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# Comparison of corrosion of orthodontic miniscrew in different surface media: An electrochemical and SEM study

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## Abstract

A study was conducted to measure the corrosion resistance of orthodontic miniscrew in different surface medias. A total of 80 miniscrews were divided into two groups on the bases of the type of manufacture. They were then subdivided into four subgroups according to the surface medias; Subgroup a: Artificial saliva. Subgroup b; Artificial saliva +Cold drink. Subgroup c: Artificial saliva + Apple cider vinegar and subgroup d: Artificial saliva+ Orange juice. Open circuit potential, polarization resistance and corrosion current were measured for each miniscrew. Surface analysis was tested with the help of scanning electron microscope to compare the effect of corrosion in different subgroups. Maximum corrosion was observed in subgroup b: artificial saliva + cold drink and minimum in subgroup a: artificial saliva.

**Keywords**: Corrosion, orthodontic miniscrews, artificial saliva, SEM, anchorage,

## Introduction

Orthodontic miniscrews have gained popularity since past few years as a mean of skeletal anchorage. Miniscrews were introduced as absolute anchorage device in orthodontic treatment as the procedure for placement and removal is less invasive when compare to commercial dental implants.[1] They provide stable anchorage for the different tooth movements including intrusion, extrusion, distalization, protraction, retraction, midline coordination and correction of tilted occlusal plane. Aluminium (Al) and Vanadium (V) are incorporated with titanium to yield a strong alloy (Ti-6Al-4V). However addition of aluminium and vanadium decrease the corrosion resistance of miniscrews[2].

Fluoride containing adhesive paste and oral rinses are commonly used to prevent dental caries and tooth mineralization in orthodontic treatment. Previous studies have measured corrosion properties of orthodontic miniscrews in artificial saliva with fluoride corrosion resistacne of orthodontic alloys depend on oral environment which influence not only by amount and quantity of saliva but also the pH of the food and the type of beverages consumed. However lack of data exist regarding the corrosion of miniscrews in relation to the beverages consumed.[3]

**Aim and Objectives**

The aim and objective of the study was to compare the corrosion resistance and surface characteristics of orthodontic miniscrews between artificial saliva and artificial saliva with

1. Cold drink.
2. Orange juice.
3. Apple cider vinegar.

**Materials and Methodology**

**Materials (Fig 1)**

1. Orthodontic Miniscrews
2. Artificial Saliva
3. Cold Drink(Cocacola)
4. Orange Juice(Tropicana)
5. Apple Cider Vinegar (Heinz)
6. Electrochemical Cell And Potentiostat

(Auto Lab Potentiostat Bt-11 Biosensor Technique)

7. Scanning Electron Microscope (Jsm 6100)

**Methodology**

**Preparation of Artificial saliva**

Artificial saliva was prepared in Department of biochemistry Swami Devi Dyal hospital and Dental College Barwala with the following composition. KCL - 0.4gm/l, NaCl 0.4gm. $CaCl_2$-0.6gm/l.-$NaH_2Po_4$.0.690gm/l. Urea -1 gm. pH was maintained at 5.8 with the help of pH strip (Fig 2)[4]

**Grouping of sample**

A total of 80 miniscrews were divided into two groups (group 1: S.K surgical and group 2: BK surgical) in the bases of the type of manufacturer. Both group 1 and group 2 orthodontic miniscrew were divided into four subgroup (a, b, c, d = 10 each) on the basis of type of surface medias. (Electrolytes). (Gp 1a, 1b, 1c, 1d and group 2a, 2b, 2c, 2d)

Subgroup a: Artificial saliva

Subgroup b: Artificial saliva +cold drink

Subgroup c: Artificial saliva + apple cider vinegar.

Subgroup d: Artificial saliva +orange juice.

**Surface analysis testing of orthodontic miniscrew. (Fig 3)**

**Before subjecting them for corrosion testing**

Orthodontic miniscrew (1 each) in group 1 and group 2 were tested for surface analysis with the help of Scanning Electron Microscope (SEM).

**Electrochemical testing of orthodontic miniscrew**

**Preparation of orthodontic miniscrew for electrochemical study. Fig 4**

The threaded tip of each miniscrew up to a standardized level of 3mm was coated with a nail polish and mounted in epoxy resin, within a polyvinyl siloxane tube of 4 mm. thus allowing the remainder of the miniscrew toward the collar/head to be exposed to the test solution. Electrical connection was established via a connector below which miniscrew was threaded and suspended into the test solution. It served as a working electrode. The platinum wire served as a counter electrode and Ag/AgCl was the reference electrode. All the three electrode were then attached to a computer driven potentiostat and then subjected for electrochemical testing. The electrochemical testing was divided into three steps.(Fig 5)

**Step 1 open circuit potential (OCP)**

OCP of an electrode reflects the thermodynamic parameter which guide us about the thermodynamic tendency of that metallic materials to participate in electrochemical corrosion with the electrolyte or neighboring medium. Therefore, a potential below the OCP is more thermodynamically stable (less tendency to take part in corrosion) whereas the potential above the OCP is considered as thermodynamically unstable and prone to corrosion. The OCP was monitored for two hours. The 2 hours of immersion was used as it correspond to the approximate use of oral rinses for 6 month. (40 seconds daily).

**Step 2- Polarization resistance**

The polarization resistance is the measurement of how quickly the metal/alloy is oxidized during application of an external potential. Current was measured in different subgroups where as the potential of the miniscrew as scanned at 0.05mv/sec from -20mv to +20mv.

**Step 3 corrosion current**

This gives an indication of how much orthodontic miniscrew in each sub group a, b, c and d corroded with respect to the surface media.

**Surface analysis testing of orthodontic miniscrew after corrosion. (Fig 6).**

Orthodontic miniscrew in each sub group (2 each) (group 1a, 1b, 1c, 1d and group 2a, 2b, 2c, 2d) were tested for surface characteristics after subjecting them for corrosion testing.

**Result and Observation**

**Measurement of OCP Open circuit potential. (Table I)**

In both group 1 and group2, the open circuit potential was found to be maximum in subgroup a (artificial saliva) and minimum in subgroup b (artificial saliva and cold drink). It was observed in the following order Subgroup a (Artificial saliva)>sub group d(Artificial saliva + orange juice)> sub group c(Artificial saliva + vinegar)> subgroup b( Artificial saliva + cold drink).OCP of the miniscrew in artificial saliva was more stable and thereby less prone for corrosion. The comparison of open circuit potential between various subgroups using ANOVA test showed statistically significant difference ($p<0.01$*). In both groups Tukey HSD post hoc tests also recorded statistically significant difference between the different subgroups.

B. Measurement of polarization resistance (Table-II )

In both group 1 and group2, maximum polarization resistance was observed in subgroup a (artificial saliva) and minimum in sub group b( artificial saliva+ cold drink). It was observed in the following order sub group a(artificial saliva) > sub group d **(**artificial saliva +orange Juice) > sub group c **(**artificial saliva+ apple cider vinegar) > sub group b( artificial saliva+ cold drink. In group I comparison of polarization resistance among various sub groups using ANOVA test showed no statistically significant difference results among various subgroups. In group 2; statistically significant difference ($p<0.01$) was observed among various subgroups.

C. measurement of corrosion current. (Table III)

In both group 1 and group 2 maximum corrosion current was observed in subgroup b **(**Artificial Saliva+Cold Drink) and minimum in subgroup a(Artificial Saliva). It was observed in following order sub group b( artificial saliva+ cold drink) sub group c (artificial saliva+ apple cider vinegar) > sub group d (artificial saliva +orange Juice) > sub group a(artificial saliva) The comparison of corrosion current among group 1 and group2 using ANOVA test showed no statistically significant difference. Further post hoc analysis also showed no statistically significant difference among different sub group.

**Surface analysis**

The surface morphology of orthodontic miniscrews using SCM at 23x and 200x after electrochemical testing as shown in Fig 7.

However surface groove are seen comparatively more in group 1 than group2 orthodontic miniscrews. Pitting corrosion was comparatively more in subgroup b (Artificial saliva +cold drink) when compare to other subgroups(a, c and d).

**Discussion**

The need of skeletal anchorage in orthodontics has increased with the growing numbers of adult patients seeking orthodontic patients. Complex treatment goal, patients with missing teeth, noncompliance with extraoral anchorage all adds to the growing need of skeletal anchorage.[5] The aqueous environment of the oral cavity can be altered considerably by food and beverages, atmospheric components, temperature changes, microorganisms as well as plethora of organic and inorganic ions resulting in a reactive environment that can lead to the electrochemical corrosion of metal and alloys.[9]

Dietary habits affect wellbeing and health of an individual. This has raised several concerns about the health consequences such as obesity, diabetes, hypocalcaemia, dental caries, dental erosion and mental health problems. Dietary habits can adversely affect orthodontic treatment by reduction in the shear bond strength of brackets, increased risk of dental caries and enamel micro hardness and change of colour stability of orthodontic adhesives and elastic ligatures.[10]

The consumption of soft drinks, primarily among young adults and teenagers is increasing worldwide[11]. Fruit juices are most commonly preferred, included in everyday diet structure and recommended due to their nutritional value. In tropical countries, these juices are extensively consumed in many ways, e.g as condiments, digestives, electrolyte or health drinks, nutritional supplements and so on.[12] Apple cider vinegar, or cider vinegar is a vinegar made from fermented apple juice and used in salad dressings, marinades, food preservatives and chutneys. It is made by crushing apples, then squeezing out the juice.[13]

In an oral environment, orthodontic miniscrews are exposed to a number of potentially damaging physical and chemical agents; these conditions may contribute to corrosion of the metal components of any intraoral appliance. An increasing number of studies have demonstrated that the oral cavity owing to its peculiar physical, chemical, enzymatic and microbial characteristics, play a significant role in the biodegradation of metallic biomaterials.[14] To replicate the chemical conditions, the present study used cold drink, apple cider vinegar, orange juice as a study group and artificial saliva as control group. According to the findings in the study, maximum amount of corrosion was recorded in cold drink followed by Apple cider vinegar, orange juice, and least in artificial saliva.

Shahabi et al in 2011 studied the effect of different nutritional diets on the corrosion of brackets wherein the amount of corrosion caused by lemon juice, vinegar and coca cola on orthodontic brackets in vitro was compared.They observed that the amount of corrosion was most for cola followed by vinegar and then lime juice similar to our results.[6] On the contrary, another study by Holla et al in 2012 concluded that, acidic beverages were seen to have a lower corrosive effect on orthodontic wires as compared to artificial saliva.[15]

Artificial saliva contains chloride which is considered to be most detrimental to stainless steel. Acidic beverages can reduce the pH and redox potential of the oral cavity to levels below that required for enamel dissolution and consumption of beverages causes an increase in salivary flow leading to more chloride ions into the oral cavity. Regular consumption of acidic beverages can lead to frequent leading to frequent reduction in oral pH thereby affecting the corrosion behaviour of orthodontic alloys which supports our results. Corrosion is also affected by the temperature of the medium, the lower the temperature, the lesser will be the corrosion potential. Since soft drinks are consumed at lower temperature there corrosion potential will be lower. Acidic medium and presence of aggressive ions such as chloride ions; both can accelerate the rupture of protective passive film and can induce corrosion. [16]

Incorporation of 1500ppm fluoride in the artificial saliva significantly lowers the OCP, reduces polarization resistance and increases the corrosion current of each miniscrew product.[4] The corrosion behaviour of stainless steel orthodontic archwire is influenced by the presence of fruit juices and salt. All fruit juices increased the rate of corrosion process in artificial saliva in the presence or absence of salt. Solanum lycopersicum (Tomato) and Durio zebethinus (Amra) were rated as most detrimental to surface followed by prunus domestica linn ( Plum) juice.[17]

In the present study pitting corrosion in the form of pits on SEM analysis was evident in all subgroups more so in subgroup b (artificial saliva +cold drink).[5] The most common types of corrosion in the various parts of orthodontic appliances and devices were pitting and crevices.[18] In a previous study, widespread areas of pits and crevices could be observed in the regions of miniimplants that were immersed in fluoridated mouthwashes of more acidic pH. However in the artificial saliva there were less obvious pits and crevices. This occurred mainly because the acidic state creates a reducing media resulting in the diminished stability of the protective oxide film of SS oxide, which is needed for the corrosion resistance. Field - emission scanning electron microscopic analysis of the surface morphology of the titanium alloy samples revealed that all samples had some defects, crevices or pitting after exposure to the oral rinses than before treatment. In particular the samples in solution A (pH 4.46/260ppm fluoride) showed the most changes.[8]

Another study showed that all new miniscrew examined under optical microscope showed an irregular surface with machining and polishing defects in the form of stripes that could serve as a starting point for electrochemical attacks. These defects were present both in the head and in the coils of the mini-implant.[7]

**Limitation of the study**

A miniscrew in clinical use will interface with hard and soft tissues as well as a variety of solutions including saliva, blood, interstitial fluid and beverages as well as dental related pastes, rinses or gels. These yield distinct and sometimes isolated and transient environments that differ from those in this study. Further studies are indicated to simulate the oral conditions in the mouth and to yield more appropriate results.

**Conclusion**

Within the limitation of this in vitro study, the following conclusions were drawn.

1. Both group 1(S.K surgical) and group 2 (B.K surgical) orthodontic mini screws exhibited similar corrosion properties in different surface medias.
2. Maximum corrosion was observed in subgroup B (artificial saliva +cold drink) > subgroup C (artificial

saliva + apple cider vinegar)> subgroup D (artificial saliva +orange juice) > subgroup A (artificial saliva).

3. Exposure to the cold drink, apple cider vinegar, and orange juice decreases the open circuit potential, reduces the polarization resistance, and increases the corrosion current.
4. It is advisable to limit the use of cold drink to the patients who have undergo orthodontic miniscrew insertion.
5. Pitting corrosion is mainly observed as a result of corrosion.
6. B.K surgical (group 2) orthodontic miniscrews were found to be less prone to corrosion when compare to S, K surgical (group 1) orthodontic miniscrews.

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**Legends Figures and Tables**


Fig. 1: Materials and Armamentarium

Fig. 2: Preparation of Artificial saliva

Fig. 3: Surface analysis testing of orthodontic miniscrew.

Fig. 4: Before subjecting them for corrosion testing

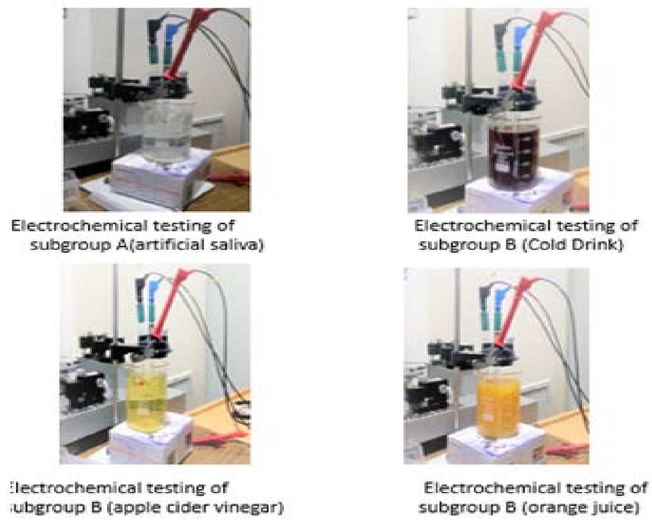


Fig. 5: electrochemical testing for orthodontic miniscrews

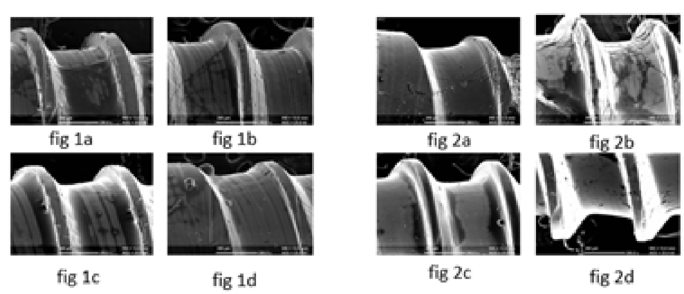


Fig. 6: SEM analysis of subgroups after corrosion

Table I: Inter Mean Comparison of OCP (in mV) among the Groups

| Groups | Subgroup a | | Subgroup b | | Subgroup c | | Subgroup d | |
|---|---|---|---|---|---|---|---|---|
| | Artificial Saliva | | Artificial Saliva+Cold Drink | | Artificial Saliva+Apple Cider Vinegar | | Artificial Saliva+Orange Juice | |
| | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| Group 1 | -0.01 | 0.001 | -0.051 | 0.001 | -0.038 | 0.003 | -0.012 | 0.011 |
| Group 2 | -0.008 | 0.018 | -0.047 | 0.004 | -0.042 | 0.005 | -0.012 | 0.006 |
| t test | 0.17 | | 0.29 | | 0.36 | | 0 | |
| p value | 0.82 | | 0.69 | | 0.61 | | 1 | |

Table-II :Measurement of polarization resistance ( kΩ )

| Groups | Subgroup a | | Subgroup b | | Subgroup c | | Subgroup d | |
|---|---|---|---|---|---|---|---|---|
| | Artificial Saliva | | Artificial Saliva+Cold Drink | | Artificial Saliva+Apple Cider Vinegar | | Artificial Saliva+Orange Juice | |
| | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| Group 1 | 25.169 | 3.139 | 15.016 | 5.705 | 18.393 | 5.638 | 19.746 | 17.746 |
| Group 2 | 65.658 | 8.379 | 14.025 | 2.409 | 27.207 | 15.289 | 34.361 | 4.176 |
| t test | 14.31 | | 0.51 | | 1.71 | | 2.53 | |
| p value | <0.01* | | 0.62 | | 0.10 | | 0.02* | |

Table III measurement of corrosion current (uA)

| Groups | Subgroup A | | Subgroup B | | Subgroup C | | Subgroup D | |
|---|---|---|---|---|---|---|---|---|
| | Artificial Saliva | | Artificial Saliva+Cold Drink | | Artificial Saliva+Apple Cider Vinegar | | Artificial Saliva+Orange Juice | |
| | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| Group 1 | 174.24 | 136.14 | 450.94 | 184.77 | 279.12 | 103.31 | 230.59 | 45.26 |
| Group 2 | 204.90 | 168.15 | 441.64 | 267.87 | 373.62 | 267.87 | 342.18 | 173.25 |
| t test | 0.45 | | 0.09 | | 1.04 | | 1.97 | |
| p value | 0.66 | | 0.93 | | 0.31 | | 0.06 | |