Research Article

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How Safe are Silver Soldered Appliances???

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ABSTRACT

Aims: The metal ion released from the orthodontic appliance may cause allergic reactions particularly nickel and chromium ions. The chances of leaching of metal ions may increase if the appliance is already exposed to soldering or welding procedures, as these procedures remove the protective layer applied on the material. This study aimed to assess and compare the leaching potential of hazardous metal ions from silver soldered orthodontic appliance and to determine the conformity of the leached metal ions with the established health and safety standards published by WHO.

Materials and Methods: 15 Soldered appliances (Transpalatalarch) were immersed in "Wet mouth" artificial saliva for a period of 24 hours and 20 days. The release of nickel, chromium and lead was determined by using a ICP-OES. Data collected was analyzed using IBM SPSS Data Editor Version 20. Student 't' test was used to compare the difference between various metal ions leached at day 1 and day 20. 'ANOVA' test used to compare difference between various metal ions concentrations.

Results: In this study result showed that at day 1 metal ions leaching increases and at day 20 metal ions leaching decreases from silver soldered appliance immersed in artificial saliva. All the metal ions studied, exceeded safety value published by WHO standards on day 1 and remained so even at day 20 except Ni which was higher on day 1 but dropped down at day 20.

Conclusion: From this study, we concluded that leaching of metal ions was seen at day 1 reaching to a toxic level, however this leaching was found to be dramatically lowered at day 20. The potential of metal toxicity carried by this appliance must be carefully considered when advocating this appliance to patients.

Keywords: Artificial saliva, chromium ions, ICP-OES (Inductively Coupled Plasma-Optical Emission Spectrometer), lead ions, nickel ions, TPA (Transpalatalarch).

INTRODUCTION

Oral cavity has a dynamic environment where various factors may influence the corrosion process of metallic appliance used in orthodontic treatment. Among the components contributing towards the dynamicity of oral environment are salivary pH (which composed of enzymatic activity of the saliva, organic acids produced by the bacterial flora, and variability of food pH) and mechanical activities occurring within the oral cavity. [1-3] In orthodontics, soldering is a standard method used for the

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application of auxiliaries and for the modification of force systems by joining wires of different cross-sections. Among commonly used silver solder appliance are transpalatal arch (or lingual arch), quad helix and rapid maxillary expander. In both appliances, a stainless steel wire of certain design is joined to the molar bands across the palate (or mandible) to serve their designated function. These joints are established by mean of soldering technique. Silver based solder alloy used in certain orthodontic appliances may create a galvanic couple with stainless steel alloys, remove protective layer by soldering, inducing leaching of metal ions from the appliances.[4] Therefore, the biocompatibility of these appliances has been a topic of concern of many literatures since some of the metal used in these appliances was classified as mutagenic, allergenic and cytotoxic to living tissue.[5-7] Leaching of metallic ions from corrosion activity can produce metal discoloration of adjacent soft tissues and caused allergic reaction to susceptible patients.[8-10] Besides, some of these ions may accumulate in organs and tissues thus interfere with the normal physiology of body systems.[11] Many studies have been conducted to examine the corrosion effect of orthodontic appliance. The most common appliances researched are orthodontic brackets, archwires and bands.[1,12,13] However, studies that looked into the corrosion effect of silver solder appliance (SSA) are still lacking. Also among the various metal ions, lead is considered the most toxic ion, however research are lacking. Therefore, the aim of this study was to assess and compare the leaching patterns of hazardous metal ions from silver soldered orthodontic appliance and to determine the conformity of leached metal ions with the established health and safety standards.

MATERIALS AND METHODS

Fabrication of Transpalatal Arch

For the purpose of investigating the leaching of metal ions from silver soldered appliances, 15 transpalatal arches were fabricated on 15 duplicated upper dental stone cast. One laboratory technician was assigned to construct the SSAs. Each of the appliance consisted of two molar bands conjoined to a 1.00 mm stainless steel wire by silver soldering technique. The composition of metal alloy used in fabrication of SSA (**Table 1**).

Table 1. Composition of metal used in fabrication of SSA (in percentage).

Component	C	Mn	Si	Cr	Ni	P	S	Fe
Stainless steel	0.15	2.0	1.0	17.0-19.0	8.0-0.0	0.045	0.03	Balance
Molar bands	0.12	2.0	1.0	17.0-19.0	10.5-13			Balance
	Cu	Ag	Tin	Zn				
Silver solder	20.0-41.0	24.0-57.0	1.5-5.5	15.0-35.0				

IMMERSION PROCEDURE

All the 15 transpalatal arches (TPA) **(Fig.1)** were soaked in separate glass beaker containing 50 ml of artificial saliva **(Fig.2)** each. After 24 hours of immersion, 2 ml of artificial saliva was removed from each sample and sent to the lab to measure leaching of metal ions. The soaking of appliances was continued for remaining 20 days in the same artificial saliva. After 20 days, saliva was sent to the laboratory to measure the amount of metal ions leached.

Fig.1 Transpalatal arch

Fig 2: Artificial Saliva

SAMPLE ANALYSIS

Analysis of the sample was done using Inductively Coupled Plasma-Optical Emission Spectrometer (ICP-OES) at MIT – Center for Analytical Research and Studies (MIT-CARS), Aurangabad, Maharashtra **(Fig.3)**. Three types of metal ions have been selected for analysis; nickel, chromium and lead.

Fig.3 ICP-OES

STATISTICAL ANALYSIS

Data collected was analyzed using IBM SPSS Data Editor Version 20. Student 't' test used to compare the difference between different metal ions leached at day 1 and day 20. 'ANOVA' test used to compare difference between different metal ions concentrations.

RESULTS

At day 1, mean nickel, chromium and lead ions leached were 1.1724 ± 0.00649 mg/L, 1.8212 ± 0.00556 mg/L & 0.7073 ± 0.00383 mg/L respectively (Table 2 & Graph no.1). When comparison done between Ni, Cr and Pb more amount of Cr was leached and less amount Pb was leached at day 1, however the levels of all the three ions investigated were higher to the WHO health and safety limit (Table 3 & Graph no.2). At day 20, mean nickel, chromium and lead ions leached were 0.0000 ± 0.0000 mg/L, 0.2047 ± .00931 mg/L , 0.2628 ± 0.00395 mg/L respectively (Table 4 & Graph no.3).

Table 2: Leaching of metal ions at Day 1

Group	N	Mean	Std. Deviation	Std. Error
Nickel	15	1.1724	.00649	.00168
Cr	15	1.8212	.00556	.00143
Pb	15	.7073	.00383	.00099
Total	45	1.2336	.46198	.06887

Table 3: Multiple Comparison between Metal Ions - Day 1

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.
Nickel	Cr	-0.6488	.00197	.000
	Pb	0.46507	.00197	.000
Cr	Nickel	0.6488	.00197	.000
	Pb	1.11387	.00197	.000
Pb	Nickel	-0.46507	.00197	.000
	Cr	-1.11387	.00197	.000

Table 4: Leaching of Metal Ions at Day 20

Group	N	Mean	Std. Deviation	Std. Error
Nickel	15	0.0000	0.00000	0.00000
Cr	15	.2047	.00931	.00240
Pb	15	.2628	.00395	.00102
Total	45	.1558	.11413	.01701

Table 5: Multiple Comparison between Metal Ions - Day 20

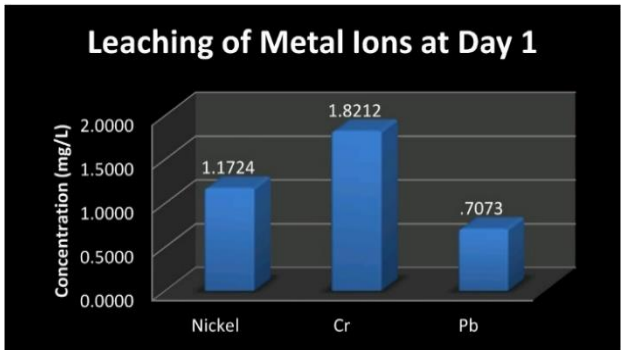
(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.
Nickel	Cr	-0.20467	.00213	.000
	Pb	-0.2628	.00213	.000
Cr	Nickel	0.20467	.00213	.000
	Pb	-0.05813	.00213	.000
Pb	Nickel	0.2628	.00213	.000
	Cr	0.05813	.00213	.000

Table 6: Comparison of Metal Ions Leaching between Day 1 and Day 20

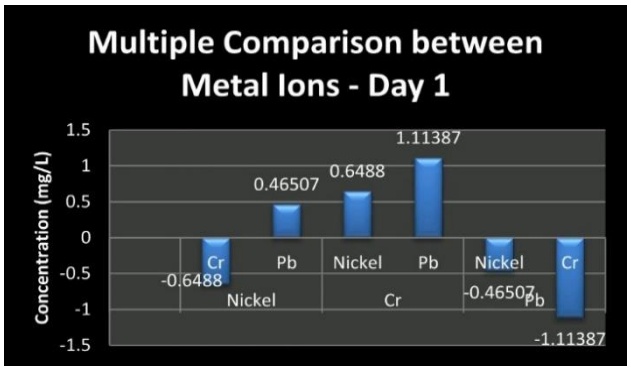
Group	Time	Mean	Std. Deviation	Std. Error Mean
Nickel	Day 1	1.17240	.006490	.001676
	Day 20	0.00	0.000	0.000
Cr	Day 1	1.82120	.005557	.001435
	Day 20	.20467	.009309	.002404
Pb	Day 1	.70733	.003830	.000989
	Day 20	.26280	.003950	.001020

Table 7: Difference of Metal Ion Leaching between Day 1 - Day 20

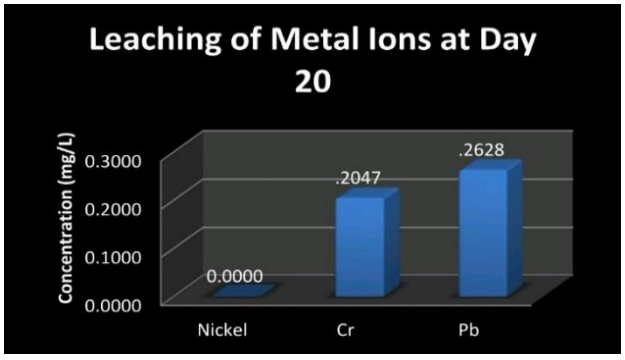
Group	Time	Mean Difference	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
Nickel	Day 1 - 20	1.172400	.006490	.001676	699.692	14	.000
Cr	Day 1 - 20	1.616533	.009672	.002497	647.296	14	.000
Pb	Day 1 - 20	.444533	.005263	.001359	327.150	14	.000



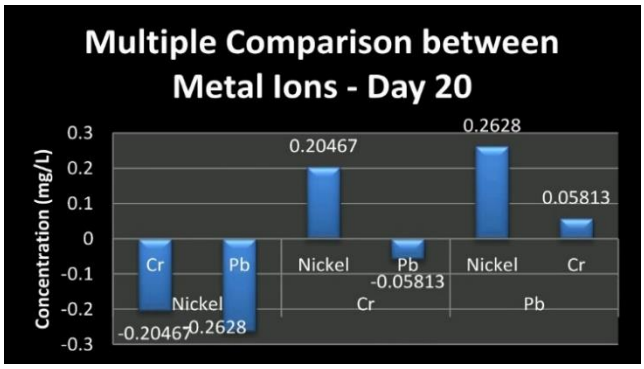
Graph 1: Leaching of metal ions at day 1.



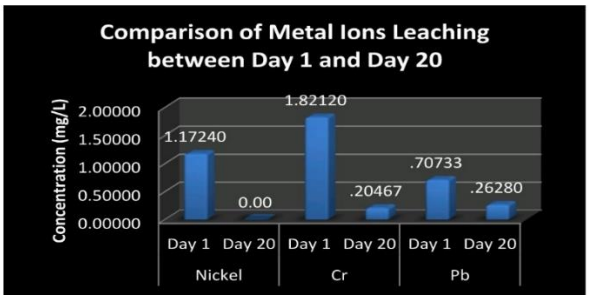
Graph 2: Multiple comparison between metal ions – day 1.



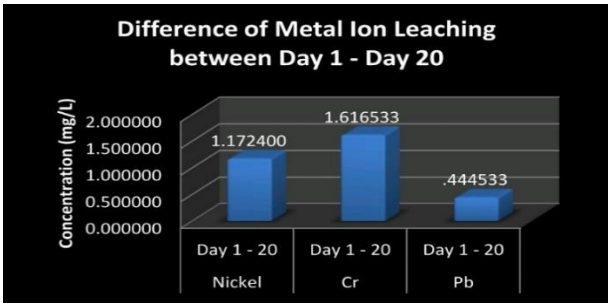
Graph 3: Leaching of metal ions at day 1.



Graph 4: Multiple comparison between metal ions – day 20.



Graph 5: Comparison of metals ions leaching between day 1 and day 20.



Graph 6: Difference of metal ion leaching between day 1 – day 20.

When comparison was done between Ni, Cr and Pb, more amount of Pb was leached and no release of Ni at day 20 (Table 5 & Graph no.4). When compared with the WHO health and safety limit, both the Chromium and Lead levels were above the toxic levels whereas Nickel levels were below the health and safety limit determined by WHO. When comparison was done between metal ions leaching at day 1 and day 20, it was found that the metal ions leaching at day 1 was higher as compared to day 20 (Table 6 & Graph 5) & significant difference between metal ions leaching at day 1 & day 20 (Table 7 & Graph 6).

DISCUSSION

Nickel and chromium are two metals often used in the construction of various parts of orthodontic appliances. Acidic condition, chloride and fluoride ions are detrimental to the passive surface oxide film, which protects the metal alloy from corrosion.[14] Barret et al. proposed that in the oral cavity, enzymatic activity and acidity of the saliva, and also bacterial flora activity might create an environment that favours corrosion.[1] Stainless steel material lost its corrosion resistance when being heated during soldering process.[4] As a result, metal ions were easily leached out as a result of

intergranular corrosion as shown by the present study. Furthermore, the presence of silver soldered joint in SSA is believed to create a galvanic current within the oral cavity that induces the metal ion release.

The toxicity risk of the metal release was assessed by comparing the daily release amount to the health and safety value published by the WHO. Overall nickel, chromium & lead release at day 1 from this study was 1.1724mg/L, 1.8212mg/L & 0.7073mg/L respectively. Overall nickel, chromium, lead release at day 20 from this study was 0.000mg/L, 0.2047mg/l, & 0.2628mg/L respectively. Based on this value, nickel, chromium & lead release exceeds the health and safety limit of nickel, chromium & lead exposure determined by WHO, i.e. 0.07mg/L, 0.014mg/L, & 0.01mg/L except nickel release at day 20.

Table 8: Conformity of Ni, Cr & Pb ions leaching to the WHO health and safety standard value.

Metal Ions	At Day 1(mg/L)	At Day - 20(mg/L)	WHO standard value(mg/L) (drinking water)
Ni	1.1724	0.000	0.07
Cr	1.8212	0.2047	0.014
Pb	0.7073	0.2628	0.01

Ni-Nickel, Cr-Chromium, Pb- Lead.

Nickel & chromium studied here are major components of wires, brackets, bands. Leaching of these metal ions have been detected in various studies, however in our study we have found that soldering removes the protective layer of the metal, exposing the underneath to more corrosive effect. Lead studied in this study is not a component of any wire, bracket, band & silver soldered wire. It was taken into consideration as per WHO lead is the most toxic metal ion coming in contact with humans. Surprisingly, lead ions leaching was found in this study, which was higher to the WHO safety standards at day 1 and continued to be so on day 20. This leaching of the lead metal ions may be attributed to the fact that the SS wire and band material used in this study may be coated with metallic paint with high lead content. Further investigations are needed in this aspect.

The potential health effects from exposure to nickel and chromium and their compounds have been scrutinized for more than 100 years. It has been established that these metals could cause hypersensitivity, dermatitis, and asthma, so there is the possibility that nickel and chromium released from stainless steel orthodontic bands, brackets, and wires might elicit an allergic reaction.

Clinical Implication

Orthodontic appliances including silver soldered appliances tested in this study are worn by orthodontic patients for a long term period. Orthodontic appliance in mouth is an additional metal exposure borne by orthodontic patients compared to other people without the appliance. The result of the present study indicates that SSA might contribute to additional exposure of nickel, chromium and lead to the patient. Silver soldered joint was proven as a potent corrosion inducer and may be a potential toxicant; therefore, orthodontist must recognize the risk of prescribing this appliance to patient. Other alternatives are available as substitutes to the present design of silver soldered appliance. Removable pre-formed TPA or QH slotted into palatal sheath of the bands can be a good alternative to avoid having soldered joints. Furthermore, laser welding is another option to be considered when joining metal in place of silver soldering. As for the alternative of anchorage device as served by the TPA, mini implant is known for its promising skeletal anchorage device. Besides, mini implant also has been proven to have low toxicity and corrosion level due to its titanium content. To reduce the metal ion leaching from SSA, orthodontist must remind their patients to maintain a good oral hygiene throughout the treatment. Advice such as avoiding acidic food should be given to patients to avoid similar condition of leaching that has been shown by our study.

CONCLUSION

From this study, we concluded that leaching of metal ions (Nickel, Chromium and Lead) from the soldered TPA appliance was seen at day 1 and was higher to the WHO safety standards. The leaching of metal ions continued on day 20, but was found to dramatically lowered to its day 1 values. Nickel metal ion leaching decreased to below WHO safety standards on day 20, however Chromium and Lead

continued to remain above the safety standards as determined by WHO even on day 20.

Nickel and Chromium are the major content of the SS wire and band material used in the study. Leaching of these metal ions is the common findings of various studies, however in this study the values found were higher and toxic. This may be attributed to the fact that soldering procedure removes of the protective layer of the metal, making it more susceptible to corrosion. It has also be to be considered that in this study, only soldering factor was considered, however the values may defer in oral cavity due to further exposure to various intrinsic and extrinsic factors (change in pH, temperature, brushing, bacterial effect etc)

Lead was not the content of the metal used in this study, however, surprisingly, lead ion leaching was found. Values of the lead metal ion leaching were higher on day 1 and day 20 as per the WHO standards. This definitely arouses a red alert, as WHO considers lead as the most toxic metal in contact with humans. The leaching of lead ions may have been from the coating of the metal.

Nickel, Chromium and Lead ions leaching in artificial saliva from a soldered TPA appliance above the WHO safety standards definitely need to be cause of concern. Further investigations in this aspect are anticipated.

CONFLICTS OF INTEREST

The authors declare they have no potential conflict of interests regarding this article.

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