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Dr. Khadeer Riyaz
Reader, Department of Orthodontics, The Oxford Dental College, Bengaluru, Karanataka, India

Dr. Rajat Suri
Orthodontist, Private Practitioner, 362/1, Civil Lines, Nehru Marg, Jhansi, Uttar Pradesh, India

Dr. Raghunandan Chunduri
Professor, Department of Orthodontics, The Oxford Dental College, Bengaluru, Karanataka, India

Dr. Kenneth FH Tan
Professor, Department of Orthodontics, The Oxford Dental College, Bengaluru, Karanataka, India

Dr. Laxmikanth SM
Professor, Department of Orthodontics, The Oxford Dental College, Bengaluru, Karanataka, India

Dr. Sameena Begum
Reader, Department of Orthodontics, The Oxford Dental College, Bengaluru, Karanataka, India

Dr. Salim Shamsuddin
Senior Lecturer, Department of Orthodontics, The Oxford Dental College, Bengaluru, Karanataka, India

Dr. Anju Varughese M
Senior Lecturer, Department of Orthodontics, The Oxford Dental College, Bengaluru, Karanataka, India

Corresponding Author:
Dr. Khadeer Riyaz
Reader, Department of Orthodontics, The Oxford Dental College, Bengaluru, Karanataka, India

Evaluation of metal ions released from orthodontic attachments that were spot-welded and laser-welded while submerged in various mouthwashes: A study done *in-vitro*

Dr. Khadeer Riyaz, Dr. Rajat Suri, Dr. Raghunandan Chunduri, Dr. Kenneth FH Tan, Dr. Laxmikanth SM, Dr. Sameena Begum, Dr. Salim Shamsuddin and Dr. Anju Varughese M

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Abstract

Background of study: In Orthodontics, welding is a technique for joining stainless steel strips to create bands for both fixed and removable appliances. The main disadvantage is that they are susceptible to corrosion under various oral cavity environments. Therefore, the major goals of this study was to evaluate the release of metal ions from spot welded/Laser welded orthodontic attachments when immersed in various mouthwashes and also to compare the corrosion resistance of spot-welded with laser welded orthodontic attachments.

Materials and Methods: The 72 samples used in this investigation were split into two groups according to the following methodology: 36 laser-welded attachments for Group I. 36 spot-welded attachments for Group II. Each welded group's samples were subsequently separated into four subgroups. Artificial saliva (AS) was used as a control group, in which the samples were submerged for 24 hours before being withdrawn, and each subgroup had 9 samples from its respective group. ICP-MS (Scientific's inductively coupled plasma mass spectrometry) was used to calculate the sample's metal ion release.

Results: The attachments that were laser-welded produced less ions than those that were spot-welded. Both the laser-welded and spot-welded attachments emitted Fe, Ni, and Cr ions, but when the releases were compared, it was discovered that the Fe and Ni ions releases were significantly higher than the Cr ions releases. Additionally, it was determined that CHX (Chlorhexidine) mouthwash should be used as it released metal ions the least compared to the other mouthwashes.

Conclusion: When immersed in various mouth washes, the results showed that the laser-welded attachments discharged less ions than the spot-welded attachments. Comparing CHX mouthwash to others, it was discovered that it released less ions.

Keywords: Corrosion, chlorhexidine, ion release, laser welding, mouthwashes, spot welding

Introduction

A wide range of metallic alloys are frequently used in orthodontics for wires, brackets, bands, and attachments. Dental and biomedical specialists have become more interested in the adverse effects of using biomaterials, particularly metallic materials, during the past ten years. Metal brackets and arch wires are used in fixed equipment in orthodontics. The majority of materials used in orthodontics are typically steel-based alloys that comprise iron, nickel, and chromium. Electrochemical corrosion may happen when these alloys are exposed to the oral cavity, which is a potentially hostile environment [1, 2].

In the discipline of orthodontics, linking wires with various cross sections using soldering or welding is a common technique for attaching auxiliary devices and modifying force systems.

Components of orthodontic appliances used to be soldered together. Spot welding and laser welding are being utilized to combine two metal surfaces as a result of advancements in the dentistry sector. Nowadays, the most popular method for joining stainless steel strips is welding.

This is done to create bands, secure attachments to the bands, build fixed and portable appliances, etc. Welding has been recommended by researchers because, due to far less metal ion leaching than silver soldering, it would be less harmful [3].
When two or more surfaces are welded together by spot welding, heat is produced by running an electric current through the components that are fastened together with the help of two electrodes. It benefits from quick welding, low cost, and easier laboratory work. Due to its great biocompatibility, laser welding is one of the bonding techniques that cells have successfully tolerated [4].
The principal elements identified to be released when orthodontic appliances are exposed to the oral environment are iron, nickel, and chromium ions. These discharged ions have the potential to be carcinogenic, cytotoxic locally, and allergic. In addition to their usefulness, these equipment have the disadvantage of being prone to corrosion in the various oral cavity circumstances.
Almost majority of the alloys used in orthodontics include nickel. Dentists are becoming more concerned as nickel hypersensitivity, dermatitis, and urticaria can manifest far from the nickel source. Due to the composition and manufacturing process, nickel and chromium are released when held in physiological saline. Due to the way that dynamic circumstances change the corrosion behaviour of alloy in a simulated oral environment, the amount of nickel released rises under functional stress [5].
It might be difficult to manage plaque adequately during orthodontic treatment, especially in kids and teenagers. The mastication, brushing, and salivary flow are all hindered by an orthodontic device. These individuals frequently have unhealthy gingiva and discolouration or staining of the tooth structure. It is very advised that people receiving orthodontic treatment use mouthwash [6]. Mouthwash with various ingredients has been advised to lessen the buildup of bacterial plaque, improve gingival health, and lower the incidence of dental caries. In the presence of certain mouthwashes, it has been shown that orthodontic equipment produce metallic ions, which have been shown to be allergenic, locally cytotoxic, and carcinogenic [7].
In order to examine their corrosion resistance, this study compared the discharge of metal ions from spot-welded and laser-welded orthodontic attachments after being submerged in various mouthwashes.

Materials and Methods

The following materials were utilized for this study: Sodium Fluoride Mouthwashes: Colgate Plax Colgate-Palmolive (Thailand) Ltd. Sodium fluoride combined with alcohol: Johnson & Johnson (India) Privately Held Limited. Hexidine: Chlorhexidine. The company ICPA Health Products (India) Ltd. Synthetic saliva: diastase AMD Laboratories in Bangalore, India, Molar bands, molar tube, and language sheath, Hyderabad, Telangana, India, Metro Orthodontics, Laser Welder: Puchheim, Germany's Alpha Laser GmbH, and Spot welder:C-36, Bangalore, India, Confident Dental Equipment's Ltd. Pipette 5 ml, Borosil Test Tubes 55 ml, Borosil Test Tube Holder, Distilled Water, Light Wire Cutter, Tweezers, and Fungal Diastase Powder (artificial saliva)(Fig 1-9). Table 1 displays the ingredients of the mouthwashes. Based on the above study materials a total of 72 samples were created, and they were split into two groups as follows: A one kilowatt power shot was set to stay on the surface of the solder for 1.1 milliseconds in Group I, which had 36 laser-welded attachments (ALPHA LASER GmbH, at Wintegral Engineering Pvt. Ltd., Bengaluru). Seven shots were fired every second. The shot diameter was fixed at 0.3 mm. After uniting its two electrodes, Group II's spot welder (Confident spot welder) produced 36 spot-welded attachments with a 40W power output.
Both groups were further divided into four subgroups, labelled a, b, c, and d, comprised of nine orthodontic attachment samples (Table 2). Subsequently, the samples were immersed in Group I. (a) and Group II. (a) with sodium fluoride (NaF), Group I. (b) and Group II. (b) with sodium fluoride + alcohol (NaF + alcohol), and Group I. (c) and Group II. (c) with chlorhexidine (CHX) mouth washes, respectively. Group I. (d) and Group II. (d), which served as the control group, were submerged for twenty-four hours prior to extraction (Fig 10-11).
A 25-ml solution containing either 91 percent mouthwash or 9 percent AS was formulated. 25% of the control group contains 25 ml of 100% AS. Four samples were selected from each subgroup for scanning electron microscopy (SEM) at 200x magnification using GEMINI-ULTRA 55 to investigate surface morphological changes (Fig 12). The metal ion release from the sample was quantified using inductively coupled plasma mass spectrometry (ICP-MS) from Thermo Scientific, and the results were expressed in parts per billion (ppb). For each group, measurements were computed, values were recorded, and analysis of variance (ANOVA) was used to determine statistical differences.

Results

When comparing the mean metallic ion release of iron, nickel, and chromium (in ppb) from laser-welded orthodontic attachments when submerged in different mouthwashes with sodium fluoride, sodium fluoride with alcohol, and chlorhexidine contents with a p-value of < 0.05, the values in Table 3 showed a high level of statistical significance. The release of iron, nickel, and chromium ions was statistically significant in the laser-welded group in several mouthwashes, with the release of ions being least in CHX and highest in NaF+Al.
Spot-welded orthodontic attachments were put in different mouthwashes with sodium fluoride, sodium fluoride with alcohol, and chlorhexidine. The values in Table 4 show that there is a high statistical significance between the mean release of iron, nickel, and chromium. Spot welding caused considerable ions of iron, nickel, and chromium to be released in several mouthwashes; ions were released least in CHX and most in NaF+Al.
Comparing the mean difference in metallic ions released (in ppb) between various mouthwashes produced by spot orthodontic attachments that were welded using a significance level of < 0.05, as shown in Table 5, revealed a statistically significant level of significance. All mouthwashes emit significant amounts of Fe ions. CHX experienced substantial Ni ion leakage. Significant Cr ion emission from NaF in the presence of alcohol, CHX, and synthetic saliva.
The aforementioned data in Table 6 demonstrated a statistically significant multiple comparison at a significance level of < 0.05 of the mean difference in metallic ions produced (in ppb) between different mouth washes from laser-welded orthodontic attachments. Ions of Fe were released. significant across all mouthwashes and AS when compared to NaF. The Ni ion released by any mouthwash or AS was insignificant. The amount of Cr generated by NaF was significant when compared to that of other mouthwashes and AS.

In spot-welded groups, more Fe ions were released. In laser-welded groupings, there were more freed chromium ions. The average number of metallic ions (measured in ppb) released by the laser and spot-welding groups in sodium fluoride mouthwash are compared in Table 7.

The data in Table 8 showed that the comparison between the laser and spot-welding groups was statistically significant by comparing the average number of metallic ions released (in ppb) in a mouthwash made of sodium fluoride and alcohol. The Fe, Ni, and Cr ions liberated in spot-welded groups increased.

Comparing the mean metallic ion release (in ppb) between the laser-welded and spot-welded groups in chlorhexidine mouthwash, the results in table 9 showed excellent statistical significance. At $p<0.05$, the released amounts of Fe and Ni were statistically significant. Compared to spot-welded groupings, laser-welded groups emitted fewer ions.

The results in table 10 indicated substantial statistical significance when comparing the mean metallic ion release (in ppb) between the laser-welded and spot-welded groups in AS. The emission of Ni and Cr was statistically significant at a p value of < 0.05. Laser-welded groupings released fewer ions than spot-welded groupings did. The Cr ion release was the smallest, whereas the Ni ion release was the biggest overall. Statistical Package for Social Sciences [SPSS] for Windows Version 22.0 Released 2013 was used to conduct the statistical analysis. IBM Corp., Armonk, New York. The expression of Metallic Ions release in terms of Mean and SD was included in the descriptive analysis. The mean Metallic Ions emitted (in ppb) from the laser-welded and spot-welded groups by various mouthwashes were compared using a one-way ANOVA Test and Tukey's Honestly Significant Difference (HSD) Post hoc Analysis. The mean metallic ion release (in ppb) between the laser and spot-welded groups in various mouthwashes was compared using an independent student's t test. The significance threshold was set at $p<0.05$.

Discussion

Welded or soldered attachments are frequently observed in the mouth cavity during orthodontic treatment. The literature claims that welding is more biocompatible than soldering since it does not employ filler metal. Despite the need for soldering when using stainless steel wires, employing arch wires that can be welded is a biologically safer option. Welding is the process of applying pressure to two pieces of metal that are similar to one another to connect them together. Stainless steel strips may be welded together to form bands and hold fasteners to the bands for the construction of stationary and mobile appliances.

These appliances offer several useful benefits, but they also have the drawback of being susceptible to corrosion under different oral cavity conditions. The component emissions resulting from corrosion in orthodontic appliances were studied. Iron, nickel, and chromium ions were the main substances that were found to be released by stainless steel orthodontic appliances. These released ions have the potential to cause allergies, localized cytotoxicity, and cancer. Orthodontic devices that were laser-welded were less susceptible to corrosion than those that were silver-soldered [8].

Metal ions are released into the saliva by orthodontic alloy electro-galvanic currents. Asthma, cytotoxicity, contact dermatitis, and hypersensitivity may all be brought on by the discharge of nickel ions, an immunologic sensitizer that is powerful. However, earlier studies have shown that the amount of nickel and chromium ions released in a short amount of time is significant. This information cannot be used to establish the biocompatibility of orthodontic appliances that have been in the mouth for two to three years or of arch wires that have been in situ for a comparable period of time.

It is extremely difficult to maintain sufficient cleanliness when bands, wires, and ligatures are present. Within 1-2 months of the appliance's installation, hyperplastic gingivitis has been documented by authors. After receiving orthodontic treatment, the gingival tissues may experience inflammatory changes that can be treated. Mouthwashes were suggested as a way to improve gingival health and reduce bacterial plaque buildup [6]. The current study compared the metal ions produced from samples that were spot and laser welded and then submerged in mouthwashes of various compositions.

Because orthodontic bands and attachments have high concentrations of nickel, chromium, and iron, this study looked at those concentrations. However, in past studies, the metal ions emitted from different orthodontic device types in different solutions were examined at various times before the corrosion was identified after the first 24 hours. [9] In some of the older *in vitro* studies, corrosion was evaluated on the first day, whereas in others, it was evaluated on successive days. Because different experimental methodologies were employed, the results of the investigations were different from one another.

These ions are capable of causing allergic and toxicological reactions. Some of these symptoms may resolve, while others may have developed into a chronic condition because they were either brief and severe or moderately persistent and mild. Due to nickel's potential toxicity and the fact that nickel can be naturally eliminated more rapidly than it can be accumulated, the risks were the lowest [10].

However, the release of metal ions may cause local hypersensitivity at oral soft-tissue sites, such as moderate erythema or redness with or without edema. In addition to poor oral hygiene, hypersensitivity reactions to Ni or Cr ions emitted by stainless steel are associated with severe gingivitis [11]. In addition, it was essential to ascertain if the produced ions had any clinical significance for sensitizing patients with a history of hypersensitivity.

When the orthodontic attachments were submerged in different mouthwashes with sodium fluoride, sodium fluoride with alcohol, and chlorhexidine, the average amount of iron, nickel, and chromium that was released was measured in parts per billion (ppb). This one-way ANOVA test revealed a highly statistically significant difference with a p value of $<$ 0.05. Significant amounts of iron, nickel, and chromium ions were released in the spot-welded group in several mouthwashes; these ions were liberated least in CHX and most in NaF+Al.

The present study was comparable to the study done by Erdogan *et al*. in which they stated that metal ions released from the samples were less in laser welding group and also reveals that the lowest amounts of metal ions were released in CHX as compared to other mouthwashes [8]. (Table 3, Table 4).

Lasers offer superior levels of precision and control. Laser welding technology minimizes component distortion by employing low-temperature applications. Spot-welded attachments exhibited increased surface roughness, more fractures, and surface discoloration, as evidenced by SEM photographs that supported the ICP-MS. Therefore, laser welding was the least susceptible to corrosion. Compared to spot welding, this method is both faster and more durable.

Saliva serves as the vehicle for the discharge of metal ions into the oral cavity. Factors such as a high chloride combination in the saliva or consuming foods and beverages with a low pH can influence this process. In addition, the quality of the patient's saliva varied dependent on his or her health and the time of day [12]. In a static situation, in our study, three distinct mouthwashes were used: sodium fluoride, a mixture of sodium fluoride and alcohol, and CHX. Artificial saliva served as the control. Using Tukey's post-hoc analysis, a multiple comparison of the average difference in metallic ions generated (in ppb) across different mouth washes from spot-welded orthodontic attachments revealed a statistically significant difference with a p value of 0.001. < 0.05. All mouthwashes emitted a substantial quantity of Fe ions. Significant quantities of Ni ions were liberated by CHX. Compared to alcohol, the ions released by NaF were substantial. (Table 5).

Tukey's Post Hoc analysis on a repetitive comparison of the mean difference in metallic ions produced (in ppb) by different mouth washes from laser-welded orthodontic attachments revealed a statistically significant difference with a p value of < 0.05. In comparison to NaF, the amount of Fe ion generated by AS and all mouthwashes was significant. The quantity of Ni ions emitted by mouthwashes and AS was negligible. In contrast to other mouthwashes and AS, NaF produced a significant quantity of Cr. (Table 6)

The present study was comparable to the study done by Erdogan *et al*., in which the Fe ion released was high as compared to Ni and Cr ions [8].

Comparison of the mean metallic ions released (in ppb) by the laser and Spot-welding groups in Sodium Fluoride mouth rinse using the Independent Student's t Test with a significance level of 0.05. In spot-welded groups, more Fe ions were liberated. In laser-welded groups, the emission of chromium ions was greater. According to Erdogan *et al*. [8], the amount of chromium released by artificial saliva and CHX was lower than that of NaF and NaF with alcohol, which was consistent with the results of the current study (Table 7).

A comparison of the average metallic ions emitted (in ppb) in mouthwash containing chlorhexidine between groups that were spot-welded and those that were laser welded. With a p value of 0.05, the Independent Students' T test revealed a statistically significant difference between the discharge of Fe and Ni. Comparatively, laser-welded groups emitted fewer ions than spot-welded groups. (Table 9). Spot-welded attachments discharged a higher proportion of ions, as determined by Park HY *et al*., whose findings were supported by the current investigation [11].

Comparing the mean metallic ion emission (in ppb) between laser-welded and spot-welded groups in AS The Independent Student's t test with a significance level of 0.05 revealed a statistically significant distinction between the Ni and Cr ions produced. Statistically, the release of Ni ions in AS was significantly greater than the release of Cr ions. Comparatively, laser-welded groups emitted fewer ions than spot-welded groups. The outcomes of this investigation were comparable to those of Chung-Ju *et al*., which demonstrated that nickel ions discharged between groups were more abundant than chromium ions (Table 10).

The elevated temperature and galvanic response in the region contributed to the enhanced corrosion on the surface of the spot-welded attachments. Due to the surface irregularity caused by spot welding, the crystal structure of the material disintegrated, making the spot-welded surface more susceptible to corrosion. According to the SEM images, the samples exposed to mouthwash containing NaF had a few fractures and a rough surface. Colour modifications were observed on the surface of specimens treated with mouthwashes containing NaF, alcohol, and CHX. SEM photographs confirmed the results of ICP-MS. Laser welding is chosen by manufacturers because it produces high-quality welds and allows for clear processing. This is particularly true in the medical and dental industries, where the safety of the device is of the uttermost importance.

Fig 1: Sodium Fluoride Mouth Wash

Fig 2: Sodium flouride with alcohol containing Mouth Wash.

Fig 3: Chlorhexidine Mouth Wash

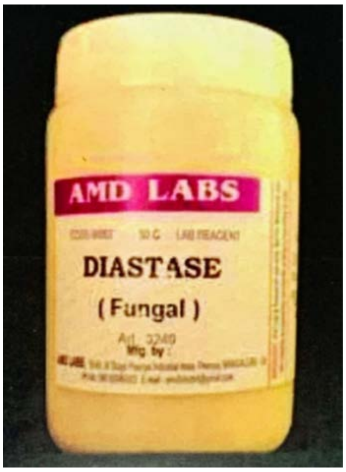

Fig 4: Diastase Powder (Artificial Saliva).

Fig 5: Lingual sheaths. Molar bands &molar tubes.

Fig 6: Laser welder (ALPHA LASER GmbH).

Fig 7: Spot Welder (Confident electronic welder C-36).

Fig 8: Test tube holder.

Fig 9: Distilled water

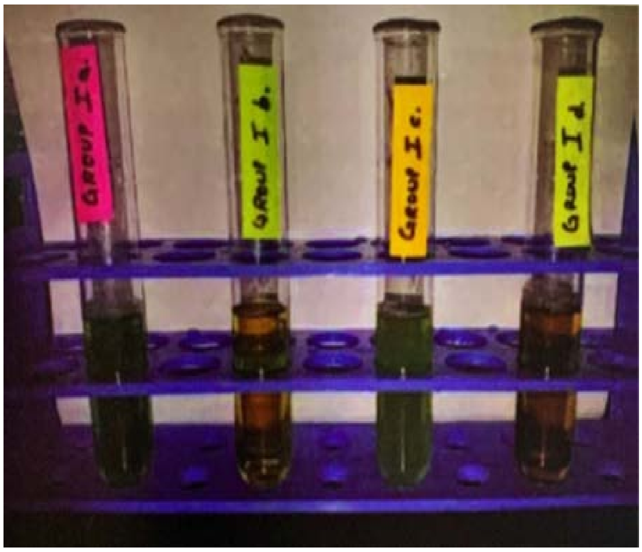

Fig 10: Test tube with laser welded Attachments with respective mouth washes.

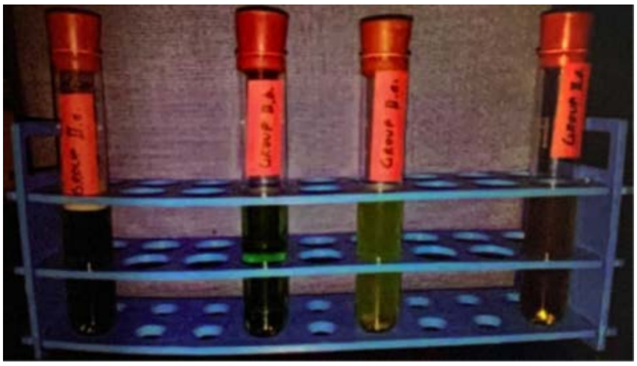

Fig 11: Test tube with spot welded attachments with respective mouth washes

Fig 12: Scanning Electron Microscope. GEMINI ULTRA 55

Conclusion

The following conclusions were obtained in our study

1. When compared to spot-welded attachments, laser-welded attachments produced fewer ions.
2. The laser-welded and spot-welded attachments emitted iron, nickel, and chromium ions. Fe and Ni ions emitted were found to be considerably more abundant than Cr ions.
3. Furthermore, it was determined that using CHX mouthwash should be preferred because it released the fewest metal ions compared to the other options.
4. SEM images also support the use of inductively coupled plasma mass spectrometry because they reveal more surface roughness, more cracks, and surface discoloration in spot-welded materials.

Conflict of Interest

Not available

Financial Support

Not available

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