Release of titanium ions in titanium alloys used in dentistry - A systematic review

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INTRODUCTION

Human saliva is ideal for the degradation of metals. Oral environment can promote corrosion of dental alloys when exposed to conditions such as dietary intake, temperature, and acidic pH. The pH of saliva varies from 5.2 to 7.8. Nickel is the most common cause of allergic reaction like contact dermatitis. Titanium is considered the most biocompatible due to its corrosion resistance. However, there are studies that show there is release of titanium ions in saliva. Nickel has been studied for its systematically detrimental effects.

Corrosion stress and the presence of microbial flora can contribute to implant failure. The compatibility of the implant to the associated structures is important for long-term prognosis of the implant. Corrosion can compromise the strength of the material leading to mechanical failure.

The presence of different alloys in the oral cavity may cause galvanic corrosion. Corrosion, the degradation of materials by electrochemical attack is of concern. The released metal ions can enter the bloodstream and can cause varying degrees of health ailments in addition to local allergic reactions.

In the present work, a systematic review on release of titanium ions from titanium dental appliances is described.

MATERIALS AND METHODS

The following search criteria were used to find papers describing the release of titanium ions from dental appliances [Figure 1].

Inclusion Criteria

The following criteria were included in the study:
1. Studies conducted using artificial saliva.
2. Studies conducted under oral environmental conditions.

KEY WORDS: Alloy, Biocompatibility, Dental, Ions, Titanium
3. Amount of ions released measured in µg/L.
4. Amount of ions released measured in ppb.
5. Release of titanium ions.
6. Randomized control trials.

Exclusion Criteria
The following criteria were excluded from the study:
1. Other language studies.
2. Studies were done in acidic environment.
3. Metal ions measured using other units.
4. Other biological changes.

RESULTS
The PubMed search identified 83 studies [Table 1]. No additional search in other database was performed.

From 83 identified studies, four met the selection criteria. Other studies were excluded from the selection criteria due to reasons mentioned in Table 2. The description of the studied materials is mentioned in Table 3.

DISCUSSION
No local and systematic reactions to titanium have been documented, and it is considered to be an inert metal. The high biocompatibility of Ti is due to the formation of TiO film on the surface. Surface oxide plays a role in corrosion.¹ The action of fluorine on titanium causes a special type of pitting corrosion.² The fluoride is also found to dissolve the oxide layer. Among the different titanium alloys, TiAl6V4 alloys
have good corrosion resistance, whereas NiTi and NiTiCo alloys have poor corrosion resistance.\textsuperscript{[9-11]}

Any metal in human body is a potential source of toxicity. Concern about release of metallic ions is discussed widely. Corrosion has been observed in hip implants, bone screws, and plates. Some experiments conducted revealed release of metallic ions from dental implants. Alterations in the passive layer due to changes in the oral environment causes corrosion.\textsuperscript{[12]}

Alloy of titanium-containing nickel may cause localized tissue reaction.

The amount of free metal ions released by NiTi alloy is greater than any other titanium alloys. The amount of Cu, Ti, Ni, Cr, and Fe ions released by recycled NiTi alloy is significantly more than the new NiTi alloy.\textsuperscript{[13]}

As far as the results obtained by studies conducted in artificial saliva, the titanium alloys were electrochemically stable.\textsuperscript{[14-17]} When artificial saliva with fluoride ions was used for the experiment, varying results were obtained. Overall, most of the studies concluded that the titanium alloys are electrochemically stable and no significant corrosion was seen.\textsuperscript{[1,18]} The titanium ion content in unstimulated saliva was found to be insignificant compared to the require daily allowance.\textsuperscript{[19]}

Patients with metal prosthesis which are indicative of corrosion showed hypernickelemia. Blood levels of nickel are not significantly greater than that in healthy individuals.\textsuperscript{[20-23]}

Factors such as temperature, quantity and quality of saliva, salivary pH, and physical and chemical properties of foods and liquids influence the corrosion in the oral cavity resulting in release of metal ions from dental appliances and prosthesis.\textsuperscript{[24]} The application of the same type of alloys produced by different manufacturers yielded different results. The general conclusion that arose from all the studies was that the amount of nickel ions released from SS elements was the greatest.\textsuperscript{[25-27]} However, titanium ions concentration was similar to the control group or had values less than the detection limit. Biocompatibility of titanium alloys is because of its corrosion resistance.\textsuperscript{[28,29]}

**CONCLUSION**

*In vitro* studies are valuable because they are performed under controlled laboratory conditions. However, the disadvantage of *in vitro* tests is that the experimental setup did not simulate the presence of biofilm. The obtained results may not correspond to metal ions

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**Table 2: Excluded articles and reason for exclusion**

<table>
<thead>
<tr>
<th>S. No</th>
<th>Article</th>
<th>Reason for exclusion</th>
</tr>
</thead>
</table>

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**Figure 1: Flowchart depicting search methodology**
### Table 3: Description of studies met the selection criteria

<table>
<thead>
<tr>
<th>S. No</th>
<th>Author</th>
<th>Year</th>
<th>Study design</th>
<th>Study group</th>
<th>Intervention</th>
<th>Outcome parameters</th>
<th>Measurement unit used</th>
<th>Statistics used</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sedo Gursoy, PhD</td>
<td>2005</td>
<td>In vitro</td>
<td>Group 1 - new brackets and archwires&lt;br&gt;Group 2 - new brackets and recycled archwires&lt;br&gt;Group 3 - recycled brackets and new archwires&lt;br&gt;Group 4 - recycled brackets recycled archwires</td>
<td>Artificial saliva pH-7 at 37°C</td>
<td>Concentration of metal ions (µg/L) in artificial saliva using inductively coupled plasma mass spectrometry (ICP-MS)</td>
<td>µg/L</td>
<td>Duncan multiple range test</td>
<td>There was a significant increase in Ni and Ti ions in Group 3 and 4</td>
</tr>
<tr>
<td>2</td>
<td>Chung-Ju-Hwang DDS, PhD</td>
<td>2001</td>
<td>In vitro</td>
<td>Group A - Ormco 0.016X.022 SS&lt;br&gt;Group B - Dentaurum 0.016X.022 SS&lt;br&gt;Group C - Ormco 0.016X.022 CuNiTi&lt;br&gt;Group D - Tomy. 016X.022 bio force stent alloy</td>
<td>Artificial saliva at pH 6.75 at 37°C</td>
<td>Concentration of released ion (ppb) in artificial saliva using ICP-MS</td>
<td>ppb</td>
<td>t-test</td>
<td>The concentration of nickel ions increased up to the 7th day and then it was constant after that at 17.03±0.47 ppb titanium values were below 0.3 ppb which is the titanium detection limit</td>
</tr>
<tr>
<td>3</td>
<td>Antonio Jose Ortiz</td>
<td>2011</td>
<td>In vitro</td>
<td>Group 1 - control without metals&lt;br&gt;Group 2 - stainless steel&lt;br&gt;Group 3 - titanium&lt;br&gt;Group 4 - nickel free</td>
<td>Supplemented MEM</td>
<td>Concentration of metal ions(µg/L) in artificial saliva using ICP-MS</td>
<td>µg/L</td>
<td>For Ti - one-way ANOVA, Tukey test&lt;br&gt;For Ni - Kruskal-Wallis, Dunn tests</td>
<td>The concentration of nickel ions increased in stainless steel samples, and there was no significant increase in titanium ions to the control group</td>
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</tbody>
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(Contd...)
release in in vivo conditions. Analyzing the results of both in vitro and in vivo tests, it seems that there is a necessity to elaborate standardized procedures, with detailed methodology provided. Only then, the results will be comparable.

REFERENCES


