Access this article online
Quick Response Code:
Website:
www.jorthodsci.org
DOI:
10.4103/jos.jos_157_21

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

Ramiro Estacia da Silveira, Tatiana Siqueira Gonçalves, Helena Reis de Souza Schacher and Luciane Macedo de Menezes

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

Dental Program, Orthodontics – School of Health and Life Sciences, Pontifícia Universidade Católica do Rio Grande do Sul, Porto Alegre, Brazil

Address for correspondences:
Dr. Luciane Macedo de Menezes, Pontifícia Universidade Católica do Rio Grande do Sul, Dental Program - Building n.6, Av. Ipiranga 6681/209, Porto Alegre - 90619-900, RS, Brazil.
E-mail: luciane.menezes@pucrs.br

Submitted: 28-Jun-2021
Revised: 05-Oct-2021
Accepted: 20-Oct-2021
Published: 04-May-2022

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

How to cite this article: da Silveira RE, Gonçalves TS, de Souza Schacher HR, de Menezes LM. Ion release and surface roughness of silver soldered bands with two different polishing methods: An *in-vitro* study. J Orthodont Sci 2022;11:11.

DNA damages and oral lesions.[11,12] Some studies have already shown the release of metal ions into saliva and the cytotoxicity and genotoxicity of silver solder in oral cells.[13-17] 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).[13]

Most contact allergy cases are caused by Ni.[18] 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.[19] 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.[20] 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-solder 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 cm^2/1 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 cm^2) 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 SSPS 10.0 software (SPSS Inc., Chicago, Illinois, USA). Significance was considered at a level of 5% ($P \leq 0.05$). 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.

Table 1: Characteristics of each group evaluated

Group	Treatment	Polishing	Number of bands evaluated for surface roughness	Number of tubes for evaluation of ion release (each tube containing 10 bands)	Ions quantified
SP1	Silver solder	Sequence of silicone tips: L22 (15′), EVEFLEX 708 (30′), EVEFLEX HP 808 (30′)	12	5	Fe, Ni, Cr, Ag, Cu, Cd, Zn
SP2	Silver solder	Gray stone drill (20′), L22 (15′)	12	5	Fe, Ni, Cr, Ag, Cu, Cd, Zn
SS	Control	-	-	5	Fe, Ni, Cr

Table 2: Comparison of ion release (Fe, Ni, and Cr) in groups SS, SP1, and SP2

Ion	Group	*n*	Median	P25	P75	*P*
Iron (mg L-1)	SS	5	6.94	2.38	19.1	0.613 ns
	SP1	5	9.25	8.68	10.6	
	SP2	5	13.86	9.20	15.0	
Nickel (μg L-1)	SS	5	32.35	27.5	32.4	0.009**
	SP1	5	1088.00	674	2055	
	SP2	5	1238.00	534	1572	
Chromium (μg L-1)	SS	5	0.00	0.00	0.00	0.008**
	SP1	5	677.20	97.8	821	
	SP2	5	630.10	569	700	

**$P \leq 0{,}01$; P25=percentile 25; P75=percentile 75; ns=no significance

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

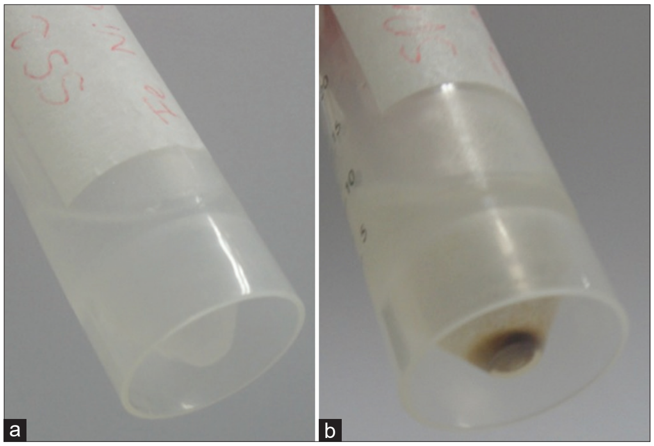

Figure 1: Immersion solution (a) before and (b) after the elution period

Table 3: Comparison of ion release (Cd, Zn, Cu, and Ag) in groups SP1 and SP2

Ion	Group	*n*	Median	P25	P75	*P*
Cadmium (µg L-1)	SP1	5	1.91	1.46	4.69	0.421[3] ns
	SP2	5	0.00	0.00	1.47	
Zinc (mg L-1)	SP1	5	8.51	7.63	10.4	0.548[3] ns
	SP2	5	7.82	6.22	8.01	
Cooper (mg L-1)	SP1	5	28.87	28.5	30.3	0.310[3] ns
	SP2	5	23.85	18.9	24.0	
Silver (mg L-1)	SP1	5	1.66	1.29	1.78	0.008[3]**
	SP2	5	2.51	2.33	2.95	

**$P \leq 0,01$; P25=percentile 25; P75=percentile 75; ns=no significance

Table 4: Comparison of surface roughness between SP1 and SP2 groups

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	

**$P \leq 0,01$; SD=standard deviation

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.[32] Higher release of Cu in the silver alloy[33] 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*.

Figure 2: Bands (a) before and (b) after the elution period

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.

Grant support

Financial code 001/Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES, Brazil).

Financial support and sponsorship

The work was supported by the authors and the Dental Program, School of Health and Life Sciences, Pontifícia Universidade Católica do Rio Grande do Sul (PUCRS).

Conflicts of interest

There are no conflicts of interest.

References

1. Heidemann J, Witt E, Feeg M, Werz R, Pieger K. Orthodontic soldering techniques: Aspects of quality assurance in the dental

laboratory. J Orofac Orthop 2002;63:325-38.
2. Williams DF. On the mechanisms of biocompatibility. Biomaterials 2008;29:2941-53.
3. Ghazal AR, Hajeer MY, Al-Sabbagh R, Alghoraibi I, Aldiry A. An evaluation of two types of nickel-titanium wires in terms of micromorphology and nickel ions' release following oral environment exposure. Prog Orthod 2015;16:9.
4. Sifakakis I, Eliades T. Adverse reactions to orthodontic materials. Aust Dent J 2017;62(Suppl 1):20-8.
5. Senkutvan RS, Jacob S, Charles A, Vadgaonkar V, Jatol-Tekade S, Gangurde P. Evaluation of nickel ion release from various orthodontic arch wires: An *in vitro* study. J Int Soc Prev Community Dent 2014;4:12-6.
6. Bhasin V, Pustake SJ, Joshi V, Tiwari A, Bhasin M, Punia RS. Assessment of changes in nickel and chromium levels in the gingival crevicular fluid during fixed orthodontic treatment. J Contemp Dent Pract 2017;18:675-8.
7. Tahmasbi S, Sheikh T, Hemmati YB. Ion release and galvanic corrosion of different orthodontic brackets and wires in artificial saliva. J Contemp Dent Pract 2017;18:222-7.
8. Azizi A, Jamilian A, Nucci F, Kamali Z, Hosseinikhoo N, Perillo L. Release of metal ions from round and rectangular NiTi wires. Prog Orthod 2016;17:10.
9. Quadras DD, Nayak USK, Kumari NS, Priyadarshini HR, Gowda S, Fernandes B. *In vivo* study on the release of nickel, chromium, and zinc in saliva and serum from patients treated with fixed orthodontic appliances. Dent Res J (Isfahan) 2019;16:209-15.
10. de Souza Schacher HR, de Menezes LM. Metal ion quantification in the saliva of patients with lingual arch appliances using silver solder, laser, or TIG welding. Clin Oral Investig 2020;24:2109-20.
11. Kapadia JM, Agarwal AR, Mishra S, Joneja P, Yusuf AS, Choudhary DS. Cytotoxic and genotoxic effect on the buccal mucosa cells of patients undergoing fixed orthodontic treatment. J Contemp Dent Pract 2018;19:1358-62.
12. Faccioni F, Franceschetti P, Cerpelloni M, Fracasso ME. *In vivo* study on metal release from fixed orthodontic appliances and DNA damage in oral mucosa cells. Am J Orthod Dentofacial Orthop 2003;124:687-93; discussion 93-4.
13. Freitas MP, Oshima HM, Menezes LM. Release of toxic ions from silver solder used in orthodontics: An *in-situ* evaluation. Am J Orthod Dentofacial Orthop 2011;140:177-81.
14. Goncalves TS, Menezes LM, Trindade C, Machado Mda S, Thomas P, Fenech M, *et al*. Cytotoxicity and genotoxicity of orthodontic bands with or without silver soldered joints. Mutat Res Genet Toxicol Environ Mutagen 2014;762:1-8.
15. Goncalves TS, de Menezes LM, Ribeiro LG, Lindholz CG, Medina-Silva R. Differences of cytotoxicity of orthodontic bands assessed by survival tests in saccharomyces cerevisiae. Biomed Res Int 2014;2014:143283.
16. Goncalves TS, Menezes LM, Trindade C, Thomas P, Fenechc M, Henriques JA. *In vivo* evaluation of the genotoxic effects of Hyrax auxiliary orthodontic appliances containing silver-soldered joints. Mutat Res Genet Toxicol Environ Mutagen 2015;791:25-9.
17. Jacoby LS, Rodrigues Junior VDS, Campos MM, Macedo de Menezes L. Cytotoxic outcomes of orthodontic bands with and without silver solder in different cell lineages. Am J Orthod Dentofacial Orthop 2017;151:957-63.
18. Tramontana M, Bianchi L, Hansel K, Agostinelli D, Stingeni L. Nickel allergy: Epidemiology, pathomechanism, clinical patterns, treatment and prevention programs. Endocr Metab Immune Disord Drug Targets 2020;20:992-1002.
19. Gölz L, Papageorgiou SN, Jäger A. Nickel hypersensitivity and orthodontic treatment: A systematic review and meta-analysis. Contact Dermatitis 2015;73:1-14.
20. Syverud M, Dahl JE, Hero H, Morisbak E. Corrosion and biocompatibility testing of palladium alloy castings. Dent Mater 2001;17:7-13.
21. Menezes LM, Quintão CCA. The release of ions from metallic orthodontic appliances. Semin Orthod 2010;16:282-92.
22. Bishara SE. Oral lesions caused by an orthodontic retainer: A case report. Am J Orthod Dentofacial Orthop 1995;108:115-7.
23. Quirynen M, Marechal M, Busscher HJ, Weerkamp AH, Darius PL, van Steenberghe D. The influence of surface free energy and surface roughness on early plaque formation. An *in vivo* study in man. J Clin Periodontol 1990;17:138-44.
24. Goncalves TS, Spohr AM, de Souza RM, Macedo de Menezes L. Surface roughness of auto polymerized acrylic resin according to different manipulation and polishing methods: An *in situ* evaluation. Angle Orthod 2008;78:931-4.
25. Fleischer M, Sarofim AF, Fassett DW, Hammond P, Shacklette HT, Nisbet IC, *et al*. Environmental impact of cadmium: A review by the panel on hazardous trace substances. Environ Health Perspect 1974;7:253-323.
26. Berge M, Gjerdet NR, Erichsen ES. Corrosion of silver soldered orthodontic wires. Acta Odontol Scand 1982;40:75-9.
27. Huff J, Lunn RM, Waalkes MP, Tomatis L, Infante PF. Cadmium-induced cancers in animals and in humans. Int J Occup Environ Health 2007;13:202-12.
28. Novelli ELB, Hernandes RT, Novelli Filho JLBV, Barbosa LL. Differential/combined effect of water contamination with cadmium and nickel on tissue of rats. Environ Pollut 1998;103:295-300.
29. Arora M, Weuve J, Schwartz J, Wright RO. Association of environmental cadmium exposure with periodontal disease in U.S. adults. Environ Health Perspect 2009;117:739-44.
30. Arora M, Weuve J, Schwartz J, Wright RO. Association of environmental cadmium exposure with pediatric dental caries. Environ Health Perspect 2008;116:821-5.
31. Wataha JC. Principles of biocompatibility for dental practitioners. J Prosthet Dent 2001;86:203-9.
32. Wataha JC, Lockwood PE, Schedle A. Effect of silver, copper, mercury, and nickel ions on cellular proliferation during extended, low-dose exposures. J Biomed Mater Res 2000;52:360-4.
33. Shigeto N, Yanagihara T, Hamada T, Budtz-Jorgensen E. Corrosion properties of soldered joints. Part I: Electrochemical action of dental solder and dental nickel-chromium alloy. J Prosthet Dent 1989;62:512-5.