Ion release and surface roughness of silver soldered bands with two different polishing methods: An in‑vitro study

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Abstract

OBJECTIVE: To evaluate the surface roughness and ion release of silver‑soldered joints by using two polishing methods.

METHODS: 174 orthodontic bands with and without silver‑soldered joints were evaluated and divided into three groups: two experimental, with different polishing methods (SP1 and SP2), and one control (SS) composed of bands without silver solder. For ionic release, 50 bands of each group were immersed in saline solution and submitted to atomic absorption spectrophotometry to quantify the amount of Fe, Ni, Cr (in all the three groups), Ag, Cu, Cd, and Zn (in the two experimental groups). A rugosimeter was employed to verify the surface roughness.

RESULTS: Ni and Cr were released in higher amounts after soldering. Cd, Ag, Zn, and Cu may be released from silver‑soldered bands independently of the polishing method employed. Ag was released in higher amounts from the soldered bands that presented higher surface roughness.

CONCLUSIONS: Differences exist in relation to the surface roughness of silver‑soldered bands when distinct polishing methods are used. Toxic ions may be released from silver soldered joints and higher surface roughness may cause higher ionic release.

Keywords: Biocompatibility, ion release, orthodontic bands, silver solder, surface roughness

Introduction

Soldering in orthodontics is a widely employed procedure. Silver solder alloy is still the most common way to connect wires in orthodontics due to its affordable price, effectiveness, and ease of confection. The quality of the soldered unions depends on factors such as its mechanical stability, amount of contact between the two soldered metals, properties of the metallic alloys, extension of the imperfections in the soldered area, and especially on its resistance to corrosion.[1]

Several orthodontic appliances present silver‑soldered joints and as they should remain in the mouth for a long time, the concern of using biocompatible materials is essential. Biocompatibility is the ability of a material to perform its desired function with respect to medical therapy without eliciting any undesirable local or systemic effects and generating the most appropriate beneficial cellular or tissue response in that specific situation.[2] Metals in contact with saliva are subject to corrosion, and this is the main concern relating to orthodontic appliance biocompatibility.[3,4] Orthodontic appliances may release amounts of metal ions;[5‑10] this can lead to diverse toxic effects such as...
DNA damages and oral lesions. Some studies have already shown the release of metal ions into saliva and the cytotoxicity and genotoxicity of silver solder in oral cells. In addition to the metallic elements of stainless steel, such as nickel (Ni), chromium (Cr), and iron (Fe), silver solder alloys contain silver (Ag), copper (Cu), and zinc (Zn).

Most contact allergy cases are caused by Ni. A meta-analysis identified 30 studies to investigate the effect of orthodontic treatment or other factors on nickel hypersensitivity and found 19% of the overall prevalence of Ni hypersensitivity, with high heterogeneity. Polishing of the silver solder was considered by the author as one of the factors that may favor the release of toxic ions from silver alloy. Meanwhile, different polishing methods have not been compared yet and the influence of roughness on metal ion release is not clear. In view of this, the aim of this in vitro study was to evaluate if the surface roughness affects the ion release of silver-soldered joints comparing two polishing procedures.

Methods

This study was approved by the Ethics Committee of the Pontifical Catholic University of Rio Grande do Sul (Porto Alegre, Brazil).

One-hundred seventy-four stainless steel metallic orthodontic bands (Universal bands for upper molars, Morelli, Sorocaba/SP, Brazil) were evaluated. The bands, according to the manufacturer’s information, are composed of Cr, Ni, Molybdenum (Mo), and Fe. Two experimental (SP1, n = 62; SP2, n = 62) and one control (SS, n = 50) groups were assembled. For silver-soldered groups (SP1, SP2), a segment of stainless steel 1.0 mm wire was soldered in each band. Soldering was performed with silver solder and flux (Morelli, Sorocaba/SP, Brazil) and heated by a butane micro-torch (GB 2001, Blazer, Farmingdale, NY, USA). The silver alloy was composed of Ag, Cu, Zn, and Tin (Sn), and flux was composed of boric acid, potassium bifluoride, potassium hydroxide, and water. For both SP1 and SP2 groups, finishing and polishing of the silver-soldered joint were performed right after soldering. SP1 group was polished using a sequence of silicone tips: L22 for 15 seconds, EVEFLEX 708 and EVEFLEX HP 808 for 30 seconds each (EVE, Pforzheim, Germany). SP2 group was polished using a gray stone drill for 20 seconds and the L22 silicone tip for 15 seconds. The control group (SS) was composed of bands without any solder, evaluated as received.

Assessment of eluted ions

Atomic absorption spectrophotometry was employed for assessing the number of ions eluted. For this evaluation, 50 bands were assigned to each of the three groups. The experiments were done according to ISO 10993-12, which recommends a relation of (3 cm²/1 ml) between the area of the evaluated material and the amount of the immersing liquid. After polishing, five Falcon tubes containing 10 bands (corresponding to 28 cm²) and 9.33 ml of saline solution each were prepared for each of the three groups (SS, SP1, and SP2). The tubes were stored for 72 hours at 37°C under agitation. Then, the bands were removed from tubes and the solutions were analyzed. Fe, Ni, and Cr were quantified in all three groups; Cd, Cu, Zn, and Ag were quantified in SP1 and SP2 groups. Saline solution was used as blank. Flame atomic absorption spectrophotometer (SpectrAA 110 – Varian) was used to quantify Cu, Fe, Ag, and Zn, while a graphite furnace atomic absorption spectrophotometer (ZEEnit 600, Analytik Jena) was used to quantify Ni, Cr, and Cd. The characteristics of each group and evaluations are summarized in Table 1.

Surface roughness

After polishing, the remaining 12 bands of each of the experimental groups (SP1, SP2) were evaluated for surface roughness. A rugosimeter (Mitutoyo Surftest SJ-201, Kanagawa, Japan) was used for surface roughness. The silver solder joints were settled over a wax lamina and five roughness measurements were performed on each sample using the rugosimeter, previously calibrated, with a cutoff value of 0.25 mm. An average surface roughness (Ra, µm) of the readings was obtained. Data obtained were disposed in tables and the average of the five readings was calculated.

Statistics

The statistical analysis was performed using the SPSS 10.0 software (SPSS Inc., Chicago, Illinois, USA). Significance was considered at a level of 5% (P ≤ 0.05). Kolmogorov–Smirnov test was used to check normality. Kruskal–Wallis nonparametric test was applied for the Fe, Ni, and Cr released from all the groups. For Ag, Cd, Zn, and Cu, each ion was evaluated separately using Mann–Whitney test compared in relation to the polishing method used (SP1 and SP2). Student’s t test was used to evaluate the surface roughness results.

Results

Fe, Ni, and Cr were quantified for SS, SP1, and SP2 groups, and the data are shown in Table 2. Kruskal–Wallis test showed no statistical differences between all groups for the iron evaluation. In contrast, for nickel and chromium, SP1 and SP2 groups showed higher release of these ions; however, with no statistical differences between SP1 and SP2 groups.

Zn, Cu, and Ag ions, which are present in the composition of the silver alloy, were quantified in SP1 and SP2.
Besides these ions, cadmium, which is not described in the composition of the silver alloy tested, was also quantified, as it has been detected in other studies that evaluated this material.[13] Data are shown in Table 3. Mann–Whitney test showed that only silver ion had significant differences between the two groups. For this ion, SP2 showed a higher release of silver when compared to the SP1 group \((P = 0.008)\). The corrosion effects can be observed in Figures 1 and 2.

Table 4 presents the results of surface roughness (µm) for SP1 and SP2 groups. SP2 had higher surface roughness with a statistical difference when compared to SP1 \((P = 0.000)\).

**Discussion**

Corrosion is an electrochemical process that occurs either through the loss of metal ions directly into solution or by the progressive dissolution of a surface film, typically an oxide or sulfide, on the metal.[21] It is considered that the corrosion may be related to the surface roughness and the polishing of a given metallic surface.[21] The resulting products from metallic corrosion, that is, the release of several metallic ions, may trigger inflammatory responses of the soft tissues and cause irritation or dermatitis.

There is a lack of information in relation to the different polishing procedures of silver solder used in orthodontics and its possible effects on corrosion and the release of toxic ions. Bishara[22] proposed the hypothesis that the higher the surface roughness, the higher the ionic release. In the present study, two polishing methods were tested. The SP1 group showed a shining bright and smooth surface, which showed lower levels of surface roughness when compared to the SP2 group. The better the polishing, the lower the surface roughness and, in consequence, the lower the amount of biofilm adhered to the surface of the metal. Smooth surfaces are important dental materials as there is a positive association between surface roughness and microorganism accumulation,[23] and are more comfortable for the patient.[24]

In the present study, the bands were prepared in a standardized way, always by the same operator, to avoid inter-operator variations and the assessment of ions eluted was performed according to ISO 10993-12. When the bands were removed from the Falcon tubes after being immersed in saline solution for 72 hours, a turbid solution was observed, with the precipitation of salts in the bottom of the flasks from SP1 and SP2 groups. The visible aspect of the immersion medium was evidently connected to the corrosion of the metallic bands from the silver-soldered groups, which was not observed for the control group. Besides that, corrosion cells could be observed on the surface of the bands, mainly in the interface of the soldered wire and the silver alloy.

The assessment of the ions eluted was performed using spectrophotometry, a commonly used method for this type of evaluation.[5-10,13] Ions Fe, Ni, Cr, Zn, Cu, and Ag were quantified. In addition to the materials listed by the manufacturers, Cd was also found in the solutions that stayed in contact with the silver-soldered bands. Potential contamination may have happened during the extraction of Zn.[25] Some decades ago, Cd was commonly added to the silver solder composition in order to lower the fusion temperature of the alloy.[26] Professionals should be aware that Cd is associated with cancer;[27] can cause liver, kidney, and heart injury,[28] and has already been connected to caries and periodontitis.[29,30]

Although the release of a certain toxic ion may not be directly related to its amount on the metallic alloy,[31] there was a higher release of silver in the group which presented higher surface roughness [Table 3]. For the other ions, there was no statistical difference when both soldered groups were compared. As expected, greater amounts of Fe, Ni, and Cr were released in the soldered
groups when compared to the control (without any solder). It may be explained by the fact that the heat, which is necessary to melt the silver alloy, may increase the subsequent rate of corrosion. Higher release of Cu in the silver alloy may also lead to the release of toxic ions present in the composition of the metals soldered. It could be observed from this present and in vitro investigation that several toxic ions are released from silver-soldered bands independently of the polishing method adopted. Silver soldering can affect ion concentrations in a saline solution and the surface roughness can contribute to higher release. There is a trend that the lower the surface roughness, the lower the levels of ions released. Nonetheless, our study conducted in vitro research, testing two polishing methods, and used saline solution for evaluation. It is also important to emphasize that the saline solution by itself may have caused corrosion in joints. Due to this limitation, it would be important that further studies investigate other methods and verify this data in vivo.

| Ion             | Group | n | Median | P25  | P75  | P     |
|-----------------|-------|---|--------|------|------|-------|
| Cadmium (µg L⁻¹)| SP1   | 5 | 1.91   | 1.46 | 4.69 | 0.421* |
|                 | SP2   | 5 | 0.00   | 0.00 | 1.47 |       |
| Zinc (mg L⁻¹)   | SP1   | 5 | 8.51   | 7.63 | 10.4 | 0.548* |
|                 | SP2   | 5 | 7.82   | 6.22 | 8.01 |       |
| Cooper (mg L⁻¹) | SP1   | 5 | 28.87  | 28.5 | 30.3 | 0.310* |
|                 | SP2   | 5 | 23.85  | 18.9 | 24.0 |       |
| Silver (mg L⁻¹) | SP1   | 5 | 1.66   | 1.29 | 1.78 | 0.008**|
|                 | SP2   | 5 | 2.51   | 2.33 | 2.95 |       |

**P≤0.01; P25=percentile 25; P75=percentile 75; ns=no significance

| Group | n | Minimum | Maximum | Average | Median | SD     | P     |
|-------|---|---------|---------|---------|--------|--------|-------|
| SP1   | 12| 0.28    | 0.71    | 0.47    | 0.44   | 0.12   | 0.000**|
| SP2   | 12| 0.71    | 1.65    | 1.05    | 0.96   | 0.33   |       |

**P≤0.01; SD=standard deviation

Conclusions
The findings of the present study suggested the following:

a. Ni and Cr are released in higher amounts after soldering
b. Differences exist in relation to the surface roughness of silver soldered bands when different polishing methods are used
c. Cd, Ag, Zn, and Cu ions may be released from silver solder bands independently of the polishing method employed. Ag ions were released in higher amounts from the soldered bands that presented higher surface roughness.

Compliance with ethical standards
The present research did not involve human participants and/or animals.

The study was approved by the Research Ethics Committee of the Pontifical Catholic University of Rio Grande do Sul.

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Conflicts of interest
There are no conflicts of interest.

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