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Assessment of the Amount of Nickel and Chromium Released from Two Types of Stainless Steel Crowns

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ABSTRACT

Purpose: Estimate the release of Nickel and Chromium in artificial saliva from two types of commercially available Stainless Steel Crowns (3M and Kids Crowns). **Materials and methods:** Twenty fixed-size Stainless Steel crowns (lower left E4) from two manufacturers were immersed in 10 ml of artificial saliva and stored in separate tubes at 37°C for 21 days. Every seven days, the crowns were withdrawn from each tube and inserted in new tubes with fresh artificial saliva. At the end of 1, 7, 14, and 21 days a Flame Type Atomic Absorption Spectrophotometer was used to check for the release of metal ions in the solution inside each tube. **Results:** The findings were analyzed using ANOVA test for calculation of the released amount of Nickel and Chromium among the crowns. Each of the Stainless Steel Crowns (SSCs) examined showed statistically significant differences in Nickel and Chromium release on various days. However, there was no detectable difference in the timing of the releases of both metals between the two groups. **Conclusion:** There was a release of Nickel and Chromium in all of the SSCs examined. The difference between the two types was not significant, so the metal ion release should not be a cause for concern when using any of the SSCs.

KEYWORDS

Chromium, Nickel, stainless steel crowns.

INTRODUCTION

Stainless Steel Crowns (SSCs) were originally introduced by Rocky Mountain Company and were used as the preferred choice for treating primary teeth. SSCs have high durability, tarnish resistance, low technical sensitivity and cost (1). Nickel appliances used in pediatric dentistry include SSCs and orthodontic appliances. Iron (65–70%), Chromium (17–20%), Nickel (8%–13%), Manganese (2%–3%),

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Silicone and Carbon make up the composition of these crowns.

Nickel and Chromium are the key components utilized in stainless steel orthodontic appliances, brackets, space maintaining bands and SSCs. Nickel and Chromium, as well as their compounds have been shown to be harmful for up to 100 years [2].

Nickel is a known contact allergen,and the dangers of metal ions such as Nickel and Chromium have been studied for over a century,with the recognition that these metal ions can cause dermatitis, allergy, and asthma[3]. Nickel at low concentrations can cause DNA strand breaks, DNA base damage, DNA lesions repair inhibition and mouth cancer. Nickel ion can activate monocytes and possibly promote an inflammatory response in soft tissues in small amounts [4]. Quantified metal ions released from fixed orthodontic appliances, such as Stainless Steel wires, Ni-Ti wires and orthodontic brackets, were reported to be significantly lower than the average dietary intake, while others expressed concern about the harmful effects and low dose effect of Nickel and Chromium ions [5].

The mouth cavity is a good place to study the many biological processes that occur when metallic equipment is used. Corrosion is a major concern, especially when Stainless Steel appliances are used in an electrolytic oral environment, where materials degrade at different rates due to electrochemical attack. In the oral cavity, oral tissues are exposed to a variety of physical, chemical, and microbiological stimuli, including saliva, plaque, temperature, pH, proteins and the physical/chemical properties of solids/liquids. The corrosion process may be influenced by food and oral circumstances [6].

Recent research has demonstrated the carcinogenic effects of Ni by inhalation, ingestion, and parenteral injection of Ni compounds. Because of its widespread use in dentistry, determining the amount of Ni and Chromium emitted from various dental materials is critical [7].

MATERIALS AND METHODS

This in vitro study was to assess the amount of Nickel (Ni) and Chromium (Cr) released from forty Stainless Steel Crowns (SSCs) of fixed size (lower left E4) of two manufacturers immersed in artificial saliva. Twenty 3M SSCs (3M ESPE Dental products, St. Paul MN, USA) (Fig.1) and twenty Kids SSCs (Shinhung Company Ltd, Korea) (Fig. 2) were studied. Polycarboxylate cement (Aria Dent, ACT, Tehran, Iran) was used to fill the fitting surfaces of the crowns. Artificial saliva (freshly prepared at Medicinal Chemistry Department, Faculty of Pharmacy for girls, Al-Azhar University) was prepared from 0.14g of NaCl (Sodium chloride),0.42 g of KCl (Potassium chloride),0.26 g $NaH_2 PO_4 2 H_2O$ (Disodium anhydrous phosphate), 0.017g $Na_2S,9H_2O$ (Sodium sulphide), 0.35 g $(CO(NH_2)_2)$ (Urea) and 350 ml distilled water. The Flame Type Atomic Absorption Spectrophotometer (AA-6601G/GFA 6500, Shimadzu, Kyoto, Japan) in the National Research Centre was used to detect the amount of Nickel and Chromium released in the artificial saliva.

Figure (1) 3M Stainless Steel Crowns

Figure (2) Kids Stainless Steel Crowns

Sample size was calculated using computer sample block randomization type. Sample size was calculated based on population size (6000), the response distribution of 50%, it was calculated through: N= (t^2×p (1-p)) ÷ m^2 Description: N =Required sample size t= Confidence level at 95% (standard value of 1.96) p= Estimated prevalence of Stainless Steel Crowns (SSCs). m = Margin of error at 5% (15.5). Sample Size = N / [1 + (N/ Population)]. Assuming = 0.05, we calculated that we would need 40 SSCs (20 for 3M and 20 for kids) to achieve, a power of 90% (= 0.9) [(3)].

Initially, the internal surfaces of the crowns were filled with polycarboxylate cement to prevent contact with artificial saliva, then after being fully set, they were divided into two groups: 20 3M SSCs and 20 Kids SSCs. The crowns were placed in centrifuge tubes filled with artificial saliva and each crown were placed in a separate tube. Each tube was tightly closed to prevent evaporation of the solution. Two tubes containing only the artificial saliva and set pieces of polycarboxylate cement with no crowns were used as controls. All tubes were stored at 37°C in an incubator [(3)].

At the end of 1st day, crowns were removed from each tube. The Ni and Cr were measured in artificial saliva then the same crowns were placed in new tubes with freshly prepared artificial saliva for further 7 days. At the end of the 7th day, the crowns were removed from each tube and Ni and Cr were measured, then the crowns were placed in a new set of tubes with freshly prepared artificial saliva. All tubes were stored in an incubator for a period of three weeks and the procedure repeated at the end of 14 and 21 days. The samples of artificial saliva collected inside each tube after the removal of crowns and the control samples at the end of day 1, 7, 14, 21 were analyzed to determine the Ni and Cr content using Flame Type Atomic Absorption Spectrophotometer [(3)].

Statistical analysis

Over a 21-day period, the results of the ANOVA test were evaluated for the estimation of released Nickel and Chromium between the two groups of Stainless Steel Crowns.

RESULTS

In the two sets of Stainless Steel Crowns (SSCs) examined (3M Crowns and Kids Crowns), both metal ions Nickel and Chromium were released (Tables 1 and 2). The Nickel and Chromium release between the 3M and Kids crowns was not significant, but the Nickel and Chromium release in the two types of crowns at different days was extremely significant, $P< 0.00$ and $P<0.05$, according to the ANOVA results of the experimental samples examined. In both types of crowns, the highest release of both metal ions occurred after 7 days, and subsequently the release of both metal ions gradually declined (Tables 1 and 2).

Table(1) *Mean and standard deviation of the Chromium released from 3M, Kids crowns and control saliva samples at different observation times (ANOVA test).*

Chromium		Mean	Std. Dev	95% Confidence Interval for Mean		Min	Max	*F*	*P*
				Lower Bound	Upper Bound				
1day	**3M SSCs**	0.2158	0.0182	0.21	0.22	0.20	0.25	436.59	0.000*
	Kids SSCs	0.2155	0.0092	0.21	0.22	0.21	0.23		
	Control samples	0.000	0.0000	0.00	0.00	0.00	0.00		
7days	**3M SSCs**	0.2503	0.0126	0.24	0.26	0.24	0.27	858.45	0.000*
	Kids SSCs	0.2270	0.0104	0.22	0.23	0.21	0.24		
	Control samples	0.00	0.00	0.00	0.00	0.00	0.00		
14days	**3M SSCs**	0.220	0.0117	0.21	0.23	0.21	0.24	675.61	0.000*
	Kids SSCs	0.2085	0.0115	0.20	0.21	0.19	0.22		
	Control samples	0.00	0.00	0.00	0.00	0.00	0.00		
21days	**3M SSCs**	0.207	0.0120	0.20	0.21	0.20	0.23	302.06	0.000*
	Kids SSCs	0.1538	0.0195	0.14	0.16	0.13	0.18		
	Control samples	0.00	0.00	0.00	0.00	0.00	0.00		

*Significance level p≤0.05, *significant*

Table (2)*Mean and standard deviation of the Nickel released from the 2 groups and control at different observation times (ANOVA test).*

Nickel		Mean	Std. Dev	95% Confidence Interval for Mean		Min	Max	*F*	*P*
				Lower Bound	Upper Bound				
1day	**3M SSCs**	0.1048	0.0031	0.10	0.11	0.10	0.11	436.59	0.000*
	Kids SSCs	0.1055	0.0026	0.10	0.11	0.10	0.11		
	Control samples	0.000	0.0000	0.00	0.00	0.00	0.00		
7days	**3M SSCs**	0.124	0.0083	0.12	0.13	0.11	0.13	858.45	0.000*
	Kids SSCs	0.1258	0.0077	0.12	0.13	0.11	0.13		
	Control samples	0.000	0.0000	0.00	0.00	0.00	0.00		
14days	**3M SSCs**	0.1143	0.0073	0.11	0.12	0.10	0.12	675.61	0.000*
	Kids SSCs	0.116	0.0076	0.11	0.12	0.11	0.13		
	Control samples	0.000	0.0000	0.00	0.00	0.00	0.00		
21days	**3M SSCs**	0.1075	0.0048	0.11	0.11	0.10	0.11	302.06	0.000*
	Kids SSCs	0.1088	0.0048	0.11	0.11	0.10	0.12		
	Control samples	0.000^{c}	0.0000	0.00	0.00	0.00	0.00		

*Significance level p≤0.05, *significant.*

DISCUSSION

It is extremely advised that Stainless Steel Crowns (SSCs) can be used to reconstruct carious primary molars under general anesthesia. Chromium (Cr), Nickel (Ni), Manganese, Silicon and Molybdenum are all present in these crowns. Crowns are immersed in saliva in the oral environment, which functions as an electrolyte, promoting corrosion [(8)].

SSCs were investigated in this study because they are commonly used in pediatric dentistry and most previous studies focused on space maintainers[(7)] and orthodontic appliances (such as Twin-block appliances and arch wires [(4,5)]). 3M and Kids crowns were chosen because they were the most readily available and widely utilized in dental clinics. To prevent the release of Nickel and Chromium from the inner surface of the crowns, the inner surface was sealed with cement. The samples were shaken after the crowns were immersed in the artificial saliva. This step resulted in an increase in the release of Nickel and Chromium, in addition to guarantee a uniform solution. Saliva was also replaced on a weekly basis to avoid saturation [(8)].

The study samples were placed in a 37°C incubator to replicate oral temperature. The PH was fixed at 7, whereas artificial saliva employed in a previous study had pH values of 6.8, 5, and 3.5. The decrease of PH increase the Nickel released [(1)]. The Flame Type Atomic Absorption Spectrophotometer was used in this study as it's the available device in the National Research Centre and it's the most common device used in similar studies [(3,7)]. In another investigation, Nickel and Chromium ions were detected using Inductively Coupled Plasma Mass Spectrometry and Gas Chromatography–Mass Spectrometry [(5)].

The results revealed that at the end of seven days, the rate of released Nickel and Chromium from Stainless Steel Crowns increased, but the release of both metal ions gradually dropped as the time period increased. The release of Nickel and Chromium did not differ much between 3M and Kids Stainless Steel Crowns at the end of 1,7,14,21 days. These findings matched those of a study that looked at the emission of Nickel and Chromium from three sets of SSCs [(3)]. It was showed that all three sets of SSCs examined released both metal ions (Nickel and Chromium). The release of Nickel and Chromium in each group on various days was highly significant, whereas the release of Nickel and Chromium between the groups was not. Nickel and Chromium emission begins on day one and continues to increase until day seven (maximum release of metal ions) then gradually decreased until day twenty eight (minimum release of metal ions)[(3)].

This similarity in the results between this study and the previous study may be due to similarity in methods as the both studies assessed the Ni and Cr released in artificial saliva with constant PH and temperature. Also, both studies used the same device for detection of metal ions (Flame Type Atomic Absorption Spectrophotometer). The corrosion of SSCs in saliva may occur due to microorganisms as microbes and bacteria produce acidic waste products that corrode metal surfaces. As a result, microbiological causes are responsible for the biodegradation of metals in Stainless Steel, which could result in release of Ni and Cr [(3)].

The findings of this study also matched those of another study that looked at the biodegradation of space maintainers and Stainless Steel Crowns from various manufacturers. The leaching impact was investigated by incubating the appropriate number of Stainless Steel Crowns and space maintainers in artificial saliva at 37°C for 1,7,14,21, and 28 days and evaluating for Nickel release using an Atomic Absorption Spectrophotometer. It revealed that there was a quantifiable release of Nickel, which peaked at a statistically significant amount at the end of seven days [(7)].

It has been reported that due to the high haptenic capability of the released Ni ions, the amount of Ni ion level reported in their study is adequate to create an allergic reaction and hence it can cause allergic reactions in children. Haptens are tiny molecules that by themselves cannot cause immune system reactivity, however hapten protein conjugates can cause an allergic reaction. The conjugated haptens act as antigens, causing antihapten antibodies to develop. This method is also used to make antibodies that are selective for metal ions like Nickel [7].

On the other hand, a previous study showed that Nickel release was unaffected by the passage of time. This was against the results of this study. This may be due to difference in the methodology as the study used crowns with and without trimming. Also, there was change in pH (3.5, 5, or 6.75) and temperature (27°C, 37°C, or 47°C). The results showed that the crown trimming reduced the amount of Nickel released and there was a difference in the amount of released Nickel at 37°C compared to 47°C and 27°C. However, there was no detectable variation in the concentration of released Nickel in three pH settings or three-time intervals. In another word, higher acidity and duration had no impact on Nickel release [2].

CONCLUSION

Nickel and Chromium were released in all of the SSCs tested. The difference between the two types was not significant, so the release of metal ions from any of the currently available SSCs should not be a cause for concern.

RECOMMENDATION

It is recommended to complete the findings of this study with an in vivo evaluation to examine the effect of the use of Stainless Steel crowns on allergic patients.

CONFLICT OF INTEREST

No conflict of interest.

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