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Comparitive evaluation of ion release from orthodontic brackets in two mouthwashes and two gels: an in vitro study

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Abstract
Background of the study: The stainless steel bracket is widely used in orthodontics because of its mechanical properties, strength, and good biocompatibility. However, under certain conditions, it can be susceptible to corrosion. Moreover, metal ion release can cause adverse local or systemic biological effects on patient's health. During orthodontic treatment, practitioners recommend that their patients use mouthwashes or gels to ensure a satisfactory oral hygiene regime to reduce the risk of dental caries. Hence, the purpose of this study was to observe metal ion release from 2 mouthwashes and 2 gels.
Methodology: The sample size consisted of 75 brackets, divided into 5 groups of (15 brackets each) and were tested in 5 different medium.
Group 1-Clohex® -ADS mouthwash
Group 2-Colgate Plax® mouthwash
Group 3- Hexigel®
Group 4-Rexidin -M forte® gel
Group 5-Deionized distilled water (control group)
As divided in the groups above, the brackets were immersed in the various media. Each bracket were incubated in an oven at a constant temperature of 37˚in individual plastic capped vials for 45 days. After the incubation period the solutions were tested with an inductively coupled Plasma (ICP)spectrometer to detect the ions released. Each solution was analysed for chromium, copper, iron, manganese and nickel ions. The measurement of pH of each medium was measured by a pH meter. The data obtained was noted and subjected to statistical analysis.
Results: Group 1 -Clohex -ADS (Chlorhexidine mouthwash) showed highest release of chromium, nickel, iron and chromium ions when compared to the remaining groups.
Conclusion: The study concluded that the Group 1 (Clohex -ADS) mouthwash showed highest release of chromium, nickel, iron, manganese ions when compared to Colgate plax (group 2), Hexigel (group3), Rexidin-M (group 4) and deionized distilled water (group 5). Hence chlorhexidine can cause increased surface roughness of the metal brackets with decreased efficiency of the appliance by creating friction. Also, the release of copper ion was found to be higher in group -3 hexigel and group -4 rexidin -M forte gel.

Keywords: Orthodontic brackets, corrosion, gels, mouthwashes, ion release

1. Introduction

Fixed appliances in Orthodontics includes brackets and arch wires most of which are metallic. Various metallic brackets are made of stainless steel (iron, chromium and Nickel), Titanium and Cobalt chromium alloys [1]. These metallic brackets, bands and wires are universally made of austenitic stainless steel containing approximately 18% chromium and 8% nickel.

The oral cavity is potentially a hostile environment for electrochemical corrosion to occur and one factor that can alter the oral environment is a mouth wash [2]. Studies have reported that the release of nickel and chromium ions due to corrosion can cause allergic reactions in some individuals and are potentially mutagenic [3]. In dentistry many alloys consist of precious and non precious metals and use of these alloys particularly those containing nickel may have carcinogenic, toxic or allergenic properties.

The amount of metal ion release from dental alloys has become of increased interest [4].
Orthodontic attachments, in the oral cavity are exposed to potentially damaging physical and chemical agents. These metal brackets and wire can corrode in an acidic solution and release undesirable metal ions [5]. Park and Shearer reported an average release of 40µg and 36µg of chromium per day from a simulated full mouth orthodontic appliance [6].
The oral environment is a particularly ideal climate for corrosive attack on metal because of its microbiological and enzymatic phenomenon, which may accelerate the corrosion process [7]. The corrosion process of metallic brackets has been linked to the deterioration of their mechanical properties and to adverse biologic effects, none of which are desirable in Orthodontics [8]. Many studies have addressed the release of metallic ions from orthodontic brackets, especially iron, chromium and nickel which are the main products of corrosion of stainless steel [9].
It was established that Nickel and Chromium could cause hypersensitivity, dermatitis and asthma. In addition, a significant carcinogenic and mutagenic potential has been demonstrated for compounds containing these metals. The manifestations of Nickel allergy, dermatitis and urticaria, can be found distant from the nickel source and is one of the reasons why nickel hypersensitivity has been of growing concern among dentists [10].
In a study in which cultured human cells were used, Nickel was recently reported to be moderately toxic, while chromium was considered to have a lesser cytotoxicity. Therefore, there is a possibility that nickel and chromium ions released from stainless steel brand, brackets and arches might elicit an allergic reaction [11].
The uniform use of Fluoride containing products such as tooth paste, gels and fluoride mouthwashes are recommended in orthodontic patients on a regular basis to reduce the risk of dental caries. Numerous studies have shown that in an acidic environment and presence of fluoride ions (fluoride mouthwashes) the corrosion resistance of certain materials can deteriorate [12]. These products in turn would create an environment in the oral cavity that could lead to biodegradation of the orthodontic appliances and the byproducts of which can be absorbed by the patient.
Keeping in view the above literature the aim of this study was to compare the ion release from orthodontic brackets in different mouthwashes and gels.

2. Materials and Methods

This in vitro study consisted of 75 stainless steel orthodontic brackets manufactured by (Ormco - MBT -0.022" slot) MINI 2000, which were divided into 5 groups (15 brackets each) and were tested in 5 different media.

1. Chlorhexidine (CHX) Mouthwash (CLOHEX ADS)- Group 1
2. Sodium fluoride (NaF) Mouthwash: (Colgate plax)- Group 2
3. Chlorhexidine gluconate gel: (Hexigel)- Group 3
4. Chlorhexidine Gluconate, Metronidazole & Lignocaine Hydrochloride gel: (Rexidin – M forte gel)-Group 4
5. Distilled deionized water- Group 5 (control group).

This invitro study was conducted with the following inclusion criteria, stainless steel brackets of the same company in each group, mouthwashes/gels of different companies, concentration of solution and duration kept constant and the exclusion criteria being not using any expired mouthwashes /gels the composition of each are represented in table no 1.
Since the brackets could not be immersed directly in Hexigel and Rexidin M forte gel. An alternate method was used to prepare the solution of Hexigel and Rexidin- M Forte gel by the following method, around 2 cm gel weighing around 1.2 gm was taken on baking paper which was transferred to a plastic capped vial containing 20 ml of deionized distilled water and was shaken well. The gel was completely dissolved in deionized distilled water to make a test solution for immersion of brackets in Group 3 and Group 4 respectively.
As divided in the groups, the brackets were immersed in the various mediums. Each bracket was immersed in the different mediums contained in individual plastic capped vials and were incubated in an oven set at a constant temperature of 37˚C for 45 days. 15 ml solution of, mouth washes, gels and deionized distilled water was used in each plastic capped vial for each group.
After the incubation period the immersed solutions were tested with an inductively coupled plasma (ICP) spectrometer. Standard stock solution used was 0.1-25 mg/ltr in concentration. Each solution was analyzed for chromium, copper, iron, manganese and nickel ions. The measurement of pH of each medium was measured by a pH meter & the values obtained were computed and compared with each other. Armamentarium used is shown from fig1 till fig 11.

Table 1: Composition of mouth wash & gel

S.l. No	Material used	Composition
1	Chlorhexidine mouth wash CLOHEX-ADS	Composition - Chlorhexidine Gluconate IP - 0.20% w/v Sodium Fluoride IP - 0.05% w/v Zinc chloride IP - 0.09% w/v
2	Colgate Plax Mouth wash	Aqua, Glycerin, Propyleneglycol, Sorbitol, Poloxamer, 407, Aroma, Cetylpyridinium chloride, PotassiumSorbate, Sodium fluoride, soddussaccharin, Menthol, CL42051
3	Hexigel	Chlorhexidine Gluconate IP equivalent to chlorhexidine Gluconate 1.0% w/w
4	Rexiden-M Gel	Chlorhexidine Gluconate, Metronidazole, Lignocaine Hydrochloride Gel

Fig 1: OrmcoMINI2000-0rthodontic brackets

Fig 2: CLOHEX ADS- Mouthwash

Fig 3: Colgate Plax-Mouthwash

Fig 4: Hexigel

Fig 5: Rexidin -M Forte Gel

Fig 6: Deionized Distilled Water

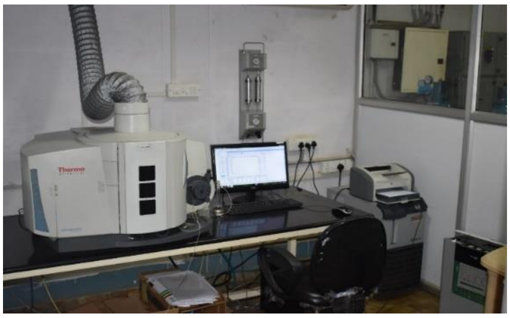

Fig 7: Inductively Coupled Plasma (icp) Spectrometer

Fig 8: pH meter (hi 2215 ph/orp meter)

Fig 9: Incubation oven set

Fig 10: Digital Weighing scale.

Fig 11: Plastic capped vials

3. Results

3.1 Statistical Analysis

Statistical Package for Social Sciences [SPSS] for Windows, Version 22.0. Released in 2013. Armonk, NY: IBM Corp., was used to perform statistical analyses. Descriptive analysis of all the study parameters was done using Mean & SD. Kruskal Wallis test followed by Mann Whitney pots hoc test was used to compare the mean ion release of different metals and pH levels of different solutions between groups. The level of significance [P-Value] was set at $P<0.05$.

In this study the following results were obtained between 5 different groups. The mean chromium ion release using Krusal Wallis test in Group 1 was 8.63 ± 2.21 followed by Group 2 was 4.82 ± 2.16, Group 3 was 6.77 ± 3.31, Group 4 was 2.68 ± 2.08 and by Group 5 was µg/l 2.60 ± 2.71 respectively. This difference in mean chromium ion release was statistically significant at $P<0.001$(Table 2). The multiple comparison of mean difference in Chromium Ion release b/w different groups using Mann Whitney Post hoc Test showed Group 1 showed significantly higher mean chromium ion release compared to Group 2, 4 & 5 at $P<0.001$. This was followed by Group 3 showing significantly higher mean chromium release compared to Group 4 & 5 at $P<0.001$. However, mean ion release between other study groups were not statistically significant (Table3).

The mean iron ion release using Krusal Wallis test in Group 1 was 110.89 ± 14.89, Group 2 was 49.71 ± 14.33, Group 3 was 37.39 ± 5.84, Group 4 was 31.65 ± 10.40 and by Group 5 was 30.95 ± 8.53. This difference in mean iron ion release was statistically significant at $P<0.001$ (Table4). Multiple comparison of mean difference using Mann Whitney Post hoc between groups reveals that Group 1 showed significantly higher mean iron ion release compared to all the other study groups at $P<0.001$*. This was followed by Group 2 which showed significantly higher mean iron ion release compared to Group 3 at P=0.03*, Group 4 and Group 5, both at $P<0.001$*. However, the mean iron ion release between the other study groups was not statistically significant (Table5).

The mean nickel ion release using Krusal Wallis test in Group 1 was 44.21 ± 2.10, Group 2 was 3.37 ± 0.63, Group 3 was 12.67 ± 1.17, Group 4 was 2.27 ± 0.34 and by Group 5 was 2.54 ± 0.82 (Table 6). This difference in mean nickel ion release was statistically significant at $P<0.001$. Multiple comparison using Mann Whitney Post hoc test of mean difference between groups reveals that Group 1 showed significantly higher mean nickel ion release compared to all the other study groups at $P<0.001$*. This was followed by Group 3 which showed significantly higher mean nickel ion release as compared to Group 4 and Group 5 at $P<0.001$*. However, the mean nickel ion release between the other study groups was not statistically significant (Table 7).

The mean copper ion release using Krusal Wallis test in Group 1 was 6.57 ± 2.36, Group 2 was 9.21 ± 5.45, Group 3 was 15.36 ± 5.46, Group 4 was 9.38 ± 4.27 and by Group 5 was 8.18. ± 5.41. This difference in mean copper ion release was statistically significant at $P<0.001$(Table 8). Multiple comparison of mean difference between groups using Mann Whitney Post hoc test revealed that Group 3 showed significantly higher mean copper ion release compared to group 1 at $P<0.001$*, Group 2 at P=0.006*, Group 4 at P=0.008* and Group 5 at P=0.001*. However, the mean copper ion release between the other study groups was not statistically significant (Table 9).

The mean manganese ion release using Krusal Wallis test by Group 1 was found to be 2.70 ± 3.13 followed by Group 2 was 0.89 ± 0.75, Group 3 was 0.41 ± 0.51, Group 4 was 0.11 ± 0.03 and by Group 5 was 0.10 ± 00(Table 10). This difference in mean manganese ion release was statistically significant at $P<0.001$. Multiple comparison of mean difference between groups using Mann Whitney Post hoc test revealed that Group 1 showed significantly higher mean manganese ion release compared to Group 2 at P=0.009* and Group3, Group4 and Group5 at $P<0.001$* respectively. However, the mean ion release between other study groups was not statistically significant (Table 11).

The mean difference in pH value using Krusal Wallis test showed value of Group 1 was 5.51±0.01 in Group 1 followed by Group 2 5.80±.01, Group 3 4.46±0.01, Group 4 5.67±0.01 and group 5 6.29±0.01 respectively (Table 12). The mean pH values were statistically significant at $P<0.001$. Multiple comparison of mean difference between groups using Mann Whitney Post hoc test revealed Group 3 showed significantly lowest mean pH value as compared to the other Groups at *P*<0.001*. This was followed by Group 1showing significantly lesser mean Ph value as compared to other Groups at *P*<0.001. This was followed by Group 4, Group 2 and highest with group 5. Statistically significant at *P*<0.001 (Table 13).

Table 1: Comparison of mean Chromium ion release b/w different groups using Kruskal Wallis Test

Groups	N	Mean	SD	Min	Max	P-Value
Group 1	15	8.63	2.21	4.2	12.1	<0.001*
Group 2	15	4.82	2.16	0.8	7.8	
Group 3	15	6.77	3.31	2.6	13.6	
Group 4	15	2.68	2.08	0.1	6.2	
Group 5	15	2.60	2.71	0.1	7.8	

Table 3: Multiple comparison of mean difference in Chromium Ion release b/w different groups using Mann Whitney Post hoc Test

(I) Groups	(J) Groups	Mean Diff. (I-J)	95% CI for the Diff.		P-Value
			Lower	Upper	
Group 1	Group 2	3.81	1.21	6.40	0.001*
	Group 3	1.86	-0.73	4.45	0.27
	Group 4	5.95	3.35	8.54	<0.001*
	Group 5	6.03	3.43	8.62	<0.001*
Group 2	Group 3	-1.95	-4.54	0.65	0.23
	Group 4	2.14	-0.45	4.73	0.15
	Group 5	2.22	-0.37	4.81	0.13
Group 3	Group 4	4.09	1.49	6.68	<0.001*
	Group 5	4.17	1.57	6.76	<0.001*
Group 4	Group 5	0.08	-2.51	2.67	1.00

Table 4: Comparison of mean Iron ion release b/w different groups using Kruskal Wallis Test

Groups	N	Mean	SD	Min	Max	P-Value
Group 1	15	110.89	14.89	88.4	134.3	<0.001*
Group 2	15	49.71	14.33	22.3	73.9	
Group 3	15	37.39	5.84	29.5	51.1	
Group 4	15	31.65	10.40	20.4	55.2	
Group 5	15	30.91	8.53	20.7	50	

Table 5: Multiple comparison of mean difference in Iron Ion release b/w different groups using Mann Whitney Post hoc Test

(I) Groups	(J)Groups	Mean Diff. (IA)	95% CI for the Diff.		P-Value
			Lower	Upper	
Group 1	Group 2	61.18	49.59	72.77	<0.001*
	Group 3	73.51	61.92	85.09	<0.001*
	Group 4	79.24	67.65	90.83	<0.001•
	Group 5	79.98	68.39	91.57	<0.001•
Group 2	Group 3	12.33	0.74	23.91	0.03•
	Group 4	18.06	6.47	29.65	<0.001*
	Group 5	18.80	7.21	30.39	<0.001*
Group 3	Group 4	5.73	-5.85	17.32	0.64
	Group 5	6.47	-5.11	18.06	0.53
Group 4	Group 5	0.74	-10.85	12.33	1.00

Table 6: Comparison of mean Nickel ion release b/w different groups using Kruskal Wallis Test

Groups	N	Mean	SD	Min	Max	P-Value
Group 1	15	44.21	2.10	41.1	48.3	<0.001*
Group 2	15	3.37	0.63	1.8	4.2	
Group 3	15	12.67	1.17	10.7	14.8	
Group 4	15	2.27	0.34	1.7	2.8	
Group 5	15	2.54	0.82	1.8	5.3	

Table 7: Multiple comparison of mean difference in Nickel Ion release b/w different groups using Mann Whitney Post hoc Test

(I) Groups	(.1) Groups	Mean Diff. (I-1)	95% Cl for the Diff.		P-Value
			Lower	Upper	
Group 1	Group 2	40.85	39.64	42.05	<0.001*
	Group 3	31.55	30.34	32.75	<0.001*
	Group 4	41.95	40.74	43.15	<0.001˙
	Group 5	41.67	40.47	42.88	<0.001*
Group 2	Group 3	-9.30	-10.51	-8.09	<0.001•
	Group 4	1.10	-0.11	2.31	0.09
	Group 5	0.83	-0.38	2.03	0.32
Group 3	Group 4	10.40	9.19	11.61	<0.001*
	Groups	10.13	8.92	11.33	<0.001*
Group 4	Groups	-0.27	-1.48	0.93	0.97

Table 8: Comparison of mean Copper on release b/w different groups using Kruskal Wallis Test

Groups	N	Mean	SD	Min	Max	P-Value
Group 1	15	6.57	2.36	2.4	10.8	<0.001'
Group 2	15	9.21	5.45	2.8	20.2	
Group 3	15	15.36	5.46	8.4	27.4	
Group 4	15	9.38	4.27	2.4	18.2	
Group 5	15	8.18	5.41	1.5	22.6	

Table 9: Multiple comparison of mean difference in Copper Ion release b/w different groups using Mann Whitney Post hoc Test

(I) Groups	(1) Groups	Mean Diff. (I-1)	95% Cl for the Diff.		P-Value
			Lower	Upper	
Group 1	Group 2	-2.63	-7.48	2.22	0.55
	Group 3	-8.79	-13.64	-3.94	<0.001*
	Group 4	-2.81	-7.66	2.04	0.49
	Group 5	-1.61	-6.46	3.24	0.89
Group 2	Group 3	-6.15	-11.00	-1.30	0.006*
	Group 4	-0.17	-5.02	4.68	1.00
	Group 5	1.03	-3.82	5.88	0.98
Group 3	Group 4	5.98	1.13	10.83	0.008*
	Group 5	7.18	2.33	12.03	0.001*
Group 4	Group 5	1.20	-3.65	6.05	0.96

Table 10: Comparison of mean Manganese ion release b/w different groups using Kruska I Wallis Test

Groups	N	Mean	SD	Min	Max	P-Value
Group 1	15	2.70	3.13	0.1	8.6	<0.001*
Group 2	15	0.89	0.75	0.1	2.8	
Group 3	15	0.41	0.51	0.1	1.8	
Group 4	15	0.11	0.03	0.1	0.2	
Group 5	15	0.10	0.00	0.1	0.1	

Table 11: Multiple comparison of mean difference in Manganese Ion release b/w different groups using Mann Whitney Post hoc Test

(I)Groups	(J)Groups	Mean Diff. (I-J)	95% CI for the Diff.		P-Value
			Lower	Upper	
Group 1	Group 2	1.81	0.32	3.30	0.009*
	Group 3	2.29	0.80	3.78	<0.001*
	Group 4	2.59	1.10	4.08	<0.001*
	Group 5	2.60	1.11	4.09	<0.001*
Group 2	Group 3	0.48	-1.01	1.97	0.90
	Group 4	0.78	-0.71	2.27	0.59
	Group 5	0.79	-0.70	2.28	0.58
Group 3	Group 4	0.30	-1.19	1.79	0.98
	Group 5	0.31	-1.18	1.80	0.98
Group 4	Group 5	0.01	-1.48	1.50	1.00

Table 12: Comparison of mean pH values b/w different groups using Kruska I Wallis Test

Groups	N	Mean	SD	Min	Max	P-Value
Group 1	15	5.51	0.01	5.48	5.53	<0.001*
Group 2	15	5.80	0.01	5.78	5.82	
Group 3	15	4.46	0.01	4.44	4.48	
Group 4	15	5.67	0.01	5.66	5.68	
Group 5	15	6.29	0.01	6.27	6.31	

Table 13: Multiple comparison of mean difference in pH Values b/w different groups using Mann Whitney Post hoc Test

(1) Groups	(.1) Groups	Mean Diff. (I-1)	95% CI for the Diff.		P-Value
			Lower	Upper	
Group 1	Group 2	-0.29	-0.31	-0.28	<0.001*
	Group 3	1.05	1.03	1.06	<0.001*
	Group 4	-0.16	-0.17	-0.15	<0.001*
	Groups	-0.79	-0.80	-0.77	<0.001*
Group 2	Group 3	1.34	1.33	1.35	<0.001*
	Group 4	0.13	0.12	0.14	<0.001*
	Group 5	-0.49	-0.50	-0.48	<0.001*
Group 3	Group 4	-1.21	-1.22	-1.20	<0.001*
	Group 5	-1.83	-1.84	-1.82	<0.001*
Group 4	Group 5	-0.62	-0.64	-0.61	<0.001*

4. Discussion

The stainless steel bracket is widely used in orthodontics because of its mechanical properties, strength, and good biocompatibility. However, under certain conditions, it can be susceptible to corrosion [3]. Corrosion is a natural process that converts a refined metal into a more chemically stable form such as oxide, hydroxide, or sulphide. It is the gradual destruction of materials (usually metals) by chemical and/or electrochemical reaction with their environment. Corrosion compromises the mechanical properties of metal alloys by increasing surface roughness and decreasing mechanical strength.

The brackets are exposed to the oral cavity which is a hostile environment as electrochemical corrosion phenomenon can occur. The metal can deteriorate when it is corroded and can alter the surface structure and there by decreases the efficacy of the appliance by creating friction. Moreover, metal ion release can cause both local and systemic adverse biological effects on patient's health. Locally, the released ions may adversely affect the oral tissues by inhibiting enzyme or mitochondrial activity and damaging DNA. Moreover, chromium and nickel ions may induce type IV hypersensitivity [25].

During orthodontic treatment, practitioners recommend that their patients use mouthwashes, especially since most are adolescents who do not always follow a satisfactory oral hygiene regime and have a high risk of dental caries. Several studies have shown the metal ion release from orthodontic brackets in mouth washes, acidulated phosphate fluoride gel and dentifrices. Thus, the purpose of this study was to observe metal ion release from 2 mouthwashes and 2 gels (dental gel)

. In the present study stainless steel maxillary premolar brackets (Ormco, MINI 2000) with a MBT prescription of 0.022 ″slot was used. As the bracket dimensions would be uniform, it would be eliminating any bias in the amount of metal ions released. Most of the ion release studies have used brackets which are similar [1, 3].

The gels used were Hexigel and Rexidin -M Forte gel. Hexigel an antiseptic gel, could be brushed on teeth once or twice daily for oral hygiene, plaque inhibition and gingivitis. It is used for management of apthous and oral ulcers. Rexidin – M forte gel is an antiseptic and analgesic mouth gel which is used in gingivitis oral stomatitis and apthous ulcers by applying it twice or thrice daily. A solution of each gel was prepared by taking approximately 2 cm length of gel weighing 1.2 gm and dissolving it in 20 ml of deionized distilled water to make a solution for the purpose of this study.

Clohex ADS and Colgate plax were the mouthwashes used along with Deionized distilled water which was used as the medium in the control group. These gels and mouthwashes were used in the study because of their common usage and potent action in reducing microbial content in the oral environment. Generally, it was observed that mouthwashes and gels are used at least twice a week or during maintenance phase. After usage it would be advised not to eat or drink anything for a period of 30 minutes. It was assumed that the active ingredient of the mouth wash or gel would be present in the patient's mouth for 6 hrs. As orthodontic treatment would be done for a period of 24 months approximately, the brackets were immersed in the different mediums and incubated at 37 ˚for 45 days.

In a study conducted by Danaei *et al* the brackets were immersed in different medium at 37 ˚C for a period of 45 days. They mentioned that it is very difficult to determine the exact duration of contact between the brackets and mouth washes. The components of mouthwash should be present for a longtime hence dietary restrictions are given to the patient [1]. Several studies have shown that the levels of metal ion release from fixed orthodontic appliances, peak at day 7 and that all release is completed within 4 weeks [2, 11, 18]. It should be noted that many parameters affect the corrosion of metals in a water environment like the pH level, oxygen content, water temperature and immersion duration.

In the present study it was observed that the metal ion released in deionized distilled water was least with chromium(2.6µg/L) ,iron(30.91µg/L) ,manganese(0.10µg/L) as compared to the other 4 groups compromising of 2 mouthwashes and gel solutions .However, it was observed that the release of Nickel metal ions in deionized distilled water(group 5) was only fractionally more than that of Rexidin -M(group 4) .The copper ion release in deionized distilled water was more than that of Clohex Ads (group 1).The lesser amount of ion release is because of the pH which was 6.29 and was not responsible for corrosiveness.

The comparison of Nickel ion release in various mediums showed that the maximum ion release was observed in the Clohex ADS (group 1), followed by Hexigel (group 3), Colgate plax (group 2), deionized distilled water (group 5) and Rexidin-M (group 4). The values being 44.21µg/L, 12.67µg/L, 3.37µg/L, 2.54µg/L, 2.27µg/L respectively. Clohex ADS (group 1) and Hexigel (group 3) had highest Nickel ion release. Nickel has been reported to cause hypersensitivity, dermatitis, contact stomatitis, especially in individuals with history of allergic reactions. This agrees with previous reports about irrigating effects of chlorhexidine. In a study conducted by Oztan and co- workers it was observed that 0.2% chlorhexidine gluconate caused severe corrosion on the surface of selected stainless steel endodontic files [26].

When comparing the release of chromium ions from orthodontic brackets in different medium. It was observed that Chromium ion release was maximum in Clohex ADS (group 1), followed by Hexigel (Group 3), Colgate plax (group 2), Rexidin-M (group 4) and lastly by deionize distilled water (group5). The values being 8.63µg/L, 6.77µg/L, 4.82µg/L, 2.68µg/L, 2.6µg/L respectively. It was observed that groups 1 and group 3 containing Chlorhexidine gluconate had highest release of Chromium ions.

Manganese ion release was highest in Clohex ADS (group 1), followed by Colgate plax (group 2), Hexigel (group 3), Rexidin -M (group 4) and distilled deionized distilled water (group 5). Values being 2.7µg/L,0.89µg/L,0.41µg/L,0.11µg/L and 0.10µg/L respectively. These results reveal that the level of manganese ion release was minimal amongst all the groups. Manganese ion release was marginally higher in group 1 and group 2, as the fluoride present in both the mouth washes increases the dissolution of manganese.

As regards to iron ion release, it was maximum in Clohex ADS (group1), followed by Colgate plax (group 2), Hexigel (group 3), Rexidin -M (group 4) and Deionized distilled water (group 5). The values being 110.89 µg/L, 49.71 µg/L,37.39 µg/l,31.65 µg/L and 30.91µg/L respectively. In the present study copper ion release was highest in Hexigel (group 3) followed by Rexidin -M (group 4), Colgate plax (group 2), deionized distilled water (group 5), Clohex ADS (group 1). The values being 15.36µg/L, 9.38 µg/L, 9.21µg/L, 8.18 µg/L, 6.57 µg/L. The pH values of each medium revealed that the most acidic was Hexigel (group 3) with a pH of 4.46 followed by, Clohex ADS (group 1) with a pH of 5.51, Rexidin -M (group 4) with a pH of 5.67, Colgate plax (group2) with a pH of 5.80 and deionized distilled water (group 5) with a pH of 6.29.

The general mechanism for the corrosion and subsequent release of metal ions from stainless steel involves the loss of the passivating layer consisting of chromium oxide and chromium hydroxide that forms on contact with oxygen on the surface of stainless steel. Crevice corrosion, which is an intense attack in shielded areas on a metallic surface is the mechanism involved in the corrosion of orthodontic products [27]. From a clinical point of view, the corrosion of brackets may affect how they slide on the archwire and the final results of orthodontic treatment could be compromised [12]. The movement of wires and friction on the bracket may result in other types of corrosion for example fretting which might further increase the release of metal ions from the appliance [28, 17]. The cleaning and polishing of alloys reduced the ionic release, more selectively copper and corrosion phenomenon [19].

The clinician should be alert to colour changes or any loss of metal even without notable colour change which might indicate corrosion activity [29]. Previous studies have shown that there is a significant incidence of corrosion of stainless steel brackets in clinical use with green, brown and black stains. The breakdown contributes to bond failure, staining of the enamel, and an unesthetic appearance [7]. In the present study, individual premolar brackets were subjected to solutions of commercial mouthwashes and gels. Thus, a direct comparison between the values obtained in this study and those obtained in other studies cannot be made since different methodologies were applied and different variables were tested. Barrett *et al*. and Hwang *et al*. have tested complete orthodontic appliance in different synthetic saliva formula [2, 4].

Staffolani *et al.* tested orthodontic appliances in organic and inorganic acid solutions [17]. Eliades *et al*. (2004), Huang *et al*. (2001) and Huang *et al.* (2004) observed different values of metal ion release than the present study .These studies used different immersion solutions for different periods of time [22, 4, 34]. Schiff and co workers in 2005 did a scanning electron microscopy study, ion release analysis and reported that stainless steel orthodontic brackets immersed in stannous fluoride mouth wash with a pH of 4.3 resulted in corrosion indicated by damage caused to the oxide layer protection [12].

Huang and co workers in a study in 2001 compared the release of metal ions from new and recycled brackets in artificial saliva and buffers of different pH values over a 12 week period. They reported that combination of manufacturing process and composition of the brackets affected the release of nickel, chromium, iron and manganese. Though a direct correlation between release of these metals and bracket composition was not observed [18].

In a study by Haddad *et al* in 2009, it reinforces the necessity of appropriate oral hygiene measures to minimize corrosion rates [8]. In the oral cavity factors such as temperature, quantity, quality of saliva, plaque, pH, protein, physical and chemical properties of foods, liquids, general and oral health conditions may influence corrosion by a combination of mechanisms [11, 28, 30]. In the present study, for the comparison of ion release from different mouth washes and gels, deionized distilled water was used as basic solution to obviate the effect of saliva composition on the release of metal ions, though in other studies sodium chloride and artificial saliva have been used [6, 12].

On comparing the present study with that of Danaei *et al* it was observed that the level of metal ions released was much higher than in the present study. They also reported that maximum nickel ion release from the brackets occurred in deionized distilled water and the next highest was observed in chlorhexidine mouthwash. However, in the present study it was observed that nickel ion release was maximum in the chlorhexidine mouthwash (group1) followed by Hexigel (group 3). A similarity observed was that greater amounts of nickel and chromium were released in chlorhexidine. The level of manganese ion release was higher and different in the mouthwashes and deionized distilled water when compared to the present study [1].

There are a lot of variations in study results because of different study designs, electrochemical factors that makes comparisons between studies difficult. Comparisons between studies must be done with due consideration of the problem in measuring surface areas with complex geometry [10].Huang *et al*. reported that decreasing the pH in the acidic artificial saliva can increase the corrosion reaction, in terms of the metal ions release, of the commercial NiTi archwires. During practical applications, the fluoride containing environments can penetrate into the narrow crevices between the orthodontic archwire and bracket in the mouth, which is not easy to clean out thoroughly. Topical high fluoride concentrations will stay in place and attack the archwire/bracket Interface depending on the fluoride ion concentration. This may increase the friction force between the archwire and bracket due to the increase in surface roughness. Consequently, the effectiveness of arch-guided tooth movement thus decreases [31].

The volume of artificial saliva (in milliliters) that would provide the required daily dosage of these elements would be 61 for Ni, 1,980 for Cr, 88,235 for Mn, and 7,557 for Fe. This indicates that the only possible risk of exposure for orthodontic patients would be nickel [32]. In a study by Yanisparan *et al* it was found levels of the metal ions released were lower than their toxic dose (Cr: 29mg/kg, Ni: 60mg/ kg, Fe: 60mg/kg). The metal ions released from the brackets and wires likely accumulated in the gingival fibroblast cells and resulted in reduced cell function.

Chromium is a potential marker for carcinogenic substances and free Fe ions increased lipid peroxidation inducing damage to mitochondrial function and cell organelles. These damaging effects lead to cell necrosis [25]. Metal ion toxicity has been demonstrated in many studies. Nickel and chromium have been reported to cause hypersensitivity, dermatitis, and contact stomatitis; especially in individuals with a history of allergic reactions [20].

These symptoms can be short lived and intense or long lasting and moderate and some might be resolved, whereas others can become a chronic problem. However, as the natural capacity to eliminate nickel exceeds the accumulation capacity the risks are minimal [22]. Nickel and chromium are normally present in the food consumed by man, the dietary intake of nickel was reported to be 300 to 500µg per day, while chromium intake varied from 5 to 100µg per day. Park and Shearer results showed release of 40µg nickel and 36 µg chromium per day for a simulated full mouth appliance [11, 21].

Many clinical reports observed ulcers in soft tissue in contact with orthodontic appliance, which could be a localized sensitivity caused by the release of metal ions. For an allergic reaction in the oral mucosa, an antigen must be 5 -12 times greater that needed for a skin allergy [4, 28]. In a study by House *et al* it was observed that in some instances, nickel containing orthodontic appliances have caused gingival hyperplasia, labial desquamation, angular cheilitis, swelling and burning sensation affecting the oral mucosa [33].The drawbacks, generally, in estimation of ionic release through the use of storage media is that the release rate of metal ion is "forced" to rapidly reach a plateau because of the establishment of equilibrium between the metal ions in the solution and the metal ions at the metal-solution interface.

There is a noted inability to simulate clinical factors such as bracket archwire ligation, both of which are moving elements, a fact that might induce fretting corrosion. Lack of the complex intraoral flora, and plaque accumulation and its by products, which have proven corrosive action, are additional weaknesses of in-vitro protocols. The sampling method adopted in all investigation assume that ionic release has a steady pattern and the concentration at that specific time represents the release for the full term, a hypothesis that has not been verified [25].

In the present study it was observed that on comparison of ion release between the mouth washes and gels it was seen that nickel ion release and chromium ion release was more in the Clohex ADS (group 1) compared to Hexigel (group 3), copper ion release in Hexigel (group3) and Rexidin -M (group 4) was marginally more than Colgate plax (group2), deionized distilled water (group 5) and Clohex ADS (group 1), Iron ion release in Clohex ADS (group1), Colgate plax (group 2) were more than that of Hexigel (group3) and Rexidin -M (group 4),Manganese ion release in Colgate plax (group 2) was almost similar to Hexigel (group3) and Rexidin -M (group4).

It should be noted that caution should be maintained while advising mouth washes and gels to patients with history of allergies[3].From the results obtained in the present study it was observed that the metal ion release from brackets in the mouth washes ,gels and distilled deionized water was significantly below the the dietary intake. It was observed that the nickel, chromium metal ions were higher in the chlorhexidine mouth wash (Clohex ADS) and chlorhexidine gel (Hexigel) when compared with the other groups in the study. However, the levels of the metal ions released in the present study were low when compared to the toxic doses.

5. Conclusion

This study concluded that Group 1 (Clohex -ADS) mouthwash showed the highest release of chromium, nickel, iron, manganese ions when compared to Colgate plax (group 2), Hexigel (group3), Rexidin -M (group 4) and Deionized distilled water (group 5)

Hence chlorhexidine can cause increased surface roughness of the metal brackets with decreased efficiency of the appliance by creating friction. Release of copper ion was found to be higher in group -3 Hexigel and group -4 Rexidin -M forte gel.

6. References

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