

Comparative Evaluation of Ion Release in Bonded and Nonbonded Stainless Steel Brackets with Use of Different Mouthwashes: An *In vitro* Study

Abstract

Background: Orthodontic treatment is a long-term procedure that involves the usage of brackets and archwires which are mainly metallic in nature. This study evaluated the levels of metal ions release from bonded and nonbonded orthodontic brackets after immersion in distilled deionized water and three different types of mouthwash. **Materials and Methods:** Eighty premolar stainless steel brackets (3M, Unitek) were divided into Group A (bonded brackets) and Group B (nonbonded brackets). Each group was further subdivided into four subgroups to analyze the release of ions from three different types of mouthwash along with the control group. All the samples were incubated at 37°C for 45 days, and immersion solutions were tested in inductively coupled plasma-optical emission spectrometer for the release of free metal ions. **Results:** Mean ion release in the bonded bracket group was less than that of nonbonded bracket group. Ion release in control subgroup of both groups was $0.18 \pm 0.08 \mu\text{g/dl}$ (A1) and $0.17 \pm 0.06 \mu\text{g/dl}$ (B1); in Phos-Flur mouthwash subgroup was $0.12 \pm 0.06 \mu\text{g/dl}$ (A2) and $0.13 \pm 0.05 \mu\text{g/dl}$ (B2); in chlohex mouthwash subgroup was $0.13 \pm 0.06 \mu\text{g/dl}$ (A3) and $0.14 \pm 0.06 \mu\text{g/dl}$ (B3); in Hiora mouthwash subgroup was $0.10 \pm 0.06 \mu\text{g/dl}$ (A4) and $0.12 \pm 0.05 \mu\text{g/dl}$ (B4). **Conclusions:** The mean ion release was the highest in deionized water (control group) followed by chlohex, Phos-Flur, and Hiora in both Group A and Group B. Ion leaching from bonded brackets was less compared to nonbonded brackets in all different mouthwashes except in the control group. However, this difference was statistically insignificant ($P > 0.05$) between all the groups.

Keywords: Bonded brackets, ion release, mouthwashes, nonbonded brackets

Introduction

Metallic appliances are an integral part of orthodontic treatment. During the last decade, there has been an increased interest among dental and biomedical professionals in the side effects associated with the use of biomaterials, especially the metallic materials. Fixed appliances in orthodontics involve brackets, archwires, etc., that are mainly metallic in nature. These brackets and archwires consist of precious (gold, silver, palladium, and platinum) or nonprecious metals (nickel, chromium, molybdenum, cobalt, titanium, zinc, tin, and mercury).^[1] These brackets are exposed to the oral cavity, which is a potentially hostile environment where electrochemical corrosion phenomena can occur.^[2,3]

Since the oral environment is particularly ideal for the biodegradation of metals

because of its ionic, thermal, microbiologic, and enzymatic properties, some level of patient exposure to the corrosion products of these alloys could be assumed, if not assured.^[4] In recent years, it has been reported that bracket corrosion can occur in the oral environment.^[2,5-10]

Approximately 10% of the general population has a hypersensitive reaction to nickel. Peltonen^[11] reported that women are ten times more sensitive to nickel than that of men. Nickel can cause hypersensitivity, contact dermatitis, asthma, and cytotoxicity. Therefore, the amount of metal ion intake from dental alloys has become a topic of increased interest.^[3]

During orthodontic treatment, patients are recommended to use mouthwashes, since most of them are adolescents who do not always follow a satisfactory oral-hygiene regimen and have a high risk of dental caries.^[10] The regular use of

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fluoride-containing products such as toothpaste^[12,13] and fluoride mouthwashes is also recommended to reduce the risk of dental caries. However, numerous studies have shown that in an acidic environment and in the presence of fluoride ions (fluoride mouthwashes), the corrosion resistance of certain materials, in particular, Ti, can deteriorate.^[6,7,8,11,14] Although fluoride ions in the prophylactic agents have been reported to cause corrosion, little information is available regarding the effect of different mouthwashes in the ion release of orthodontic brackets.

Chlorhexidine is one of the most commonly prescribed mouthwashes with the anti-bacterial property.

Herbal mouthwashes are another group that is finding increased application. Hiora mouthwash is one such mouthwash, manufacturer of which claim antimicrobial, antiplaque, antiseptic, and analgesic properties. This mouthwash has been known to have active herbal ingredients that act against common strains of oral bacteria and fungi and prevent periodontal disease and dental caries.

No previous studies have been performed to assess the influence and clinical implications of all these three different varieties of mouthwashes on orthodontic brackets in standard conditions. In addition, there has been very limited literature to compare the corrosive properties of bonded and nonbonded brackets. Hence, the present study is carried out to evaluate and compare the corrosive properties of bonded and nonbonded brackets.

Materials and Methods

This study was done to evaluate and compare the corrosive properties (by testing metal ion release) of bonded and nonbonded brackets in distilled deionized water and three types of mouthwash routinely recommended by orthodontists to their patients by using inductively coupled plasma optical emission spectrometer (ICP-OES). Ethical clearance was obtained from the Institutional Ethical Committee and Review Board of the Dayanand Sagar College of Dental Sciences, Bangalore, India.

Preparation of samples

Eighty premolar stainless steel brackets (3M, Unitek, Germany) were used for this study. All brackets were used as received from the manufacturer. These eighty brackets were divided into two major groups, A and B (40 in each group).

Group A contains the brackets that were bonded to the premolar tooth. Group B contains nonbonded brackets. Premolars extracted for the orthodontic purpose were used for bonding the brackets (Group A).

The bonded test specimens (Group A) were prepared as follows:

The selected teeth were stored in 2% hydrogen peroxide for 10 days to be free from all the debris. After this, the teeth

were polished with pumice, air dried, and etched for 30 s for the bonding procedure. A bonding agent (Transbond XT Bonding System, 3M, Unitek, Germany) was used to bond the brackets to the extracted teeth using visible light cure (QHL75, Dentsply, York, PA, USA). Curing was done for 10 s as specified by the manufacturer. The same standardized procedure was followed for bonding all the samples.

Bonded specimens (Group A) were subdivided as follows:

- Group A1 – Ten brackets bonded to the tooth, and the assembly immersed in distilled deionized water (control group)
- Group A2 – Ten brackets bonded to the tooth, and the assembly immersed in Phos-Flur mouthwash
- Group A3 – Ten brackets bonded to the tooth, and the assembly immersed in clohex mouthwash
- Group A4 – Ten brackets bonded to the tooth, and the assembly immersed in Hiora mouthwash.

Group B consisted of nonbonded brackets which were subdivided as follows:

- Group B1 – Ten brackets immersed in distilled deionized water (control group)
- Group B2 – Ten brackets immersed in Phos-Flur mouthwash
- Group B3 – Ten brackets immersed in chlohex mouthwash
- Group B4 – Ten brackets immersed in Hiora mouthwash.

Both the bonded brackets and the nonbonded brackets were stored in 5 ml glass vials immersed in the respective solutions and incubated in an incubator at 37°C for 45 days. After the incubation period, the immersion solutions were tested in an ICP-OES for the release of free metal ions.

Evaluation of the leached ions

The determination of the elements leached from the brackets was done with ICP-OES. ICP-OES is one of the most powerful and popular analytical tools for the determination of trace elements in a myriad of sample types. The technique is based on the spontaneous emission of photons from the atoms and ions that have been excited in a radio frequency discharge.

Results

The corrosive properties of bonded and nonbonded brackets in distilled deionized water and three different types of mouthwash were assessed using ICP-OES and were subjected to the statistical analysis. The results were analyzed using the two-way analysis of variance and Bonferroni test.

Mean ions leached out in these eight groups are tabulated in Tables 1 and 2.

The results were then subjected to statistical analysis. During the statistical analysis, the comparison was made

Table 1: Mean ions released in four subgroups of Group A

Ions released	A1	A2	A3	A4
Fe	0.137286	0.134041	0.141761	0.143441
Cr	0.192143	0.189592	0.190962	0.192528
Ni	0.292	0.286571	0.30751	0.320012
C	0.088	0.094857	0.101265	0.090017
Mn	0.176143	0.182735	0.181697	0.183368

Table 2: Mean ions released in four subgroups of Group B

Ions released	B1	B2	B3	B4
Fe	0.134857	0.12698	0.119405	0.132177
Cr	0.165857	0.163837	0.162956	0.166236
Ni	0.241857	0.240694	0.245079	0.252947
C	0.115143	0.114449	0.110799	0.105199
Mn	0.160714	0.149388	0.140729	0.140833

between the subgroups of Group A, i.e., to compare the ions leached out in various immersion solutions by the bonded brackets and the subgroups of Group B, i.e., to compare the ions leached out in various immersion solutions by the nonbonded brackets to the tooth [Tables 3 and 4].

The comparisons were also made to estimate the difference in the ions leached out when the brackets are bonded, i.e., between bonded and nonbonded brackets (A1 vs. B1, A2 vs. B2, A3 vs. B3, and A4 vs. B4) [Table 5].

The difference in mean ion release was found to be statistically significant between A1 and A2 ($P < 0.001$), A1 and A3 ($P < 0.01$) as well as between A1 and A4 ($P < 0.001$). No statistically significant difference was observed between the other pair of groups ($P > 0.05$) [Table 3].

The difference in mean ion release was found to be statistically significant between B1 and B2 ($P < 0.01$) as well as between B1 and B4 ($P < 0.001$). No statistically significant difference was observed between the other pair of groups ($P > 0.05$) [Table 4].

Hence, it may be summarized that ion release after bonding of the brackets to the teeth decreased in all the test mouthwashes but increased in distilled deionized water. However, this difference was statistically insignificant ($P > 0.05$) between all the groups [Tables 5].

Discussion

During orthodontic treatment, the orthodontic attachments are exposed to a potentially hostile environment where electrochemical corrosion can occur, leading to the release of various metal ions. The release of these metal ions may have a deleterious effect on the health of the patient. Amini *et al.*,^[15] in their *in vivo* study, also concluded that the presence of a fixed orthodontic appliance leads to an increase in metal ions in saliva.

Mouthwashes prescribed during orthodontic treatment are recommended to be used twice a week for about a minute. However, it is recommended that after mouthwash, the patient must not eat, drink, and rinse, so that the components of mouthwash are present in the oral cavity for a long time; it is difficult to determine the exact duration of contact between brackets and mouthwashes.

According to Danaei *et al.*,^[3] each time the mouthwash was used by the patient, the substantively lasted for approximately 6 h in the patient's mouth. During 24 months of orthodontic treatment, twice a week usage of mouthwash will expose the metal components for approximately 64,000 min (45 days). Hence, in this present study, brackets were incubated in mouthwashes for 45 days.

The findings of this study were similar to the observations made by Danaei *et al.*^[3] In their study, they measured the amount of metal ion release from orthodontic brackets when kept in different mouthwashes. The results of their study showed that ion release in water was significantly ($P < 0.05$) higher than the three mouthwashes (chlorhexidine, Oral B, and Persica). Higher ion release was found with chlorhexidine compared with the other two mouthwashes. The authors explained the distinct increase in the level of the release of all ions in water to its corrosive nature.^[16]

Schiff *et al.*^[10] studied the effect of ion release in fluoride mouthwashes. In their study, they found nickel to be released the most followed by chromium and iron which is similar to the observations made in this present study.

According to Szakalos *et al.*,^[16] many parameters affect the corrosion of metals in a water environment, including pH level, oxygen content, water, temperature, and duration of immersion. It has also been reported that the corrosion rates of steel increase with aeration of pure water, and dissolved oxygen in pure water is 5–10 times more aggressive than carbonic acid. The distilled water used in this study had a pH of 7.5; therefore, the water was not acidic, and hence, acidity may not be responsible for its corrosiveness. The reason for corrosiveness might be water which has an extremely low concentration of ions, and the lack of ions makes this solvent one of the most aggressive solvents known. Similar reason may be attributed to the results of the present study also.

A study conducted by Barrett *et al.*^[4] concluded that metal ion release was increased during the 1st week and gradually reduced in subsequent weeks.

A study conducted by Grimsdottir *et al.*^[17] indicated that metal ion released from the orthodontic components can be influenced by the composition employed by different manufacturers. Further, the surface area also plays a crucial role in the corrosion of metals, but determining the surface area of orthodontic brackets with their complex geometry was not done. Variations in study designs make the comparisons between the studies difficult.

Table 3: Comparison of mean ions released in the four subgroups of Group A

Subgroup (I)	Subgroup (J)	Mean difference (I-J)	P	95% CI for mean difference	
				Lower bound	Upper bound
A1	A2	0.061	<0.001*	0.026	0.095
	A3	0.043	0.006*	0.009	0.078
	A4	0.075	<0.001*	0.040	0.109
A2	A1	-0.061	<0.001*	-0.095	-0.026
	A3	-0.018	1.000	-0.052	0.017
	A4	0.014	1.000	-0.021	0.049
A3	A1	-0.043	0.006*	-0.078	-0.009
	A2	0.018	1.000	-0.017	0.052
	A4	0.032	0.095	-0.003	0.066
A4	A1	-0.075	<0.001*	-0.109	-0.040
	A2	-0.014	1.000	-0.049	0.021
	A3	-0.032	0.095	-0.066	0.003

*Significant difference. CI: Confidence interval

Table 4: Comparison of mean ions released in the four subgroups of Group B

Subgroup (I)	Subgroup (J)	Mean difference (I-J)	P	95% CI for mean difference	
				Lower bound	Upper bound
B1	B2	0.039	0.004*	0.009	0.070
	B3	0.030	0.056	0.000	0.060
	B4	0.050	<0.001*	0.020	0.081
B2	B1	-0.039	0.004*	-0.070	-0.009
	B3	-0.009	1.000	-0.040	0.021
	B4	0.011	1.000	-0.019	0.042
B3	B1	-0.030	0.056	-0.060	0.000
	B2	0.009	1.000	-0.021	0.040
	B4	0.020	0.453	-0.010	0.051
B4	B1	-0.050	<0.001*	-0.081	-0.020
	B2	-0.011	1.000	-0.042	0.019
	B3	-0.020	0.453	-0.051	0.010

*Significant difference. CI: Confidence interval

Table 5: Comparison between the subgroups of Group A and Group B

Group	Mean	SE of mean	Mean difference	t	P
Group A1	0.18±0.08	0.01	0.012	0.814	0.417
Group B1	0.17±0.06	0.01			
Group A2	0.12±0.06	0.01	-0.010	-0.905	0.368
Group B2	0.13±0.05	0.01			
Group A3	0.13±0.06	0.01	-0.001	-0.100	0.921
Group B3	0.14±0.06	0.01			
Group A4	0.10±0.06	0.01	-0.012	-1.112	0.269
Group B4	0.12±0.05	0.01			

SE: Standard error

According to the guidelines of the European Council Directive for the quality of water intended for human consumption, maximum admissible concentration for metal ions (Ni and Cr) is 5 µg/dl (50 µg/l).^[18] The results obtained in our study indicated that the release of the metal ions in all the three mouthwashes and deionized water is well within the permissible limit (0.10–0.17 µg/dl). The above

finding is similar to the study by Mikulewicz *et al.*^[19] who concluded that the quantity of metal ions released from the orthodontic appliances is well below the established toxic level.

Mikulewicz *et al.*^[19] studied the release of metal ions from fixed orthodontic appliances in which experimental conditions reflected as closely as possible (in an *in vitro* system), the environment of the human oral cavity with an orthodontic appliance. They concluded that the highest concentration of metal ions was released at the beginning of the experiment. After this, passivation probably occurred, which hindered further intense release.

Comparisons were also made to estimate the difference in the ions leached out when the brackets are bonded, i.e., between bonded and nonbonded brackets (A1 vs. B1, A2 vs. B2, A3 vs. B3, and A4 vs. B4). The results indicated that the ion release from the bonded brackets decreased in all the mouthwashes as compared to the nonbonded brackets. This could be due to the reduced surface area of the bracket exposed to the mouthwash. However, in

the control group (water), the bonded brackets showed increased release of metal ions compared to nonbonded brackets. However, the difference was statistically insignificant ($P > 0.05$). This is comparable to the findings of Gwinnett^[20] who carried out their study at the end of orthodontic treatment.

With increasing use of mouthwashes during orthodontic treatment, further research is required to assess the corrosion of brackets using different mouthwashes *in vivo* and its possible impact on the overall health of the patient.

Conclusions

The findings of this study revealed that the amount of metal ion released in all the three types of mouthwash were less than that in deionized water. Among the three types of mouthwash, the metal ion release in herbal mouthwash (Hiora) was the least followed by fluoride-based mouth rinse (Phos-Flur) and chlorhexidine (clohex). However, the metal ion released in all the three mouthwashes and deionized water was within the permissible limit. The limitation of the present study was that, it was an *in vitro* study and the evaluation method may not simulate the oral environment. Future studies evaluating the same *in vivo* or simulation techniques mimicking the oral environment may confirm the nature and types of ion release from the orthodontic attachments.

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Conflicts of interest

There are no conflicts of interest.

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