Letter

Nickel Ion Release from Orthodontic Brackets in the Presence of Three Different Mouthwashes: A Comparative In vitro Study

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Abstract

Background: Orthodontic brackets and archwires create additional retentive sites that promote bacterial adhesion, thereby increasing the risk of plaque accumulation. However, there are rising concerns about allergic reactions and toxicity associated with metal ion release, particularly with regard to the commonly prescribed mouthwashes. This study investigates the release of nickel ions from orthodontic brackets when exposed to artificial saliva and three different commercially available mouthwashes: Ayurvedic oil-pulling, chlorhexidine, and fluoridated formulations. With the growing use of Ayurvedic alternatives in India, this research aims to fill the gap regarding their comparative impact on orthodontic appliances.

Materials and Methods: Forty stainless steel orthodontic brackets were immersed in artificial saliva and three distinct mouthwashes under controlled laboratory conditions. Nickel ion release was quantified using Inductively Coupled Plasma Optical Emission Spectrometry. Statistical analysis included one-way ANOVA and Tukey's Post Hoc test to determine significant differences among the groups.

Results: ANOVA and Tukey's post hoc analysis revealed that Group D (Fluoridated mouthwash) showed the highest mean nickel ion release, significantly greater than Group A (Artificial saliva) [mean diff = -405.87, 95% CI: -413.06 to -398.68], Group B (Ayurvedic) [-415.92, 95% CI: -423.11 to -408.73], and Group C (Chlorhexidine) [-341.74, 95% CI: -348.93 to -334.55] ($p < 0.001$). Group C also exhibited higher release than Group A and Group B ($p < 0.001$), while Group A was significantly higher than Group B ($p = 0.003$). Overall, nickel ion release followed the order Group D > Group C > Group A > Group B.

Conclusion: The findings highlight the biocompatibility of Ayurvedic formulations in minimizing metal ion release. This study concludes that selecting mouthwashes with lower corrosive potential can enhance patient safety and reduce hypersensitivity risks during orthodontic treatment.

Categories: Advanced Materials, Food and Pharmaceutical Engineering, Environmental Engineering

Keywords: mouthwashes, nickel ions, orthodontic brackets, biocompatibility, nickel allergy contact stomatitis, ayurvedic oil-pulling mouthwash

Introduction

Orthodontic treatment aims to achieve optimal dental alignment, enhancing craniofacial aesthetics and biomechanical function. Orthodontic brackets and archwires create additional retentive sites that promote bacterial adhesion, thereby increasing the risk of plaque accumulation. This predisposes enamel surfaces to demineralization, resulting in white spot lesions and dental caries. Therefore, during orthodontic treatment, clinicians usually recommend mouthwashes, such as fluoridated and chlorhexidine mouthwashes. In India, people use the oil-pulling technique as a routine oral hygiene regimen. Since Ayurvedic medicine is gaining popularity, oil-pulling oils are also prescribed for a satisfactory oral hygiene maintenance, and the prevention of caries and white spot lesions.

Orthodontic appliances, particularly metallic brackets, are prone to corrosion in the oral environment, leading to the release of potentially harmful metal ions such as nickel and chromium. Changes in the chemical, thermal, microbiological, and enzymatic properties of the oral environment can lead to the corrosion of metal components in orthodontic appliances. When two alloys are present with saliva acting as an electrolyte, electrochemical reactions drive this corrosion, releasing nickel ions. For the general population, toxicology and nutrition authorities have set tolerable intake reference values for nickel. Adults are typically considered to have a tolerable upper intake level of about 1.0 mg/day of soluble nickel salts, with lower age-specific limits for children (e.g., ~0.6 mg/day for ages 9-13, ~0.3 mg/day for ages 4-8, and ~0.2 mg/day for ages 1-3) [1]. These ions may cause soft tissue discoloration, allergic reactions, pain, and other toxic effects, including cytotoxicity, mutagenesis, and even carcinogenesis. Nickel, commonly found in metallic items, is a leading cause of metal allergies. Clinically, nickel allergy in orthodontic patients may manifest as gingivitis, gingival enlargement, lip desquamation, erythema multiforme, oral burning sensation, angular cheilitis, and periodontitis. These reactions are attributed to an inflammatory response caused by the corrosion of orthodontic appliances, leading to the release of nickel ions and clinically presenting as Nickel Allergy Contact Stomatitis [2].

Kitada et al [3] observed that more opportunistic bacteria adhered to saliva-coated metallic brackets. Another study [4] revealed that non-fluoridated mouthwashes cause less release of Ni ions from the orthodontic appliances than fluoridated mouthwashes. Another study by Pugalendhi et al [5] showed that higher corrosion resistance was obtained for brackets immersed in chlorhexidine mouth rinse. These findings highlight the need to examine mouthwash interactions more broadly, especially in the context of Ayurvedic practices and products used in India.

Adding to the clinical relevance, a study by Mihardjanti et al [6] observed that a statistically significant increase in bacterial colonization in orthodontic patients compared to non-orthodontic individuals, suggesting that brackets not only increase microbial adhesion, but also pose a chemical risk due to corrosion. Another study by Mirhashemi et al [7] revealed that both NiTi and SS wires released Ni ions in the presence of different types of mouthwashes. Thus, studies on the release of nickel ions from orthodontic brackets have been conducted; however, there is a paucity of information regarding Ayurvedic mouthwashes, which are widely favored for their natural ingredients and easy availability in the Indian market. Hence, it is essential to conduct a similar study focusing on the popular and commercially available mouthwashes in the Indian market.

Objectives

1. To evaluate the nickel ions released from orthodontic brackets in the presence of artificial saliva.

2. To evaluate the nickel ions released from orthodontic brackets in the presence of three commercially available mouthwashes, namely, ayurvedic oil-pulling mouthwash, chlorhexidine, and fluoridated mouthwashes.

3. To compare the nickel ions released from orthodontic brackets in the presence of artificial saliva with those released in the presence of three different commercially available mouthwashes.

Materials And Methods

Study design: An in vitro study conducted to estimate the level of nickel ion release from 40 orthodontic premolar brackets in the presence of three different mouthwashes and artificial saliva.

Sample size estimation: The study sample comprised 40 stainless steel premolar orthodontic brackets. The sample size was estimated using the GPower software v. 3.1.9.4 (Franz Faul, Universität Kiel, Germany). Considering the effect size to be measured (f) at 58% (based on the results from previous literature from Shahla Momeni Danaei et al, 2019), the power of the study at 80% and the alpha error at 5%, the sample size needed was 40.

Analysis: A priori: Compute required sample size

Input: Effect size f = 0.58

α err prob = 0.05

Power (1-β err prob) = 0.80

Number of groups = 4

Output: Noncentrality parameter λ = 13.4560000

Critical F = 2.8662656

Numerator df = 3

Denominator df = 36

Total sample size = 40

Actual power = 0.8423261

Each study group comprised 10 samples (10 samples × 4 groups = 40 samples). All brackets used were by the same manufacturer and batch to ensure standardization.

The inclusion criteria for the study comprised stainless steel premolar orthodontic brackets obtained from a single manufacturer to ensure uniformity and consistency of material properties. Only brackets that had not undergone any prior mechanical or chemical treatment were selected. Commercially available Ayurvedic oil-pulling solution, chlorhexidine, and fluoridated mouthwash, commonly used and readily accessible in the Indian market, were included. Artificial saliva was prepared under standardized laboratory conditions, and all samples were stored and tested under identical experimental parameters, including controlled temperature, immersion duration, and volume of solution. The exclusion criteria included mouthwashes with unknown or unspecified chemical compositions, as well as brackets that were physically damaged, oxidized, or contaminated prior to experimentation. The use of any additives or external agents not specified in the study protocol was not permitted. Additionally, samples that were not maintained under the prescribed incubation temperature or duration were excluded from the analysis.

Methodology: Ten stainless steel brackets were immersed in 15 ml of artificial saliva (Group A). Ten stainless-steel brackets were immersed in a solution of artificial saliva and Ayurvedic oil-pulling mouthwash (Group B), 10 stainless-steel brackets in artificial saliva mixed with chlorhexidine mouthwash (Group C), and 10 stainless-steel brackets in artificial saliva mixed with fluoridated mouthwash (Group D), all in a 1:1 ratio. All groups (Table 1) were incubated at a constant temperature of 37°C in individual test tubes. After an incubation period of 45 days, the immersion solutions were tested for nickel ions using Inductively Coupled Plasma Optical Emission Spectrometry. The nickel ion release among the different groups was then collected and analyzed comparatively.

Groups	Solution	Composition	Sample size
A	Artificial Saliva	—	10
B	Artificial Saliva and Ayurvedic oil-pulling mouthwash (ratio of 1:1)	Cinnamon oil – 3.0193 ml, Clove oil – 2.516 ml, Coconut oil – 5.0322 ml, Yavani Satva – 6.96 mg, Tulsi – 0.00696 ml, Peppermint Satva – 330 mg, Sesame oil – 88.40 ml, Extract from Ratanjot – 1g	10
C	Artificial Saliva and chlorhexidine mouthwash (ratio of 1:1)	Chlorhexidine gluconate IP – 0.2% w/v in pleasantly flavored aqueous base	10
D	Artificial Saliva and fluoridated mouthwash (ratio of 1:1)	Cetylpyridinium chloride – 0.075% w/v, Sodium fluoride – 0.05% w/v	10

TABLE 1: Mouthwashes and their compositions

Statistical analysis: One-Way ANOVA test was used to compare the mean Ni ion release between the four groups. Tukey's Post Hoc Test was used to compare the mean difference in the Ni ion release between groups. The p value for significance was set at <0.05. The null hypothesis [H0]: There is no difference in the mean Nickel Ion Release (in µg/L) between the four groups.

Results And Discussion

Results: The comparison of the mean nickel ion release among the four groups using a one-way ANOVA test (Table 2) showed a statistically significant difference ($p < 0.001$). The highest mean nickel ion release was observed in the Fluoridated group (417.53 µg/L), followed by the Chlorhexidine group (75.79 µg/L), Control group (11.66 µg/L), and the lowest in the Ayurvedic group (1.61µg/L).

This indicates that fluoride and chlorhexidine solutions significantly increased nickel ion release compared to the Ayurvedic and control groups.

Groups	N	Mean	SD	Min	Max	p-value
Group A (Control group; Artificial saliva)	10	11.66	1.29	9.8	13.2	<0.001*
Group B (Ayurvedic mouthwash)	10	1.61	0.52	0.8	2.4	
Group C (Chlorhexidine mouthwash)	10	75.79	3.27	70.5	80.2	
Group D (Fluoridated mouthwash)	10	417.53	11.39	399.7	433.2	

TABLE 2: Comparison of mean nickel ion release (in µg/L) between the four groups using one-way ANOVA test

After multiple comparisons of mean differences between groups using Tukey's post hoc test (Table 3), the results showed that Group D (fluoridated mouthwash) exhibited the highest mean nickel ion release, significantly higher than the control group, Group A (artificial saliva), with a mean difference of -405.87 (95% CI: -413.06 to -398.68). This was followed by Group B (Ayurvedic mouthwash) with a mean difference of -415.92 (95% CI: -423.11 to -408.73) and Group C (chlorhexidine mouthwash) with a mean difference of -341.74 (95% CI: -348.93 to -334.55), with statistical significance noted at $p < 0.001$, respectively.

(I) Groups	(J) Groups	Mean Diff. (I-J)	95% CI		p-value
			Lower	Upper	
Group A	Group B	10.05	2.86	17.24	0.003*
Group A	Group C	-64.13	-71.32	-56.94	<0.001*
Group A	Group D	-405.87	-413.06	-398.68	<0.001*
Group B	Group C	-74.18	-81.37	-66.99	<0.001*
Group B	Group D	-415.92	-423.11	-408.73	<0.001*
Group C	Group D	-341.74	-348.93	-334.55	<0.001*

TABLE 3: Multiple comparison of mean difference in nickel ion release between groups using Tukey's post hoc test

On comparing the results of ANOVA and Tukey's post hoc test, it was found that Group D (fluoridated mouthwash) demonstrated the highest nickel ion release compared to all other groups, followed by Group C (chlorhexidine mouthwash), Group A (artificial saliva), and Group B (Ayurvedic mouthwash), as shown in Figure *1*.

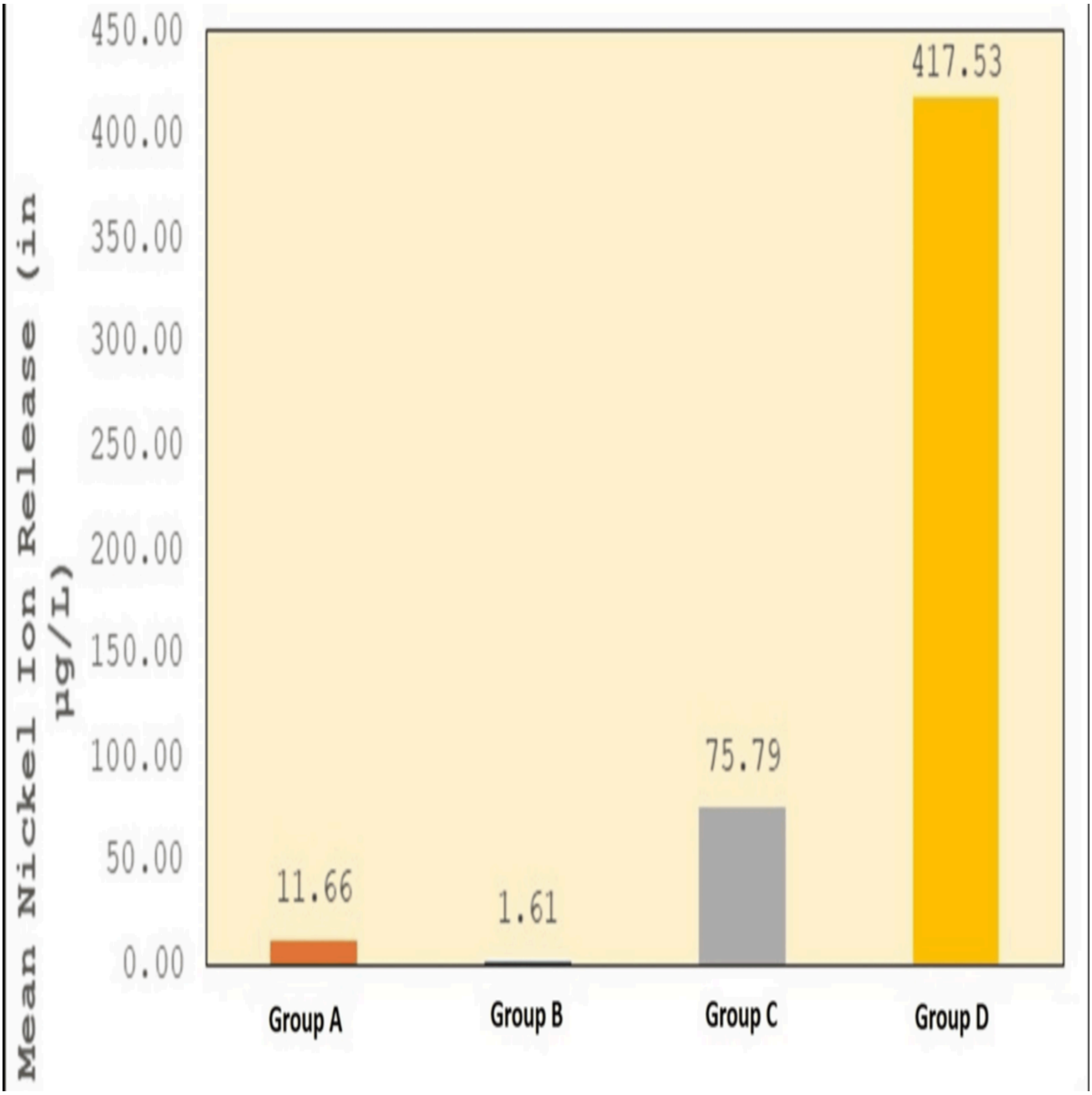

FIGURE 1: Mean nickel ion release (in µg/L) between four groups

Discussion

Orthodontic appliances are routinely exposed to various chemical agents in the oral environment, which may influence their corrosion behavior and metal ion release. Among these agents, commonly prescribed mouthwashes can alter the surface integrity of stainless steel brackets, thereby affecting nickel ion release and biocompatibility.

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In the present study, after multiple comparisons of mean differences between groups using ANOVA Test and Tukey's Post hoc Test, it showed that Group D (Fluoridated mouthwash) exhibited the significantly highest mean Nickel Ion Release compared to Group A (Artificial saliva), with the mean difference of -405.87 (95% CI: -413.06 to -398.68), Group B (Ayurvedic mouthwash) with a mean difference of -415.92 (95% CI: -423.11 to -408.73) and Group C (Chlorhexidine mouthwash) with the mean difference of -341.74 (95% CI: -348.93 to -334.55), with the statistical significances noted at $p < 0.001$. This was followed by Group C which showed significantly higher mean Nickel Ion Release compared to Group A, with a mean difference of -64.13 (95% CI: -71.32 to -56.94) and it also exhibited a significantly higher Nickel Ion Release compared to Group B, with a mean difference of -74.18 (95% CI: -81.37 to -66.99) with the statistical significances noted at $p < 0.001$. This was further followed by Group A, which exhibited a significantly higher Nickel Ion Release compared to Group B, with a mean difference of 10.05 (95% CI: 2.86 to 17.24), with the statistical significance noted at $p=0.003$.

The findings of the present study are consistent with those of Danaei et al [2] and Rafeeq et al [4], who also reported elevated metal ion release in fluoride-containing solutions due to their high chemical reactivity and ability to form soluble metal fluoride complexes. The presence of fluoride ions disrupts the passive oxide layer on metal surfaces, accelerating corrosion and subsequent ion release. Similarly, Mihardjanti et al [4] observed higher nickel and chromium ion release in chlorhexidine and fluoride mouthwashes, supporting the present results.

The chlorhexidine mouthwash group exhibited moderately elevated nickel ion release compared to artificial saliva. This can be attributed to the cationic nature and slightly acidic pH of chlorhexidine, which may compromise the stability of the protective oxide layer on orthodontic alloys and facilitate metal ion migration into the surrounding medium [7].

In contrast, the Ayurvedic mouthwash group demonstrated minimal nickel release. The antioxidant and metal-chelating properties of herbal ingredients likely contribute to stabilizing the metal surface and inhibiting corrosion. Oil pulling is a traditional oral hygiene practice that aids in mechanical cleansing and reduction of microbial load through its viscous, lipid-rich medium. Due to its hydrophobic nature and near-neutral pH, it exhibits minimal corrosive potential and lacks the ionic components that disrupt the protective oxide layer of stainless steel orthodontic brackets. Additionally, the transient lipid coating formed during oil pulling may reduce direct electrolyte contact with metal surfaces, thereby potentially limiting corrosion. These observations are in agreement with previous studies suggesting that herbal formulations may offer a biocompatible and safer alternative for orthodontic patients with nickel sensitivity [8,9].

From a clinical standpoint, the findings emphasize the importance of selecting appropriate mouthwash formulations for orthodontic patients, particularly those prone to metal hypersensitivity. Prolonged use of fluoride- or chlorhexidine-based mouthwashes may increase metal ion exposure, potentially heightening the risk of local or systemic reactions. Ayurvedic or non-fluoridated herbal rinses may thus serve as suitable alternatives that maintain oral hygiene without compromising the corrosion resistance of orthodontic materials.

The present study presented with limitations since it was conducted under in vitro conditions. It did not simulate dynamic oral factors such as salivary flow, pH fluctuations, temperature variations, and mechanical forces. Additionally, a 45-day continuous immersion protocol was used to approximate cumulative exposure, it does not accurately reflect the intermittent clinical use of mouthwashes and may exaggerate nickel ion release. Additionally, the exact pH values and fluoride concentrations of the tested mouthwashes were not experimentally determined, limiting detailed mechanistic interpretation. further studies should be conducted simulation dynamic oral conditions.

Conclusions

Nickel allergy, a Type IV delayed hypersensitivity reaction, can cause oral manifestations such as gingivitis, mucosal irritation, and cheilitis. Within the limitations of this study, it may be concluded that different mouthwash formulations significantly influence nickel ion release from orthodontic brackets. The results revealed that fluoridated mouthwash exhibited the highest ion release due to its aggressive interaction with the metal surface, while ayurvedic mouthwash showed the least, suggesting superior biocompatibility. The findings highlight the need for clinicians to consider the chemical composition of mouth rinses when prescribing them to orthodontic patients. Ayurvedic or herbal mouthwashes, owing to their natural ingredients and mild pH, may be recommended as safer alternatives for maintaining oral hygiene and minimizing corrosion-related complications during orthodontic therapy.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: JV Shreepriya, A Khushi, Nirajita Bhaduri, Paul Mampilly, V Aparna

Acquisition, analysis, or interpretation of data: JV Shreepriya, V Aparna

Drafting of the manuscript: JV Shreepriya, A Khushi, Nirajita Bhaduri

Critical review of the manuscript for important intellectual content: A Khushi, Nirajita Bhaduri, Paul Mampilly, V Aparna

Supervision: Nirajita Bhaduri

Disclosures

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