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Original Article

The effect of different mouth washes on metallic ions release from silver-soldered and laser-welded orthodontic attachments. A comparative *in vitro* study

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ABSTRACT

Background: To compare the effect of different mouth washes on metallic ions release from silver-soldered and laser-welded orthodontic attachments.

Materials and Methods: In this comparative *in vitro* study, 32 samples of molar bands without attachments were used. Sixteen samples were silver soldered to stainless steel (SS) wire and 16 samples were laser welded using laser welding device to SS wire. Each group samples were divided into four test groups and submerged in solution containing sodium fluoride (NaF), NaF + alcohol (NaF + alcohol), Chlorhexidine (CHX), and artificial saliva (AS). Samples were shaken for 24 h with an agitation rate of 60 rpm. One sample from each group was selected to study the morphologic changes on their surfaces through scanning electron microscopy (SEM), and remaining samples were studied for metal ions released and dissolved in the solutions using spectrometry. The metal ions release values of two different attachment methods in three different mouth washes and AS group were compared using the unpaired *t*-test. A two-way analysis of variance was used to identify the significant differences between the two types of orthodontic attachments immersed in four different types of solutions. $P < 0.05$ was defined to be set significant for all tests.

Results: Level of metal ions released from the samples of silver soldering was higher than from laser welding. The lowest amounts of metal ions were released in CHX while highest in NaF + alcohol. The SEM images were in accordance with these findings.

Conclusion: Laser welding should be preferred over silver soldering for the construction of orthodontic appliances. CHX containing mouthwashes such as Hexidine can be prescribed for the patients undergoing orthodontic treatment. More *in vivo* experiments will determine whether the levels of dissolved nickel ions can reach the toxic or sub-toxic concentrations or not.

Key Words: Corrosion, Ion release, Laser welding, Orthodontic attachments, Silver soldering

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INTRODUCTION

Metals used in orthodontics should have specific features such as biocompatibility, functionality, absolute no adverse tissue response, and resistance to corrosion in the oral environment. Metal alloys

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such as stainless steel which have been main stay material in orthodontics since its introduction in 1932. It has been used extensively orthodontic practice because of its physical properties such as elasticity, hardness, and stress resistance.[1] Iron, nickel, and chromium have been identified as cytotoxic, mutagenic, and allergenic. These metal ions are the components of the metal alloys such as stainless alloy.[2] Various types of wires, brackets, bands, and attachments are the components of arches, lingual arches, fixed expansion appliances, quad helices and palatal expanders, and removable appliances require soldering or welding for its use. Along with the merits of these patient-specific appliances, there are some demerits like they are prone to corrosion in the varying conditions of the oral cavity.[3] The solder alloys that are used are mostly made up of silver, copper, and zinc. The use of these alloys as welding material can induce oxidation processes and in this manner can initiate metal ions to release due to the corrosion of the metal surface.[4] In contemporary orthodontics, an alternate method for joining metal frameworks is laser welding. Crystals of yttrium aluminum garnet (YAG) doped with neodymium (Nd) are mainly used to emit laser beams (Nd: YAG laser) to weld dental alloys. The most recent laser welding technology has many advantages such as working efficiency, corrosion-resistant, solder-free joint, homogeneous structure, high mechanical strength, and suitability for practically all dental alloys. Even though it has so many advantages, still laser welding is not that enormously used because of its large size machine, high cost, and fixed-lens beam delivery system.[5,6] Previous studies have proven that there is no significant difference between laser welding and conventional soldering methods in terms of periodontal tissue response.

If we overview the effects of fixed orthodontic treatment, it can cause mild-to-moderate gingivitis, dental caries, and decalcification as a result of the food accumulation forming bacterial plaque. This is the reason for prescribing antibacterial mouth washes and educating the orthodontic patients about mechanical cleaning.[7] Even though it has been reported that mouthwashes increase the risk of corrosion and cause the release of metal ions from appliances due to fluoride ions in the prophylactic agents, we need to prescribe it to the patients for its antibacterial property. Some *in vitro* studies have reported that the metal ion release and corrosion of arch wires increase when silver soldering and heat treatment is applied. In previous studies, the release of the metal ions such as nickel and chromium from orthodontic appliances as a result of corrosion was investigated, but less information is available about the effect of these different mouthwashes on soldering and welding.[8-10] Exploration of the material toxicity is highly demanded so that the dentists should be aware of a local hypersensitivity reaction at oral soft-tissue sites, such as mild erythema or redness with or without swelling. Clinicians should be also aware of severe gingivitis can be not only due to poor oral hygiene but also hypersensitivity reaction to nickel or chromium ions released from orthodontic appliance. We also need to study whether the use of different mouth washes have any effect on these metallic ions release.

To address the above concern, the present study was conducted *in vitro* to evaluate the metal ions release from silver soldering and laser welding caused by different types of mouthwashes.

MATERIALS AND METHODS

The present *in vitro* comparative study consists of total sample of 32 units, which is further divided into 16 silver-soldered and 16 laser welded units [Table 1]. The samples were prepared using 42 size upper first molar bands without attachments (D Tech Orthodontics Pvt. Ltd. Asia, India) as they are anatomically proportioned, and its lingual indent helps for a precise fit and reduces occlusal interference. Bands were attached to the pieces of 1 mm diameter and 5 mm length of stainless steel wire (Konark, Deccan Dental Depot Private Limited) by silver

Table 1: Composition of mouth washes and artificial saliva

Mouth washes	Composition
NaF	0.05% (225 parts per million (ppm) F2) Sodium fluoride, water, glycerin, sorbitol, propylene glycol, poloxamer 407, cetylpyridinium chloride, potassium sorbate, menthol, sodium saccharin, CI 42051
NaF + alcohol	0.022% (100 ppm F2) Alcohol, sodium fluoride, water, sorbitol, poloxamer 407, benzoic acid, sodium saccharin, eucalyptol, methyl salicylate, flavors, thymol, menthol, sodium benzoate, CI 47005, and CI 42053
CHX	0.2% Chlorhexidine gluconate, peppermint essence, sorbitol, patent blue V, glycerin, and deionized water
Artificial saliva	0.5% sodium carboxy methyl cellulose, glycerin 30%, flavors

CHX: Chlorhexidine

soldering or laser welding techniques [Figure 1]. This was the first material that truly replaced the usage of noble alloys in orthodontics. Steel wire alloys, in comparison to the noble metals, were relatively cheaper. They also had better formability and can be readily used to be soldered and welded for the fabrication of complex orthodontic appliances. Sixteen units of silver soldered attachments were prepared using pieces of solder wire of 0.031 mm diameter and 5 mm length (G and H Orthodontics, Earlywood Drive Franklin, USA) which was melted and spread on the region using hydro soldering unit (Sumax Automation System Kothrud, Pune, India) [Figure 2] Another 16 units of laser welded assembly was performed with a laser welding device (Fiber Laser Automatic welding Machine, OPT-FW 1000, Made in Germany) without using any solder wire. The samples of each weld group were divided into four mouthwashes and artificial saliva (AS) test groups [Tables 1 and 2]. The mouthwashes used in the study contained sodium fluoride (NaF; Colgate Plax, Colgate Palmolive (INDIA)Ltd), NaF + alcohol (NaF + alcohol; Listerine H, Johnson and Johnson, Skillman, NJ, USA), and Chlorhexidine (CHX; Hexidine, ICPA Health Products Ltd, INDIA) and AS (AS; Wet mouth) was the negative control solution [Figure 3].

Figure 1: Armamentarium required for sample preparation

Figure 2: Silver Soldered and laser welded molar bands as a study sample

A total of 32 sterile laboratory containers of 30 mL (Made of Polypropylene, graduated and with screw cap by Astra Scientific System *P* Ltd). These containers are made of transparent polypropylene, graduated with screw cap and individually packed. These laboratory containers were used to contain the solutions. A total of 24 containers were filled with 1 mL of 10% AS and 9 ml of 90% of three types of mouth washes (eight containers with one mouth wash). The remaining eight containers were filled with 100% AS as controls. The samples with silver soldering were kept in the solutions per four containers and shaken (VDRL Rotator) for 24 h with an agitation rate of 60 rpm [Figure 4]. The amounts of metal ions released from the samples and dissolved in the solutions were subsequently measured using inductively coupled plasma optical emission spectrometry (Agilent ICP-OES 5110 Spectrometry) [Figure 5]. The eight samples, four from each subgroup, were chosen randomly for the examination of the surface changes by scanning electron microscopy(SEM TESCAN VEGA 3) at ×2003 [Figure 6]. SEM is a versatile multifunctional

Figure 3: Three different types of mouth washes and artificial saliva

Figure 4: Study sample on VDRL Rotator

tool which allows to get images of the material's surface structure and morphology with a few nm resolution; it also gives a qualitative and quantitative (EDX, lateral resolution around 1 μm) chemical information. SEM TESCAN VEGA 3 is a thermionic emission that comes either with tungsten-heated filament or lanthanum hexaboride (LaB_6) as electron source. VEGA3 is a versatile system intended for both low and high vacuum operations [Figure 5].

Statistical analysis

The obtained values from optical emission spectrometry were recorded in parts per million, and the metal release values of the two soldering methods and three mouthwashes and AS were compared using unpaired *t*-test for the statistical analysis. Statistical tests were done using PASW® version 17 (SPSS Inc., Chicago, IL, USA). A two-way analysis of variance was used to identify the significant differences between the two types of orthodontic attachments immersed in four respective type of solutions and the effects of interaction among the variables. $P < 0.05$ was defined to be statistically significant for all the tests.

RESULTS

Metal ions release is found in small or large amount in all solutions containing silver-soldering samples than in those containing laser welding samples. Silver-soldered samples released higher amounts of nickel in NaF, chromium and iron in NaF + alcohol, and copper in AS. Compare to all three mouth washes Cu, Ni, Cr, and Fe ion release is least in CHX containing solution. Even though the chromium content of the appliances is more the release of nickel ions is more in all solutions. The representative SEM images at ×2003 show the silver soldered and laser welding samples kept in different mouthwashes for 24 h. The topography of the samples immersed in NaF show more surface roughness seen with silver soldered sample. When silver soldering was compared with laser welding in relation to surface characteristics, silver soldering samples were left with rough surface. These SEM images are in accordance with ICP-OES results [Tables 3-6, Figure 7].

DISCUSSION

Nickel is found to be the most common metal causing

Table 2: Distribution of samples to the groups

Group	Sample distribution
Silver soldering samples (16) immersed in different solutions	CHX (3 + 1 SEM) NaF (3 + 1 SEM) NaF + alcohol (3 + 1 SEM) AS (3 + 1 SEM)
Laser welding samples (16) immersed in different solutions	CHX (3 + 1 SEM) NaF (3 + 1 SEM) NaF + alcohol (3 + 1 SEM) AS (3 + 1 SEM)

CHX: Chlorhexidine; NaF: Sodium fluoride, AS: Artificial saliva, SEM: Scanning electron microscopy

Table 3: ICP-OES report of Ni ions release (μg/L) for the comparison of two groups in four different solutions

	Group	*n*	Mean	SD	*P*
CHX-Ni	Silver soldering	3	130.270000	13.1962267	0.001*
	Laser welding		64.973333	4.4300602	
NaF- Ni	Silver soldering	3	299.5667	93.27484	0.139*
	Laser welding		178.1433	65.69700	
NaF Alc- Ni	Silver soldering	3	2645.156667	522.5099431	0.002*
	Laser welding		331.510000	33.8116385	
Artificial saliva- Ni	Silver soldering	3	472.0633	36.79331	0.001*
	Laser welding		165.9300	17.31373	

*significant.- 0.001, SD: Standard deviation

Figure 5: Agilent ICP-OES 5110 Spectrometry machine

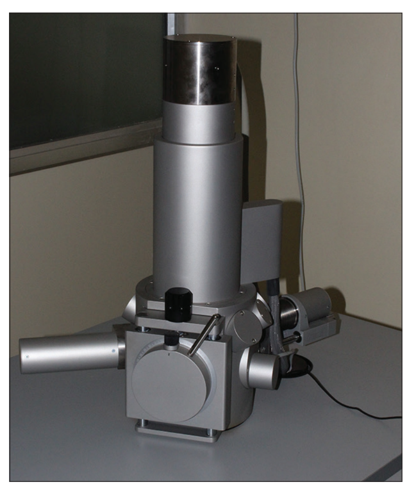

Figure 6: Scanning electron microscopy machine

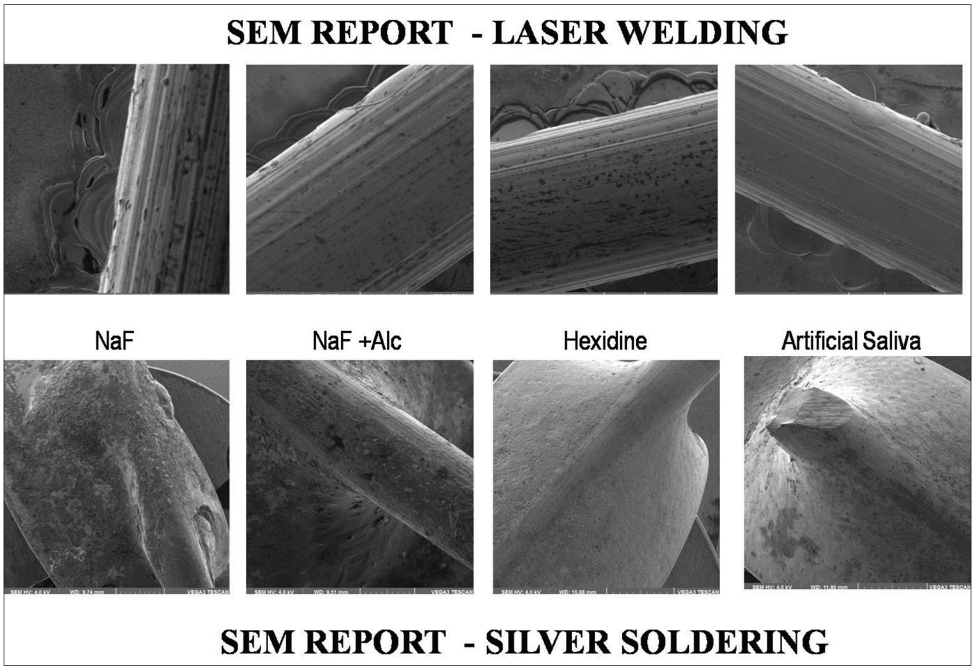

Figure 7: Scanning electron microscopy images

Table 4: ICP-OES report of Cu ions release (µg/L) for the comparison of two groups in four different solutions

	Group	*n*	Mean	SD	*P*
CHX-Cu	Silver soldering	3	16.433333	6.8145237	0.029*
	Laser welding		3.173333	0.8129166	
NaF-Cu	Silver soldering	3	3590.0833	757.90442	0.001*
	Laser welding		6.6133	1.38551	
NaF Alc-Cu	Silver soldering	3	7820.630000	832.0139448	0.001*
	Laser welding		2.813333	0.3507611	
Artificial Saliva-Cu	Silver soldering	3	9699.746667	900.1931634	0.001*
	Laser welding		3.813333	0.2871121	

*significant.- 0.001, SD: Standard deviation

Table 5: ICP-OES report of Cr ions release (µg/L) for comparison of two groups in four different solutions

	Group	*n*	Mean	SD	*P*
CHX-Cr	Silver soldering	3	7.0700	4.02134	0.653*
	Laser welding		5.7833	2.23583	
NaF-Cr	Silver soldering	3	225.7833	51.77349	0.030*
	Laser welding		101.2233	40.29501	
NaF Alc-Cr	Silver soldering	3	634.2000	134.58489	0.002*
	Laser welding		70.1967	9.06081	
Artificial Saliva-Cr	Silver soldering	3	22.4033	4.52460	0.002*
	Laser welding		2.8400	0.27839	

*significant.- 0.001, SD: Standard deviation

allergy in predisposed patients. Various *in vitro* studies were conducted during last few years to detect the amounts of allergic metal ions released from orthodontic appliances. Orthodontic appliances as a whole or its components were analyzed separately in different studies to check metal ions release in AS, which is commonly used media in *in vitro* studies to create the desired dynamic oral environment.[11-13] In many studies, different types and numbers of orthodontic appliances were used such as molar bands, brackets, arch wires, and maxillary expansion devices for detecting metal ions release.[7,8] Whole orthodontic appliance was not tested in this study to evaluate the net corrosion of the laser welded and silver-soldered parts and the ions release. Dwivedi *et al.* in 2015 conducted an *in vivo* study where they have found maximum nickel ions level than the previous studies which may be due to the inclusion of transpalatal arch inserted in lingual sheath welded to molar bands as the welded joints are more prone to corrosion.[14]

In the present study, the samples of soldered bands and laser-welded bands stored in different mouthwash solutions were shaken to imitate and create the desired dynamic oral environment. Orthodontic bands with soldered or welded attachments were selected as the study samples as it is an integral part of an orthodontic treatment and could be used for reinforcing the anchorage or for some other orthodontic purpose almost in every orthodontic patient. When stainless steel was introduced in dentistry for orthodontic purpose, it was considered as the most biocompatible and harmless material for humans, but as it was proved that it leaches ions in oral cavity, nowadays, it may be considered as harmful.

Table 6: ICP-OES report of Fe ions release (μg/L) for comparison of two groups in four different solutions

	Group	*n*	Mean	SD	*P*
CHX-Fe	Silver soldering	3	102.3133	3.02655	0.029*
	Laser welding		71.3067	15.80646	
NaF- Fe	Silver soldering	3	70.920000	1.0678483	0.001*
	Laser welding		48.376667	1.0995150	
NaF Alc- Fe	Silver soldering	3	6867.4233	41.55443	0.001*
	Laser welding		941.1000	19.85380	
Artificial Saliva- Fe	Silver soldering	3	382.8833	37.51643	0.001*
	Laser welding		164.8633	2.71251	

*significant.- 0.001, SD: Standard deviation

This study was conducted for *in vitro* comparative assessment of effect of different commercially available mouthwashes on metal ion release from silver soldered and laser welded components of orthodontic appliance. For this purpose, three different mouthwashes were used such as Hexidine, Listerine and Colgate Plax, AS was used. CHX gluconate (0.2%) is commonly used as an antimicrobial agent in the form of mouthwash. It was commercially available since many years as a general disinfectant with the broad antibacterial spectrum. Listerine was used as it is a phenolic compound which also can be used as antimicrobial agent in the form of mouth wash. Due to their low toxicity and high antibacterial activity of phenolic compounds have been incorporated in throat lozenges and mouth rinse used in oral cavity. Colgate Plax acts on bacterial cell membrane releasing large amount of fluoride damaging it by protein denaturation. AS contains sodium chloride, potassium chloride, sodium sulphate, urea, calcium chloride, and distilled water.[7,15]

In the microenvironment of the mouth, the presence of a chloride gradient could contribute to the increased metal degradation observed as one progress deeper into the crevice between the teeth.[16] Danaei *et al.* in 2011 studied metal ion release from orthodontic brackets immersed in three different mouth washes and reported comparatively more release of nickel was in deionized water and then highest in CHX mouth wash. CHX mouth wash releases the highest amount of metal ions except (Manganese) followed by oral and Persica, this does not agree with the results of the present study. In the present study, increase in the level of metal ions could be attributed to corrosive nature of silver soldered and laser welded attachments and next to the PH and fluoride content of mouth washes.[17] NaF (Colgate Plax) mouthwash has released greater amounts of nickel ions. Previous studies have claimed that increased corrosion on the surface of the silver solder is caused by the high temperature and galvanic reaction in the region.[11] Hwang *et al*. reported that surface roughness caused by silver soldering led to decomposition of the crystal structure of the material and made the soldered surface more sensitive to corrosion.[13] Laser welding was well tolerated with least corrosion and metal ions release thus higher biocompatibility over silver soldering.[18,19] Kerosuo *et al*. in their *in vitro* study on release of nickel and chromium from different types of simulated orthodontic appliances resulted significant amount of nickel ions release under dynamic loading than under static conditions, whereas the chromium ions release was significantly less and equal under both conditions.[10] Variations in study designs and different electrochemical factors make comparisons between the studies difficult. Thus, the comparisons between studies must be done with due consideration of the problem in measuring surface areas with complex geometry.

We found in our study that CHX mouthwashes release a smaller number of metal ions compared to other two mouth washes and the laser welded orthodontic appliances release less metal ions due to some amount of corrosion resistance, which may contribute to literature and clinical practice. To confirm the validity of results of such *in vitro* study, similar *in vivo* study should be performed because temperature, pH variation, and different microbiological and enzymatic activity of natural saliva could provide different environment for the corrosion of appliances and metal ions release.

CONCLUSION

Laser welding should be preferred over silver soldering for the construction of orthodontic appliances due to some amount of corrosion resistance and ultimately fewer metal ions release in clinical orthodontic practice. However, from our results, it can be concluded that the corrosiveness of the mouthwash, which in turn depends on its chemical structure, which is the main factor responsible for the release of metal ions from orthodontic appliances. More *in vivo* experiments will help in determining whether the CHX containing mouthwashes such as Hexedine could be prescribed or not for the patients undergoing orthodontic treatment rather than NaF, Naf + alcohol containing mouthwashes. Also need to determine whether the levels of dissolved nickel ions can reach the toxic or sub-toxic concentrations or not.

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Conflicts of interest

There are no conflicts of interest.

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