Original Article

Assessment of nickel release from various dental appliances used routinely in pediatric dentistry

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Abstract

Context: The use of nickel-containing alloys in dentistry has been questioned because of the biological liabilities of nickel and the release of nickel ions from dental appliances into the oral cavity. The potential health hazards of nickel and chromium and their compounds have been the focus of attention for more than 100 years. It has established that these metals could cause hypersensitivity. **Aims:** To assess the nickel release from various dental appliances used in pediatric dentistry. **Settings and Design:** It is a *in vitro* study. **Materials and Methods:** The study was undertaken to analyze *in vitro* biodegradation of space maintainers and stainless steel crowns made out of stainless steel materials from different manufacturers. The leaching effect simulating the use of clinical practice was studied by keeping the respective number of Stainless Steel Crowns and space maintainers in the artificial saliva incubating at 37°C and analyzing for nickel release after 1,7,14,21 and 28 days using atomic absorption spectrophotometer. **Statistical Analysis:** The results were statistically analyzed by using One way ANOVA and repeated measures of ANOVA was applied at different time intervals i.e. 1,7,14,21,28 days. The critical value for statistical significance was set at $P = 0.05$. **Results:** Results showed that there was measurable release of nickel which reached maximum level at the end of 7 days which was statistically significant ($P < 0.05$). **Conclusions:** The release of nickel and chromium very much below when compared with the average dietary intake of nickel (200-300 ppm/day) which were not capable of causing any toxic effects.

Key words: Allergic reaction, nickel, nickel sensitivity

INTRODUCTION

In dentistry, nickel (Ni) is used for fabrication of space maintainers, brackets, fillings, and crowns.[1] However, in oral cavity, it is subjected to biodegradation due to its ionic, thermal, microbiological, and enzymatic properties. Advantages of Ni and chromium alloys, being its high strength, corrosion resistance, and relatively low cost, have led to their common use. This has raised questions concerning their biological safety. Burrows after his study in 1986 revealed that Ni is by far the most common agent to cause sensitization due to their leaching in saliva from dental appliances.[2] Ni is a constituent of many alloys used in dental treatment to provide improved physical and chemical properties, such as durability and strength, as well as it reduces the cost of using precious alloys. The amount of Ni in dental alloys ranges from traces to over 60%. This alloy contains 11.5–27% chromium and 7–22% Ni. In relation to pediatric dentistry, Ni ions are released by stainless crowns, space maintainers, and orthodontic appliances over time in patient saliva. This has been seen to increase after tooth brush abrasion and increase in the oral pH.[3]

Ni is one of the most potent allergens and ubiquitous contact allergen among children and adolescents.[4] The most common mechanisms of adverse reactions

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induced by Ni are (a) corrosion, which depends on the presence of oxygen, chlorides, and non-noble metal alloys in the saliva and (b) the continuous and gradual release of ions from dental material. Such ionic components are absorbed in the human body, either through the oral mucosa, digestive system, skin, or airways.[5] The most frequent adverse reactions caused are hypersensitivity, sub-toxic reactions, metal toxicity, and allergic contact dermatitis. Symptoms of allergic reactions of Ni containing alloys, i.e., seeing commonly are severely inflamed hyperplastic gingival tissue surrounding crowns or space maintainers, alveolar bone loss and edema of gums, palate, and throat.

Recent studies have proven the carcinogenic effects of Ni through exposure pathways such as inhalation, ingestion, and parenteral injection of Ni compounds.[6] Because of its wide use in dentistry, it is important to assess the amount of Ni release from various dental materials.

Aim

The aim of this study is to assess the Ni release from various dental appliances used in pediatric dentistry.

Objectives

- To measure the Ni ion release from conventional preformed stainless steel crowns (SSCs)
- To determine the maximum no of appliances that can be given to an individual without reaching the toxic levels.

MATERIALS AND METHODS

A total number of 90 were studied out of which 45 were SSCs classified as Group A [Figure 1] and the other 45 were space maintainer [Figure 2] classified as Group B were studied. Each group was further divided into three subgroups [Table 1A].

Initially, the internal surface of crowns was filled with polycarboxylate cement [Figure 3] to prevent contact with artificial saliva and then after being fully set, they were placed into the saliva sample [Figures 4 and 5].

Subgroups were maintained separately in closed polyethylene jar containing 20 ml of artificial saliva (synthetic saliva with a pH of 6.43 ± 0.26 consisting of: 0.8 g NaCl, 2.4 g KCl, 1.5 g NaH_2PO_4, 0.1 g Na_2S, and 2 g $CO[NH_2]2$) [Figure 6] in an incubator at 37°C for 4 weeks [Figure 7]. The samples were placed in the solution on day 0. After day 1 and every 7 days, they were taken out from the solution and placed in another container with fresh saliva in order to avoid saturation of solution with released ions. All samples were shaken gently during immersion, to ensure bathing all crowns in saliva, and to obtain a uniform solution. The amounts of released Ni were measured on days 1, 7, 14, 21, and 28. The graphite furnace atomic absorption spectrophotometer (Varian SpectrAA 220FS Spectrophotometer*™) was used for quantitative assessment of released Ni [Figure 8]. Ni standard solution (100 mg/ml) was prepared through dissolving Ni nitrate in deionized water. Thinner solutions were prepared on daily basis by diluting the standard solution for calibration of the device. Ni level of each sample was determined twice, and the concentration of Ni below detectable level was considered zero.

Data analysis

The results were statistically analyzed by using one-way ANOVA for inter-subgroup comparison and repeated-measures ANOVA was applied for the various intra-subgroup comparisons at different time

Table 1A: Respective division into groups an subgroups

Serial number	Group A	Group B
1	3M	Dantauram
2	Kidodent	RMO
3	Pyrex	Shree

Figure 1: Stainless steel crown

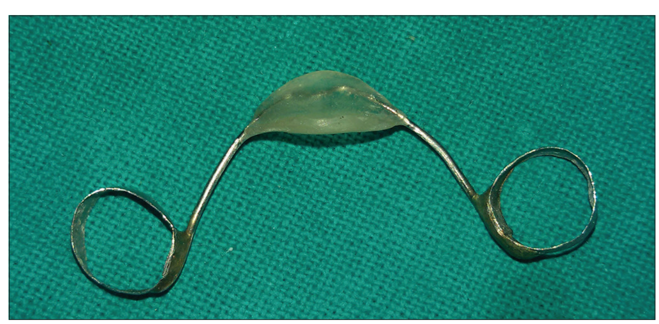

Figure 2: Space maintainer

Figure 3: Crown filled with cement

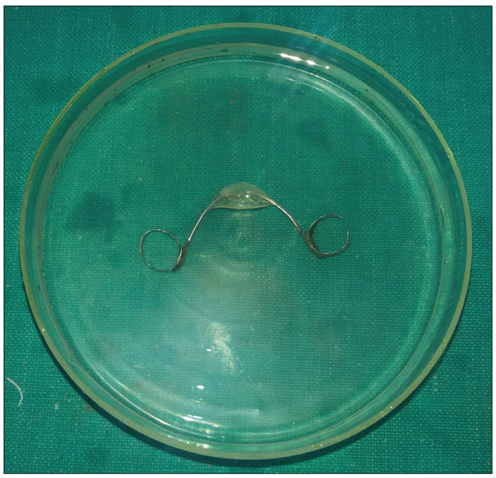

Figure 5: Space maintainer in artificial saliva

Figure 7: Incubator

intervals, i.e., 1, 7, 14, 21, and 28 days. The critical value for statistical significance was set at $P = 0.05$.

RESULTS

On assessing the ppm levels of Ni in saliva of SSC

Figure 4: Crown in artificial saliva

Figure 6: Artificial saliva used (International Cast Polymer Alliance)

Figure 8: Graphite furnace atomic absorption spectrophotometer

groups, we found that the release of Ni ions from SSC subgroup 3 (Pyrex) was significantly more than that from SSC subgroup 1 (3M) and SSC subgroup 2 (Kidodent) at the 1st, 7th, and 14th days. No significant difference was found in Ni release between

SSC subgroup 1 (3M) and SSC subgroup 2 (Kidodent). The rate of Ni release was maximum on the 1st day and after that it gradually decreased till 28 days in all three subgroups [Tables 1B and 2].

The release of Ni ions in the saliva of space maintainer group was found to be statistically significantly higher in SM subgroup 3 (Shree) as compared to SM subgroup 1 (dantaurum) and SM subgroup 2 (RMO). No Significant difference was found in Ni release between SM subgroup 1 (Dantaurum) and SM subgroup 2 (RMO). In all the cases, the release of Ni ions was maximum on the 7th day, thereafter it diminished with time [Tables 3 and 4].

Highest amount of Ni release was observed from subgroup 3 (Shree) in space maintainers i.e., 1.39 ppm and from subgroup 3 (Pyrex) in SSC, i.e., 0.6 ppm. However, these results are insignificant in terms of toxicity.

DISCUSSION

In pediatric dentistry, commonly used preformed SSCs and space maintainers are exposed to saliva in oral cavity, which is a potentially hostile environment, where electrochemical corrosion can occur.

The harmful effects of Ni its allergenicity, and its carcinogenicity have been systematically investigated at the cell, tissue, organ, and organism levels. Approximately 10% of the general population has a hypersensitive reaction to Ni. Peltonen in 1979 reported that girls are 10 times more sensitive to Ni than boys.[7]

In our study, Ni ion level (<5 ppm) were well below the critical value to produce toxicity (50 and 500 mg/kg body weight)[8] and below daily dietary intake level (200–300 μg/day). this finding is supported by Bhaskar *et al*.[9] and the WHO (1988 and 1991)[10] stated that 0.2 ppm/kg body weight of Ni can cause systemic manifestations.

To produce any mucosal allergic reactions, the antigen should be 5–12 times stronger than what is required to create an allergic reaction on the skin. The amount of Ni ion level found in our study is sufficient enough to induce an allergic reaction, due to high haptenic capacity of the released Ni ion, so it can cause allergic reactions in children. Haptens are small molecules that cannot trigger the immune system reactivity by themselves but hapten protein conjugates can act as a trigger to an allergic reaction. The conjugated haptens become antigens and induce the formation of antihapten antibodies. Even antibodies with specificity for metal ions such as Ni are produced in this way. This is supported by Ramazani *et al*.[11] However, Menek[12] *et al*. state that Ni ion cannot cause any allergic reactions in these concentrations.

The retrieval analyses are *in vitro* studies that examine *in vivo* aged samples. In an analysis of retrieved crowns by Eliades *et al*.,[13] no changes were seen in the composition of elements. This study indicated that neither Ni nor any other element could be released under clinical conditions and in other words the crowns are not prone to corrosion. They showed that clinical conditions revealed no Ni release from SSC's, which is in contrary to our results. Keinan *et al*. in 2010[14] analyzed the absorption of metal ions released from SSCs by root surface of primary molars. Higher amounts of Ni, chromium, and iron (5–6 times) were found in the cementum of molars covered with SSCs compared to intact molars. The differences between groups were highly

Table 1B: The mean release nickel on 1, 7, 14, 21, and 28 days in various subgroups of stainless steel crowns

Days groups	1	7	14	21	28	*F*	*P*
1 (3M)	0.72±0.06	0.58±0.09	0.33±0.11	0.5±0.6	0.27±0.06	76.59	0.001
2 (Kidodent)	0.77±0.075	0.58±0.06	0.36±0.07	0.3±0.07	0.26±0.07	117.11	0.001
3 (Pyrex)	0.91±0.03	0.83±0.12	0.53±0.13	0.45±0.13	0.33±0.10	71.71	0.01
ANOVA (*F*)	42.52	32.91	13.52	4.69	3.31		
P<0.5	0.001	0.001	0.015	0.054	0.051		

Table 2: Inter-subgroup comparison by *post hoc* test of Group A

	Day 1		Day 7		Day 14		Day 21		Day 28	
	Mean difference	*P* value	Mean difference	*P* value	Mean difference	*P* value	Mean difference	*P* value	Mean difference	*P* value
1 versus 2	−0.0587	0.027	−0.001	1.00	−0.032	0.69	0.108	0.011	0.01	0.94
1 versus 3	−0.196	0.001	−0.245	0.001	−0.195	0.001	0.044	0.441	−0.060	0.115
2 versus 3	−0.137	0.001	−0.244	0.001	−0.162	0.001	−0.064	0.178	−0.070	0.056

Table 3: The mean release nickel on 1, 7, 14, 21, and 28 in various subgroups of space maintainers

Days groups	1	7	14	21	28	*F*	*P*
1 (Dantauram)	1.97±0.09	2.14±0.2	1.6±0.12	0.74±0.11	0.5±0.08	455.07	0.001
2 (RMO)	1.17±0.12	1.33±0.12	0.9±0.08	0.49±0.1	0.36±0.06	268.67	0.003
3 (Shree)	1.22±0.12	1.38±0.1	0.86±0.11	0.55±0.89	0.43±0.06	263.21	0.02
ANOVA (*F*)	229.78	132.168	224.890	23.043	14.327		
P<0.5	0.001	0.001	0.001	0.012	0.042		

Table 4: Inter-subgroup comparison by *post hoc* test of Group B

	Day 1		Day 7		Day 14		Day 21		Day 28	
	Mean difference	*P*	Mean difference	*P*	Mean difference	*P*	Mean difference	*P*	Mean difference	*P*
1 versus 2	−0.0587	0.027	−0.001	1.00	−0.032	0.69	0.108	0.011	0.01	0.94
1 versus 3	−0.196	0.001	−0.245	0.001	−0.195	0.001	0.044	0.441	−0.060	0.115
2 versus 3	−0.137	0.001	−0.244	0.001	−0.162	0.001	−0.064	0.178	−0.070	0.056

significant ($P < 0.001$). This can be taken as an indication of biodegradation of NI from SSC's in oral environment. Similarly, Morán-Martínez *et al*. in 2013[5] determined both the genotoxicity of Ni in buccal epithelial cells and the urinary excretion of Ni in 37 children with metal crowns and suggest that odontological exposure to metal crowns results in genotoxic damage at the cellular level of the oral mucosa and an increase in the urinary excretion of Ni within 45 days of exposure. The most recent study was done by Ramazani *et al*. in 2014,[11] and the results were similar to our study.

In this study, the space maintainers showed higher Ni ion release than the SCCs this may be because of the solder used and also because of the heat used for soldering, and the same results were reported by Grimsdottir *et al.*[15]

CONCLUSION

- In case with history of Ni sensitivity, an alternate alloy should be recommended and a patch test could be performed before selecting Ni containing alloys
- From this study, we can conclude that restoring up to eight primary teeth with SCCs and four space maintainers cannot cause toxicity in terms of salivary Ni release
- If the stainless steel coated with proprietary material is used for fabricating crowns, it might decrease the ion release and perhaps prevent various health hazards in children.

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Conflicts of interest

There are no conflicts of interest.

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