Article

Detection of Ni, Fe, and Cr released in saliva after prefabricated metal crown placement in children

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Abstract: Dental caries is a public health problem worldwide according to WHO data. Among treatments in pediatric dentistry, prefabricated metal crowns (PMCs) have been one of the most successful options since they were introduced in cases of considerable tooth destruction. Our objective was to detect the presence and concentration of iron (Fe), chromium (Cr), and nickel (Ni) in saliva of patients who require rehabilitation with PMCs, before and after their placement. A quasi-experimental study was performed in 32 patients who attended dental care in a pediatric dentistry clinic at a public university and who required rehabilitation with PMCs. Parametric tests (ANOVA and Pearson correlation) were performed, and a $p \leq 0.05$ was considered statistically significant. Statistically significant differences were found when comparing the Ni release before, 1 week, and 1 month after placing the crowns. Similarly, we observed a positive correlation between the number of crowns and Ni release. No tests were performed for Fe and Cr because the amounts of these metals were less than 0.1 ppb, which was not detectable by inductively coupled plasma optical emission spectrometry (ICP-OES). The levels of Fe, Cr, and Ni released were below toxic health levels. Studies are required to evaluate whether this release has negative effects at cellular levels.

Keywords: prefabricated metal crowns (PMCs); nickel (Ni); chromium (Cr); iron (Fe); ion release

1. Introduction

Dental caries is a public health problem in most countries. Data from the WHO indicate that this pathology affects around 60–90% of school-age children [1], and dental caries is 32-times more common in children exposed to risk factors such as low socioeconomic status, carbohydrate-rich diet, and parents/guardians with a low educational level [2]. Currently, there are various restorative alternatives in pediatric dentistry, and PMCs have been one of the most successful options when there is considerable tooth destruction [3].

PMCs were first described by Engel followed by Humphrey in 1950 [4,5], and since then, PMCs have been used successfully in the restoration of both primary and permanent teeth [5–9]. These restorations have evolved over the years, improving their physical characteristics and clinical management [6]. Currently, the most-used PMCs are made of stainless steel, which are composed of

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iron (65–74%), chromium (17–19%), nickel (9–13%), and other elements (4%) [5,6] Similarly, there are nickel-chromium crowns, which are composed of 72% nickel, 14–17% chromium, and 6–10% iron, with small amounts of other elements [6].

Both nickel and chromium have been widely studied because of their potential health effects; it has been established that these metals can cause allergy, dermatitis, asthma, and toxicity [10]. Studies have shown that the release of Ni and Cr in patients with PMCs is much lower than levels of these elements that are ingested in the daily diet [11]. Special attention has also been paid to these metals because they have carcinogenic and mutagenic potential [12].

The objective of this study was to detect the presence and concentration of Fe, Cr, and Ni in saliva of patients who attended rehabilitation at the Clinic of the Pediatric Dentistry Specialty at the Autonomous University, State of Mexico.

2. Materials and Methods

2.1. Study design

A quasi-experimental study was performed. Both parents and children were informed about the purpose of the study, and an informed consent document was signed by the child's parent or guardian before participation. The study was performed in accordance with the ethical principles of the Declaration of Helsinki and was approved by the Research and Ethics committee of the Autonomous University State of Mexico, Faculty of Dentistry.

2.2 Study participants

The present study was performed in patients who attended Pediatric Dentistry Specialty clinic of the Advanced Studies and Research Centre in Dentistry "Dr. Keisaburo Miyata" at the Faculty of Dentistry at the Autonomous University State of Mexico, between January and June 2017. These patients had extensive carious lesions and needed restorative treatment with PMCs.

Thirty-two children, from 3 to 9 years old (average age, 5.72 ± 1.73 years), were selected to participate in the study. The inclusion criteria were as follows: a) both sexes; b) required restoration using PMCs; c) systemically healthy; d) informed consent signature; and e) cooperative patients. The exclusion criteria were as follows: a) patients who presented with previously placed PMCs; b) patients with previously placed metal restorations; c) patients in whom it was decided to place free metal crowns; and d) patients with orthopedic appliances.

2.3 Process

The placement of PMCs was performed by students in the Pediatric Dentistry Specialty at the Autonomous University State of Mexico, Faculty of Dentistry. The process was performed under local anesthesia and followed the restorative dentistry guidelines of the American Academy of Pediatric Dentistry [20]. After establishment of the preoperative occlusion, absolute isolation was achieved using a rubber dam, caries was eliminated and pulp therapy was performed in necessary cases. Subsequently, an occlusal reduction of 1.5 to 2 mm was performed using a wheel-shaped diamond bur. The proximal, vestibular, and lingual/palatal wear was from 1 to 1.5 mm, which was performed with a pencil tip diamond bur. Finally, the PMC (3M, St Paul, MN, USA) was tested, adjusted, and cemented using glass ionomer cement.

Three 5-mL samples of unstimulated saliva were taken per patient according to previously established guidelines [21]. The first sample was taken before PMCs rehabilitation, and the other two were taken 1 week after and 1 month after the PMCs placement. The samples were collected around 10 am, the patient and his/her parent were instructed to avoid eating, drinking liquids, or chewing gum 1 hour before taking the samples. The patient was instructed to rinse with deionized water and wait 5 minutes in a relaxed position, and then they were asked to avoid movement and to tilt the head at 45° and spit out the collected saliva in a polyethylene bottle until the required quantity was reached; subsequently, the samples were stored at a temperature of 5°C until processing.

The samples were pre-digested with 2% nitric acid (HNO_3) and kept refrigerated until analysis. Before analyzing the samples, they were digested using a heating plate. Metal levels were measured

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in the laboratory of the Academic Area of Earth Sciences and Materials of Basic Sciences and Engineering Institute at the Autonomous University of Hidalgo State using ICP-OES (OPTIMA 8300 by Perkin Elmer, Madrid, Spain).

2.4. Statistical process

The statistical package SPSS Version 23.0 (IBM Analytics, New York, USA) was used to perform the data analysis. In the univariate analysis, frequencies and percentages were reported for the qualitative variables, and means and standard deviation for quantitative variables. To test for differences in the included variables, a bivariate analysis was performed, in which parametric tests were used (ANOVA and Pearson's correlation). A value of $p \leq 0.05$ was considered statistically significant.

3. Results

Thirty-two patients participated in the study; they had a mean age of 5.71 years ±1.72 and 53.1% (n=17) were women. The average number of PMCs placed in the patients was 5.16 ±2.56. The rest of the variables included in the study are shown in Table 1.

Table 1. Descriptive analysis of the study variables

Variable	Mean	SD
Age	5.71	1.72
Number of PMCs	5.16	2.56
Ni [1]		
Baseline Ni amount	2	3.59
Week Ni amount	68.48	5.42
Month Ni amount	43.97	9.99
Cr [1]		
Baseline Cr amount	≤0.1	0.0
Week Cr amount	≤0.1	0.0
Month Cr amount	≤0.1	0.0
Fe [1]		
Baseline Fe amount	≤0.1	0.0
Week Fe amount	≤0.1	0.0
Month Fe amount	≤0.1	0.0
	Frequency	**Percent**
Sex		
Male	15	46.9
Female	17	53.1

[1] ppb

A repeated measures ANOVA was performed to evaluate Ni release before, 1 week after, and 1 month after the PMCs had been placed. Table 2 shows the results of Bonferroni's multiple comparisons for Ni, which showed statistically significant differences between the three comparisons. The test for Fe and Cr was not performed because the amounts of these metals were equal to or less than 0.1 ppb, which is not detectable by ICP-OES.

Table 2. ANOVA with Bonferroni multiple comparisons for Ni

		Difference of means	p value [1]
Baseline Ni amount	Week Ni amount	−66.48	**<0.001**
Baseline Ni amount	Month Ni amount	−41.97	**<0.001**
Week Ni amount	Month Ni amount	24.51	**<0.001**

[1] Analysis of variance of repeated measures (ANOVA) p value ≤0.008333.

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Table 3 shows the results of the Pearson correlation test where the amount of Ni detected, and the total number of PMCs placed in the mouth were compared. There was a slight negative correlation between the number of crowns and the baseline Ni values (r = −0.342, p = 0.056). Both week and month a strong positive correlation was found, obtaining the following values respectively: r = 0.969 (p = 001) and r = 0.926 (p = 001). Which indicates that the release of metals is related to the number of crowns placed. As with the repeated measures ANOVA test, neither the Cr nor Fe test were performed due to the same reasons.

Table 3. Pearson correlation between PMCs number and metal release.

Variable	PMCs number	p value [1]
Baseline Ni amount	r= −0.342	0.056
Week Ni amount	r= 0.969	**<0.001**
Month Ni amount	r= 0.926	**<0.001**

[1] Pearson correlation

4. Discussion

PMCs are used extensively in pediatric dentistry because of their successful use in restorations [3]; however, when exposed to the intra-oral environment, they can corrode and release metal ions [15]. Its components include the presence of Ni and Cr. These metals have been studied because of their controversial effects on health [16]. Ni is integrated into steel alloys to stabilize the austenitic phase, maintain polish, and decrease its ductility; similarly, Cr increases corrosion resistance [17]. Previous studies suggest that it is preferable to use salivary samples from patients who require oral rehabilitation with PMCs instead of an *in vitro* model, because of the advantage represented by studying this release in a dynamic environment [12].

As in other studies [11,16,18,19], the amount of Ni detected was less than the amount ingested in the daily diet, which is in the range of 300–500 ppm per day [15,18]. In contrast to other studies, in the present study, there was no presence of Fe or Cr [11], which may be because the technique used is not sensitive enough. The release of Ni by PMCs is greater 1 week after placing the PMCs; similarly, we observed that the amount decreased after 1 month [16]. Systemic studies should be performed to evaluate if this amount released is constant or lower at this level.

The results show that the amounts of metals released by the PMCs are not toxic to health (toxic dose: 2.5 mg/mL, oral lethal dose: 50–500 mg/kg) [17]. However, the risk of developing allergic reactions has been well documented [16,20]. Therefore, it is necessary to evaluate the effects of these metals at the local level, because, although the amounts are small, they can cause allergic reactions [21].

5. Conclusions

The present study showed that the amounts of Ni, Fe, and Cr are significantly lower than those ingested in the daily diet. It is recommended to conduct studies to evaluate if this release has negative effects at the cellular level.

Limitations: The present study has certain limitations that should be taken into account for future research. Measuring the release of metals only in saliva does not provide the exact concentration in the body, and it is recommended to take samples of urine or nails. Similarly, the use of more sensitive devices such as the ICP-MS is widely recommended, because in our study, we could not detect quantities lower than 0.1 ppb.

Author Contributions: César Tadeo Hernández-Martínez, Raúl Alberto Morales-Luckie, Norma Leticia Robles-Bermeo, Edith Lara-Carrillo and Carlo Eduardo Medina-Solís conceived, designed the experiments, and contributed reagents and materials; Marius Ramírez-Cardona and Verónica García-Hernández performed the experiments; César Tadeo Hernández-Martínez, Raúl Alberto Morales-Luckie, Sandra Isabel Jiménez-Gayosso, and Carlo Eduardo Medina-Solís analyzed the data and wrote the first draft of the manuscript. All the authors

were involved in the conceptualization of the paper, analysis, critical review, interpretation of the results, and made intellectual contributions, and they also accepted the final version.

Conflicts of Interest: The authors declare no conflicts of interest.

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