Influence of pH Level and Type of Archwire on the Time Bound Release of Nickel Ions from Orthodontic Appliances - An In Vitro Study

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ABSTRACT

BACKGROUND

Orthodontic metallic appliances in the oral cavity are constantly in contact with biological fluids or tissues thereby releasing particulate masses. They can be common causes of contact allergies and should be considered as a critical issue in determining properties of biomaterials. Nickel ions in various forms and compounds have been known to cause carcinogenic, mutagenic, cytotoxic and allergenic reactions. Pattern of metal ions released from different stainless steel orthodontic appliances in vitro could provide valuable information to consider their application in clinical scenarios. The purpose of the present study was to evaluate metal ions released under different ph levels, immersion period time and using different archwire orthodontic appliances.

METHODS

Orthodontic appliances were constructed consisting of five brackets from central incisor to the second premolar, a buccal tube welded molar band and an archwire that were used as samples. Total of twelve appliances were constructed; using stainless steel, Ni - Ti, and Thermal Ni - Ti wires (N = 4 each). Half of these samples were immersed in artificial saliva at pH 3.5 and the other half were immersed in artificial saliva at pH 6.75. The samples were stored in an incubator at a temperature of 37 degrees Celsius. Saliva samples from these bottles were collected at the end of 1, 7, 14 and 28 days and subjected to spectrophotometric analysis for estimation of nickel content.

RESULTS

Nickel release was maximum during the first week of immersion from orthodontic appliances comprising of Ni - Ti wires compared to Stainless steel and thermal Ni - Ti. A gradual decline in the nickel release was observed in the subsequent weeks. Ion release was increased by 30 times in the acidic pH medium, as compared to neutral pH conditions.

CONCLUSIONS

There is a definite release of nickel ions from orthodontic appliances when exposed to oral environment; however, the amounts are much lower than the daily dietary intake and don't pose risk of toxicity**.** Care should be taken in patients with nickel hypersensitivity and wires such as beta - titanium or epoxy coated wires can be substituted. As there is an increase in ion release under acidic conditions the patients need to maintain hygienic oral environment thereby limiting corrosion of appliances.

KEY WORDS

NitiAlloy, Archwires, pH, Hypersensitivity

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BACKGROUND

The materials in contact with biological fluids or tissues having the property of releasing particulate masses has been considered a critical issue in determining properties of biomaterials for a long time. The forerunner in terms of pathologic concern to humans is nickel release in the oral cavity. Humans are exposed to nickel significantly through diet, atmosphere, drinking water, clothing fasteners, jewellery and iatrogenic uses of appliances containing the metal such as joint prosthesis, dental implants, orthopedic plates, screws, surgical clips, steel sutures, pacemaker leads, prosthetic heart valves, dental alloys and orthodontic appliances.[1,2]

Corrosion of the material in the oral cavity is influenced by the quality and quantity of saliva and its pH used, general oral health conditions, plaque, consumed food and liquids.[3,4] Orthodontic appliances made of nickel, are one of the most common causes of contact allergies with a higher prevalence in females.[5]

Evidence has reported the release of nickel ions in various forms and compounds known to cause carcinogenic, mutagenic, cytotoxic and allergenic reactions.[6] Apart from corrosion, the electrochemical breakdown of orthodontic alloys can also occur. The electro-galvanic currents produced when appliances come in contact with saliva lead to the discharge of ions from metallic compounds. These products may be swallowed or attached to mucosal or dental surfaces.[7] Levels of released ions vary with the type of metal alloys used in the orthodontic appliances and type of archwire selected.[8]

Objectives

The purpose of the present study was to evaluate metal ions released under different ph levels, immersion period time and using different archwire orthodontic appliances.

- To determine the number of nickel ions released from different orthodontic appliances,
- To analyse the effect of pH on the release of nickel ions
- To analyse the effect of immersion period on the release of nickel ions

METHODS

The study was designed as an in vitro study with simulated appliances, not involving clinical subjects, hence did not necessitate acquiring informed consent and ethical clearance. Simulated fixed orthodontic appliances representing half of the upper dental arch were used for the study. The appliances consisted of five brackets, from central incisor to the second premolar, archwire with metal ligatures, and buccal tube with molar band.

Three types of wires were used for the study: Stainless steel [Dentsply Sirona, Inc. (US)], Nickel - titanium [Dentsply Sirona, Inc.(US)], and Thermal nickel - titanium [Dentsply Sirona, Inc.(US)]. Each archwire, 6 cm long was shaped in an ideal arch form. The brackets, and the buccal tubes belonged to a 0.018 slot MBT preadjusted edgewise appliance and the wires used were of dimensions 0.016 x 0.022 inches. Artificial saliva corresponding to the average pH in the oral cavity i.e. 6.75 and the lowest pH under dental plaque i.e. 3.5 was used. The artificial saliva was prepared following the composition as given by Barrett, Bishara, and Quinn.[2] (Table1)

Com-pound	Nacl	Kcl	Cacl2.2H2O	NaH2PO4.-2H2O	Na2S.-9H2O	CO(NH2)2	Distilled Water
Concent-ration g / l	0.40	1.21	0.795	0.780	0.005	1.0	1000

Table 1. Composition of Artificial Saliva

The pH values of the saliva required for the study were met using sodium hydroxide (NaOH), or lactic acid 100 ml Polyethylene bottles were used to store and vials of 5 ml each were used to collect the saliva samples for spectrophotometric analysis.

Twelve orthodontic appliances were constructed using the materials mentioned above and autoclaved. Six appliances: 2 containing NiTi, 2 containing Stainless Steel wire and 2 containing thermal NiTi wires were placed in polyethylene bottles containing artificial saliva of pH 6.75 and similarly, the other six corresponding appliances in polyethylene bottles with artificial saliva of pH 3.5.

The 12 polyethylene bottles were stored in an incubator at a temperature of 37 degrees celsius and saliva samples were collected on 1, 7, 14 and 28 days. After sample collection, 1 ml of 65 % nitric acid was added to each sample to keep the nickel ions stable in the media and the samples were subjected to spectrophotometric analysis. All 48 solution samples collected were subjected for analysis to assess the nickel ions released. The study was carried out from March 2019 to April 2020, including data collection and result analysis.

Measurement Technique

The analysis was performed with a flame absorption spectrophotometer (model GBS 932 plus atomic absorption spectrophotometer). The principle was based on the spectrum of atomic absorption and wavelength of each element. The amount of absorption is proportional to the concentration of the element that is vaporized into the light beam. Each sample was analyzed 3 times and the average was used as the result. The nickel concentrations present were calculated as micrograms / ml.

Statistical Analysis

The results were tabulated and statistically analysed. Kruskal Wallis test and Mann Whitney U test were used to assess the effect of three different types of metal alloys on the nickel ion release. Wilcoxon signed rank - sum test was used to analyse the effect of length of immersion on nickel ion release.

RESULTS

Effect of Type of Metal Alloy

The inter wire comparison was done using Mann Whitney U test and the ion release was significantly greater from NiTi wire (0.409 µg / ml at day 1 and 1.872 µg / ml at day 7) during the first 7 days of the study at pH 6.75 than stainless steel wire (0.161 µg / ml at day 1 and 0.705 µg / ml at day 7). But at pH

3.5, the ion release from both the wires showed a similar pattern.

The inter wire comparison also showed that under average pH conditions, the ion release from stainless steel and NiTi wires was significantly greater when compared to thermal NiTi wires, whereas under acidic conditions, the ion release from thermal NiTi was equivalent to stainless steel and NiTi wires with the exception of the time period between 15 - 28 days when the ion release from stainless steel and NiTi wires was significantly greater than thermal NiTi wire (Table 1).

Effect of Length of Immersion

The study results showed that nickel ion released from the simulated orthodontic appliances was at its peak on the first day of the study with a slight decrease in the time period between 2nd and 7th day followed by a marked fall in values in the remainder of the duration of the study. To determine the statistical significance, Wilcoxon signed rank - sum test was performed and the results of the test showed that the decrease in the nickel ion release over time was statistically significant for all the three archwires under both average pH and acidic conditions.

Effect of pH

Nickel ion release from orthodontic appliances containing 3 types of archwires was influenced by the pH of artificial saliva significantly. Decreasing the pH from 6.75 to 3.5 led to an average of 30 fold increase in the nickel ion concentration.

DISCUSSION

Presence of corrosion products from orthodontic appliances during orthodontic treatment and their effects on the oral environment locally or systemically reflects on the physical properties and their clinical performance. The present study was concerned mainly on the release of metal from orthodontic appliances used in dental patients. The effect of degradation products can cause foreign body reaction or induce pathologic processes. Studies done on orthodontic alloys containing nickel have reported their hazardous effects due to intra oral disintegration and need critical evaluation.

Effect Using the Type of Metal Alloy

The results of the study showed that the differences in nickel ion release from the three archwires were statistically significant overall in 4 time periods at pH 6.75. whereas at acidic pH (3.5) the release of nickel ions from all the archwires showed a similar pattern, with the only exception being during the time period of day 15 - 28 when the differences were statistically significant. The results revealed that there was a significantly greater release of nickel ion from NiTi wires as compared to stainless steel wires during the first week of immersion at pH 6.75. These findings are supported by Hera Kim,[9] who in his study reported that the breakdown potential being the point of alloy dissolution that begins from the oxide film was lower for NiTi wires (300 mV) as compared to stainless steel wires (400 mV) and so the NiTi wires were more susceptible to corrosion. Studies on corrosion behaviour of orthodontic wires having more nickel concentration have shown to have higher risk of corrosion than those of stainless steel.[10,11]

However, these findings are contradicted by the studies of Barret[2], Hwang[4], and Grimsdottlr[12] which showed that the quantity of nickel ion releases from NiTi wires was less when compared to stainless steel wires, although the nickel content was much higher in NiTi wires.

Also, the inter wire comparison between stainless steel and thermal NiTi as well as the comparison between NiTi and thermal NiTi showed that the nickel release from stainless steel and NiTi wires was significantly greater than thermal NiTi wires at pH 6.75. So the sequence of wires in the order of decreasing nickel release under average pH conditions is NiTi followed by stainless steel and then thermal NiTi.

Effect of Time of Immersion

When the release of ion calculated using storage media composed of unagitated, non replenished solutions, the ion release rapidly reaches a plateau due to the equilibrium of metal ions in the solution.[6] To counteract this effect, in the present study, the saliva solution in each of the sample bottles was replaced at the end of day 1, 7 and 14 except day 28 when the experiment ended. The ion released due to mouthwash immersion was below the limit of the daily intake recommended by the World Health Organization.

The results of the present study showed that the nickel ion release from simulated orthodontic appliances was maximum on the 1st day of the study with a slight but statistically significant decrease in the time period between days 2 - 7. This is followed by a marked and statistically significant decrease for the remainder of the duration of the study with the least values being reported in the time period between days 15 - 28. These results correspond with the studies done by Barret[2] and Hwang.[4] It was observed that nickel on the wire surface got corroded fast during the first seven days of the experiment and then the ion release rate reduced as the surface nickel was depleted. Secondly, nickel corrosion process got reduced as a film of corrosion product was formed on the wire surface after seven days.[2]

Effect of pH

In the present study, the nickel ion release values under acidic conditions i.e. pH 3.5 showed an average of 30 fold increase over the nickel release values under average conditions i.e. pH 6.75. These results correspond with the study done by Margret et al.[12] who reported that a decrease in the pH value of the immersion media caused an increase in the ion release from orthodontic brackets. Also, in a study, an average of 37 fold increase in the release of ions was reported on decreasing the pH from 6.75 to 3.5[13] However, in his study, the ions released from various metals (titanium, chromium, nickel, iron, copper, and zinc) were observed and so the 30 fold increase in the release was an average for all the ions together. These results could be explained by finding that the acidic conditions provide a reducing environment in which the stainless steel oxide film or the titanium oxide film required for corrosion resistance is less stable.[14] The release of ions was increased with decreasing the pH of the solutions, thus indicating the

breakdown of protective metal film by low pH of acids.[15,16] Nickel release was found to be highest at 6.5 pH for 1 hour and 7 days' time interval.l[17-19] The use of a constant pH value avoided additional influences of variable pH on metal release.[20] The present study showed that the release of Ni, Cr and Fe ions were dependent on pH of solution, material of archwire and duration of exposure.[21] However this being an in-vitro study, further clinical studies could confirm the clinical repercussions of long term exposure of orthodontic appliances.

CONCLUSIONS

Type of metal alloy in archwire, pH of the immersion media and immersion period–influenced the ion release. A 30 fold increase in nickel ion concentration under acidic pH (3.5) compared to neutral pH (6.75) was observed, which underlines the role of organic acids of dental plaque in the corrosion of metals. The nickel ion release was maximum for NiTi wire followed by stainless steel and thermal NiTi. Therefore, it can be concluded that there is a release of nickel ions from the fixed appliances when placed in the mouth but the amount of ions released is much below the daily dietary intake and doesn't reach the toxic level. Precautionary measures need to be taken before using appliances made of nickel and specifically in patients who are sensitive to nickel. Orthodontic appliances of different components such as beta - titanium wires or polycarbonate brackets should be considered for such patients.

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