oral cavity. The metallic materials undergo electrochemical reactions within the oral environment resulting in dissolution or formation of chemical compounds resulting into corrosion. Corrosion is one of the important factors influencing the friction. The effect of bacteria on the corrosion of orthodontic wires in oral cavity has been poorly explored till now. Thus, the objective of present research was to find the microbial corrosion on the surface of commonly used wires and its clinical applications, if any.

2. Materials and Methods

Nickel Titanium (Group A) and Stainless Steel (Group B) arch wires (0.019" x 0.025") were obtained from D-Tech orthodontics Pvt Ltd. These wires were cut in three equal segments and placed in Streptococcus mutans containing media for period of 2 months. The control media used without Streptococcus mutans inoculation. Streptococcus mutans containing media for study was prepared. The composition of artificial saliva was ascertained (7). The sterile Brain Heart Infusion (BHI) broth 10ml contained 1ml of artificial saliva and 0.5ml of 0.5McFarland Streptococcucus mutans suspension made from overnight growth of the organism on 5% sheep blood agar. The culture bottles were labelled as control, and No 1, No 2 bottles having 0.019"X0.025" Ni-Ti (Group A), 0.019"X0.025" Stainless Steel (Group B) wire. The wires were cut into three sizes of 20mm. The control bottle contained only BHI broth, artificial saliva and all the wires but no organisms. All bottles were incubated at 37^0C for 48 hours under aseptic measures; smears were prepared from the bottles to check contaminations. Bottles were free from contamination. The control bottle showed no organisms while bottles No 1 and 2 had very sparse growth of gram-positive cocci in chains.

The incubation was continued during study period with macroscopic observation of bottles at regular interval. Initial pH in all bottles was checked with pH paper and was found to be 7 (neutral). After 4 weeks, again pH was measured for all bottles and found to be 7 for the control bottle while 5.5 for bottle 1and 2.

The incubation was continued till 2 months with similar sterile conditions. After 2 months, wires were removed and placed in sterile petit dishes. The pH of bottles was measured after retrieval of wires and it was found to be 7.05 for control and 4.75 for bottles 1 and 2. Data obtained were subjected to statistical analysis. (SPSS Version 22) The weight changes and surface analysis of wires were evaluated using paired t-test and p-value <0.05 was found to be statistical significance. Wires are compared with fresh wires of same size for surface morphology using SEM and EDAX analysis. Weight of both types of wires is weighed before and after placing in media. Corrosion is determined by weight loss method.

3. Results and Observations

Figure 1 (A-D) showed surface topography of NiTi and SS wires at 4000X and 6000X. The effect of Streptococcus mutans on the surface of wires were observed in both groups as follows; Group A (Ni-Ti wire) at 1000X magnification, the linear defects appeared to be continuous with smooth shallow indentations, well defined round deep pits are visible when compared to fresh wires. These pits were mainly present at the edges of smooth shallow indentations which intensified on further magnification. (Figure 2A-B) Group B (stainless steel wire) at 4000X magnification depicts small granules with dark striations in background as compared to fresh wires. At 6000X magnification shows surface changes with corrosive effect. (Figure 2C-D)

3.1. Energy Dispersive X-Ray Analysis (EDAX)

Elemental analysis of NiTi wire retrieved from streptococcus containing medium showed decrease in percentage of nickel and titanium (Tables 3 and 4). Nickel decreased by 2.90 % and Titanium by 3.07 % by weight when compared to fresh wire. It showed leaching of nickel and titanium from surface of the wire. Figure 3 (A-B) and Figure 4 (A-B) depicted spectrum and elemental analysis of NiTi fresh and retrieved wires while Figure 3 (C-D) and Figure 4 (C-D) showed spectrum and elemental analysis of stainless steel fresh and retrieved wires. Tables 2 and 4 depicted decrease in iron by 8.82% and chromium by 1.39% by weight in retrieved stainless steel wire. The mean value of weight of Group A (NiTi wires) in Streptococcus mutans containing media was 0.220±0.0093 gm at day 0 and 0.217±0.0093 gm at 2month. The difference was found to be statistically significant with p value of <0.001. The mean value of weight of Group B (Stainless Steel wires) in Streptococcus mutans containing media was 0.248±0.0325 gm at day 0 and 0.246±0.0333 gm at 2 months. The difference was found to be statistically significant with p value of <0.001. (Table 5)

Table 1: Elemental analysis of fresh Nickel titanium wire

Element	Weight%	Atomic%
C K	6.98	25.00
Ti K	41.55	37.30
Ni K	51.46	37.69
Total	100.00	

Table 2: Elemental analysis of fresh stainless-steel wire

Element	Weight%	Atomic%
Cr K	21.30	22.52
Fe K	78.70	77.48
Total	100.00	

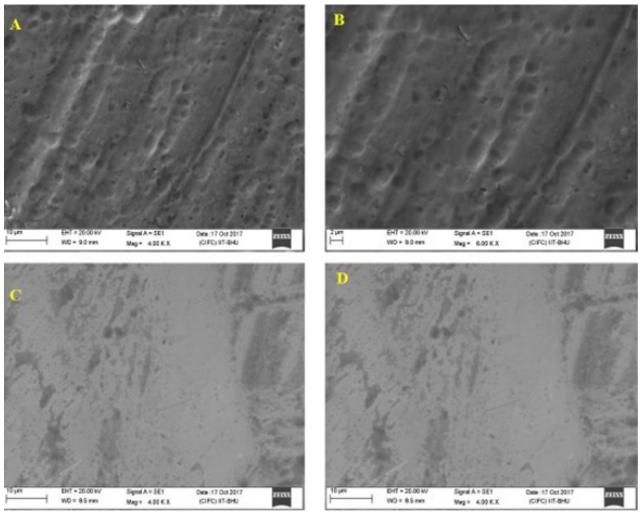

Fig. 1: A: SEM of fresh NiTi wire at 4000X magnification; **B:** SEM of fresh NiTi wire at 6000X magnification; **C:** SEM of fresh stainless-steel wire at 4000X magnification; **D:** SEM of fresh stainless-steel wire at 6000X magnification

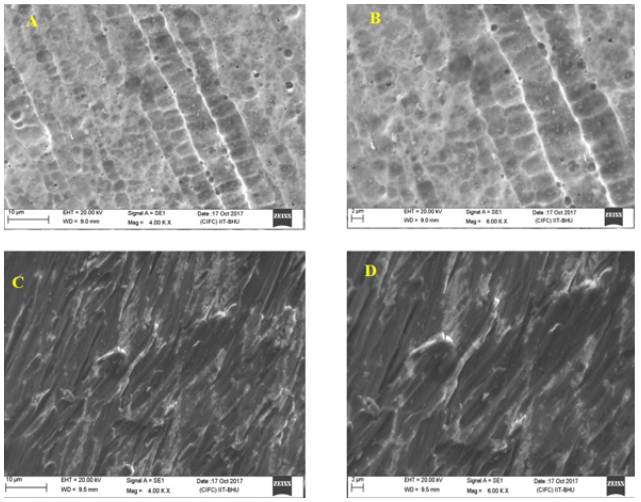

Fig. 2: A: SEM of NiTi wire after 2months in Streptococcus mutans at 4000X magnification; **B:** SEM of NiTi wire after 2months in Streptococcus mutans at 6000X magnification; **C:** SEM of stainless-steel wire after 2months in Streptococcus mutans at 4000X magnification; **D:** SEM of stainless-steel wire after 2months in Streptococcus mutans at 6000X magnification

Table 3: Elemental analysis of Nickel titanium after 2months in *Streptococcus mutans* media

Element	Weight%	Atomic%
C K	9.12	28.88
O K	3.83	9.11
Ti K	38.48	30.55
Ni K	48.56	31.45
Total	100.00	

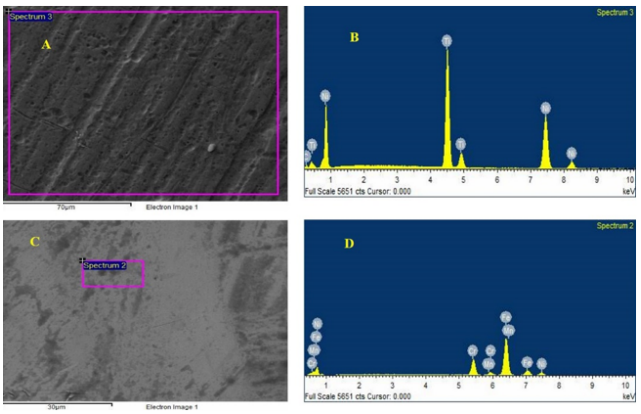

Fig. 3: A: Spectrum selected for EDXA of Fresh Nickel Titanium fresh wire**; B:** Result of EDXA for Fresh Nickel Titanium wire; **C:** Spectrum selected for EDXA of fresh stainless-steel wire; **D:** Result of EDXA for fresh stainless-steel wire.

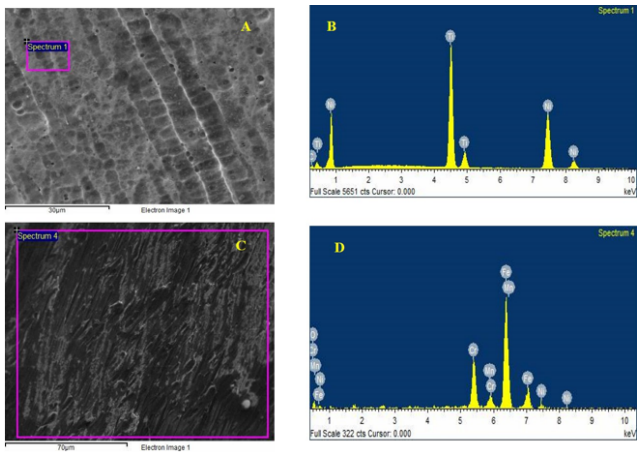

Fig. 4: A: Spectrum selected for EDXA of Streptococcus mutans retrieved Nickel Titanium wire; **B:** Result of EDXA for Streptococcus mutans retrieved Nickel Titanium wire; **C:** Spectrum selected for EDXA of Streptococcus mutans retrieved stainless-steel wire**; D:** Result of EDXA for Streptococcus mutans retrieved stainless-steel wire

Table 4: Elemental analysis of Stainless-steel wire after 2months in *Streptococcus mutans* media

Element	Weight%	Atomic%
O K	3.23	10.32
Cr K	18.91	18.59
Mn K	3.16	2.94
Fe K	69.88	63.96
Ni K	4.82	4.19
Totals	100.00	

Table 5: Changes in weight in Group A (NiTi) and Group B (SS) at start (day 1) and after 2months (day 61) of fresh wires and in *Streptococcus mutans* media

	Mean±SD	p-value	Mean±SD	p-value
	Group A		Group B	
Streptococcus media day 1	0.220±0.0093	<0.001	0.248±0.0325	<0.001
Streptococcus media day 61	0.217±0.0093		0.246±0.0333	

4. Discussion

The oral cavity provides an ideal and unique environment for studying the biological processes affecting metallic dental aids. Various types of metallic orthodontic materials, used in orthodontic treatment, go through chemical or electrochemical reaction with the oral environment resulting in dissolution or formation of chemical compounds.[8] Souzaet al[9] investigated the formation of biofilm on Titanium alloy. It was found that the growth of Streptococcus mutans on titanium surfaces stabilizes after 2 days of incubation in an enriched medium with a high sucrose concentration. The presence of Streptococcus mutans colonies on the titanium surface negatively affected the corrosion resistance.

Intra oral environment exposure of wires for 2 months causes ageing of NiTi and SS orthodontic wires and it contribute to increase in degree of debris deposition and roughness of wire. In SEM analysis at various magnifications, obvious change was found in both NiTi and SS wires. The granular structures were present over NiTi wire whereas pits and certain defects were seen on SS wire. The result supports previous studies done on retrieved NiTi wires.[10] In-vitro crevice corrosion and selective nickel dissolution from the surface has also been documented on Ni-Ti wires.[11] Presence of granules and pits over wire surface is suggestive of leaching of elements from the surface during the course of treatment which might be causative factors for metal allergy.[12,13] The changes in surface of wires suggest deteriorating effect of the oral environment and inhabiting microbes and various other factors like interaction of wire and bracket inter-surface during sliding of wire during treatment, effect of various food supplements, effect of abrasive in tooth paste, fluoride mouth rinses etc. Effect of microbes on metal appliance cannot be ignored as they cause change in pH which is detrimental for surface of orthodontic appliances and other metal alloys used in dentistry.[6,14] Elemental analysis of retrieved wires from streptococcus containing media, compared to fresh wires showed loss of metals from wires. In Nickel Titanium wire of streptococcus containing medium, Nickel decreases by 2.90% by weight and Titanium decreases 3.07% by weight. This shows the leaching of nickel and titanium from surface of wire. In case of stainless-steel wire, there is decrease in iron by 8.82% and chromium by 1.39% by weight. However, in stainless steel wire, elemental analysis shows more leaching of iron and chromium in case of patient retrieved wire as compared to wire retrieved from streptococcus containing media.[5]

The assumption of microbial colonization and subsequent corrosion is debatable in the oral cavity on the basis of a biofilm covering the material surfaces. However, the role of biofilm in corrosion has remained controversial; mechanism of microbiologically influenced corrosion and its inhibition are not completely understood. It cannot be linked to single biochemical reaction or specific microbial species or groups. Information on the identity and role of microbial communities that are related to corrosion and corrosion inhibition in different materials and different environment is scarce.[15] Various mechanism for inhibition of corrosion by biofilm producing bacteria have been described.[16,17]

Oxygen is necessary to form and maintain the film, whereas acidity can be detrimental in particular. It is known that corrosion of orthodontic alloys occurs in the intraoral environment regardless of the metallurgic structure of the alloy and presence of manufacturing defects may accelerate the process.[17] Presence of acidic pH result in pitting corrosion of NiTi wires due to hydrogen penetrating the wire.[18] During reaction, H+ ions are produced, increases pH and resulted OH^- ions adsorbed onto the surface, where they create an electric field for ion migration and subsequent oxide growth.[19] Bacteria slightly reduce the resistance and enhances corrosion in SS wire in a study.[5] Streptococcus mutans containing media with the initial pH of 7.4, exhibited acidic pH of 4.7 at the end of study. There is change in mean value from initial of 0.220±0.0093 gm to 0.217±0.0093 gm with significant p value <0.001 in Ni-Ti and change in mean value of weight 0.248±0.0325 gm to 0.246±0.0333 gm with significant p value <0.001 in stainless steel wire. It is found that % change in weight after 2 months is 1.7% and 0.8% in NiTi and SS respectively. This result is contrary to other studies as they suggest that NiTi is more resistant to corrosion as compared to stainless steel wire due to presence of passivating oxide layer.[20] However, it may be that total corrosion is more in case of stainless steel wire as compared to NiTi wire but it might be possible that due to high roughened surface of NiTi wire, it provides a good site for aggregation of bacteria over the surface of wire resulting in more corrosive effect of bacteria on Ni-Ti as compared to stainless steel wire. Bahije et al[21] demonstrated that colonization of metal surface by bacteria triggered a drop in the free corrosion potential. It was also found that in bacteria enriched solution; there is difference in corrosion current as compared to control solution. This favours more corrosion in Ni-Ti demonstrating impact of acidogenic bacteria on corrosion behaviour of NiTi. This

is inevitable in oral cavity as it cannot be made microbes free. Further, there is frequent fluctuation of pH and change in oral environment.[22] So, clinically we can only control change in pH and oral environment by critical evaluation of patient food habit before start of treatment, instruction of good oral hygiene to flush off debris and less frequent use of mouth wash until clinical condition makes it mandatory.

5. Conclusion

The microbial corrosion is significant in orthodontic wires used during treatment and it might increase friction. More corrosive effect of bacteria on Ni-Ti wire as compared to stainless steel wire was observed. With passage of time, in Streptococcus mutans containing media pH becomes acidic favours to corrosion. Changes in surface morphology and composition affect mechanical properties of wires used during treatment resulting into further increase in the treatment time and decreases effectiveness of treatment. Release of metal may be the issue of allergic reaction in some sensitive patients. Measures should be used to prevent random fluctuation in pH in food habits. Otherwise, it may aggravate the corrosion process. Future study needed to compare between mechanical properties in different environmental conditions for different wires and evaluation of effect of other oral inhabiting bacteria on corrosion both in an in-vitro and in-vivo study.

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7. Conflict of Interest

None.

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Author biography

Gitanjali Yadav, Post Graduate

Vipul Kumar Sharma, Associate Professor https://orcid.org/0000-0002-5487-2440

TP Chaturvedi, Professor

SN Upadhyay, Professor

Ragini Tilak, Professor

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