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Release and systemic accumulation of heavy metals from preformed crowns used in restoration of primary teeth

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Abstract: Preformed crowns for restoration of primary teeth are used in various treatments and are essential for restoring the crowns of primary molars. However, there are concerns that mechanical, chemical, and thermal stimulation may cause release of components of such crowns. We examined systemic accumulation of heavy metals associated with preformed crowns (3M Stainless Steel Primary Molar Crowns) used in primary tooth restoration. The participants were 37 children who had visited the Pediatric Dental Clinic of Tsurumi University Dental Hospital. They were divided into two groups: 22 participants without a history of being fitted with a preformed crown for primary tooth restoration (controls), and 15 participants with preformed crowns for primary tooth restoration. Analysis of hair samples showed a significant difference in the level of the trace element Cr – an important component of the preformed crowns – between children with and without preformed crowns, but no significant differences in Fe or Ni levels. Levels of the trace elements Ni, Cr, and Fe were within allowable ranges, indicating that these minerals were not likely to be harmful.
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Keywords: preformed crown; trace element level; accumulation; release in mouth.

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Introduction

Preformed crowns are used to restore primary teeth in various treatments in clinical dentistry. They are used to restore primary molars with heavily damaged crowns or treated pulp and as an abutment tooth for a space maintainer. The use of preformed crowns for primary tooth restoration reduces treatment time and number of visits to clinics. It was reported that use of a preformed crown was necessary to restore occlusion in the restoration of primary teeth with heavily damaged crowns. The use of a preformed crown stabilized masticatory rhythm (1) and had favorable effects on the jaw muscle reflex (2).

The preformed crowns currently used in Japan for primary tooth restoration are the 3M Stainless Steel Primary Molar Crown (composition: 65-74% iron [Fe], 17-19% chromium [Cr] and 9-13% nickel [Ni]) and the Dentsply-Sankin Anatomy Primary Crown (composition: ≥ 87% Ni, 5% Cr, 4% copper [Cu], and 0.1% other components). The frequent use of preformed crowns for primary tooth restoration in clinical pediatric dentistry has led to concerns that heavy metals in the crowns could be released into the mouth and accumulate in the body. Ryo et al. (3) reported that use of amalgam fillings for restoring decayed teeth increased mercury accumulation in the body, as shown by high mercury levels in hair samples. In addition, release of Fe, Cr, and Ni, which are components of preformed crowns, was examined by placing pieces of those metals in the mouths of laboratory animals (4). Dental metals were found to be cytotoxic to DNA and cultured cells, although the amounts of such metals released in the mouth were not harmful to human health (5,6). Systemic accumulation of heavy metals could trigger allergies (7,8). However, no study has assessed the amounts of metals released, or their

systemic accumulation, from preformed crowns used for restoration of primary teeth in clinical pediatric dentistry.

Because it is difficult to collect accurate data on oral release of dental metals, studies have generally examined accumulation of such metals in the body. Oral release of dental metals is caused by mechanical stimulation due to abrasion, and by chemical and thermal stimulation from eating and drinking (9). Generally, heavy metals ingested in such a fashion are excreted, mainly in urine and feces but also in small amounts over a long period of time in sweat, hair, and nails. For example, the half-life of chromium was reported to be 540 days in a case of acute chromium poisoning caused by chromate absorption through the skin (10).

We examined systemic accumulation due to oral release of Fe, Cr, and Ni – the main components of preformed crowns used in primary tooth restoration. The level of a trace element in hair reflects the level of that element in blood during hair growth. Because hair grows by approximately 1 cm a month, there is a delay between the trace element level in hair and that in the body at the time hair samples are collected. However, trichoscopy results were shown to correlate with results of hematologic examination, and trichoscopy is particularly sensitive in detecting heavy metals (10, United States environmental protection agency; www. epa. gov/). Despite the problem of time delay, we used trichoscopy to assess systemic accumulation of heavy metals, because a straightforward, less invasive testing method was required in a study of children.

The aims of this study were to 1) assess changes in systemic levels of Fe, Cr, and Ni caused by the release of components of preformed crowns used in primary tooth restoration and 2) compare the levels of these elements in participants with standard values published by the Research Laboratory of La Belle Vie, Inc.

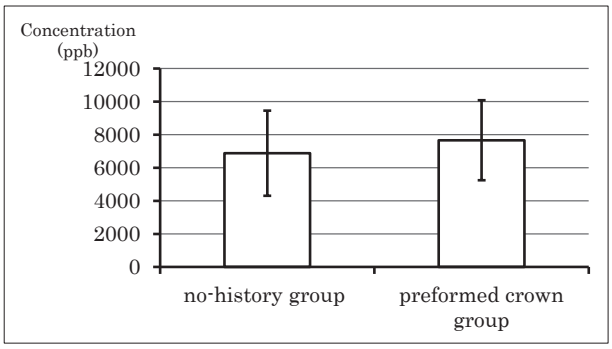

Fig. 1 Iron level in scalp hair samples. $P > 0.05$

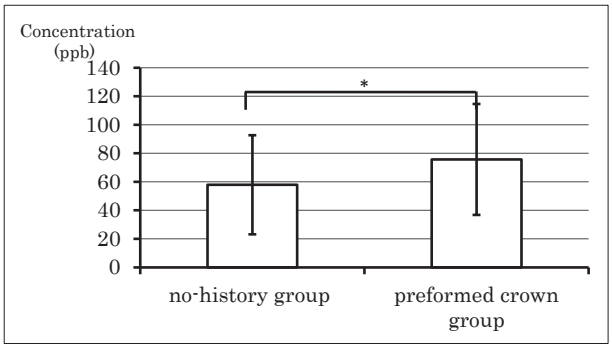

Fig. 2 Chromium level in scalp hair samples. $*P < 0.05$

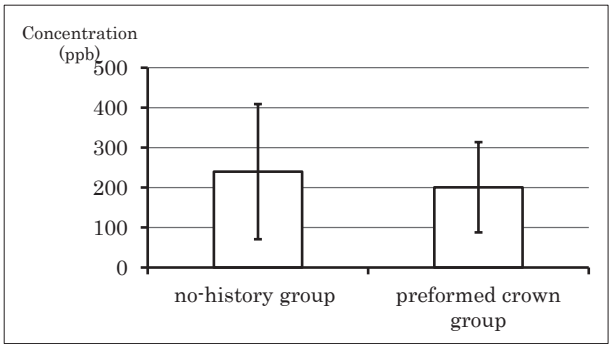

Fig. 3 Nickel level in scalp hair samples. $P > 0.05$

Materials and Methods

The participants were 37 patients (21 boys and 16 girls) aged 6 to 13 years (mean: 9.1 ± 1.8 years) who had visited the Pediatric Dental Clinic of Tsurumi University Dental Hospital. We measured levels of trace elements in the hair of participants and conducted a questionnaire survey of their lifestyle habits and daily lives. The participants were divided into two groups: 22 children (mean age: 9.3 ± 2.0 years) without preformed crowns for primary tooth restoration (hereafter, controls), and 15 children (mean age: 8.6 ± 1.6 years) with such crowns at the time of measurement (hereafter, crown group). All preformed crowns were 3M Stainless Steel Primary Molar Crowns. None of the participants had a history of treatment with other dental metallic materials. The participants in the crown group had regularly visited our hospital for at least 6 months after fitting of a preformed crown for primary tooth restoration (average duration of follow-up: 3.5 years). The average number of preformed crown restorations per person was 2.9 ± 2.0.

Levels of trace elements were measured by hair mineral analysis at the Research Laboratory of La Belle Vie, Inc. (Tokyo, Japan). Approximately 0.2 g (about 3 cm) of hair close to the scalp of each participant was collected for this analysis. To prepare a solution for measurement, collected scalp hair samples were cleaned in an ultrasonic bath with acetone and the surfactant Triton-X100 and dissolved in alkaline tetramethylammonium hydroxide (TMAH) solution. This solution was

Table 1 Mean levels (in parts per billion) of trace elements in scalp hair samples from participants with allowable ranges

	allowable range		37 participants in total (9.1±1.8 years)	
	4 to 9 years	10 to 15 years	mean value	standard deviation
Fe	6900~15581	5181~10591	7196	2544
Cr	35~146	23~114	65	38
Ni	55~333	51~331	225	148
Be	0~1	0~1	0	0
Cd	5~54	3~46	15	15
Hg	788~4939	1063~5657	5634	4766
Al	6090~21055	3653~14278	13823	7816
Pb	196~1579	164~1502	706	657
As	25~79	27~84	42	23
Na	3938~29700	5238~39460	19449	15947
K	7536~41545	7235~46189	27114	30044
Mg	8864~36706	12473~46471	43399	30327
Ca	127360~378805	163755~458602	403792	272758
Mo	26~73	19~47	51	19
Mn	113~418	81~306	162	92
Cu	8393~27707	8542~32249	19651	8325
Zn	73418~143655	94510~160207	115202	25198
P	91685~135183	101178~141007	112294	25854
Se	481~762	501~797	648	101
I	111~759	55~731	418	588
Li	1~10	0~7	1	1
Co	4~16	3~16	5	3
V	9~87	5~39	272	188
B	118~667	141~757	219	176
Ge	55~138	43~124	56	26
Br	1815~9981	1437~7422	3292	2759

highly toxic minerals
essential minerals

then analyzed by inductively coupled plasma mass spectrometry (ICP-MS) (11). Levels of 26 minerals, namely, 13 essential minerals, seven nonessential minerals, and 6 highly toxic minerals, were measured in scalp hair samples. The results show the levels of these minerals during a 3-month period because hair generally grows by 1 cm a month, although the extent of growth varies by individual and season. The results were statistically analyzed using the Welch *t*-test.

The study aims were explained to all participants and their parents, and written informed consent was obtained from all children and parents. This study was conducted with the approval of the ethical committee of Tsurumi University, School of Dental Medicine (No. 308).

Results

Levels of accumulated Fe, Cr, and Ni in hair samples

Levels of trace elements (in parts per billion [ppb]) in hair were compared between controls and the crown group. The trace elements examined were Fe, Cr, and Ni, which are components of the crowns. The Fe level was 6,878 ± 2,576 ppb in the control group and 7,662 ± 2,421 ppb in the crown group (Fig. 1). The difference was not statistically significant. The Cr level was 58 ± 35 ppb in the control group and 76 ± 39 ppb in the crown group (Fig. 2). The difference was statistically significant. The Ni level was 240 ± 169 ppb in the control group and 201 ± 113 ppb in the crown group (Fig. 3). The difference was not statistically significant. The levels of Fe, Cr, and Ni were within allowable ranges in all participants.

Comparison of element levels in participants with standard values

Table 1 shows the mean values among participants and allowable ranges (as defined by the Research Laboratory of La Belle Vie, Inc) of the 26 trace elements. The levels of all trace elements except vanadium (V) were within allowable ranges. The mean V level of the participants

was 272 ± 188 ppb, which was significantly higher than the allowable range.

Discussion

Levels of trace elements in scalp hair samples can be measured by ICP-MS, inductively coupled plasma atomic emission spectrometry (ICP-AES), atomic absorption spectrometry (AAS), X-ray fluorescence analysis (XRF), and neutron activation analysis (NAA); however, ICP-MS (used in this study) enables simultaneous measurement of many trace elements, thereby minimizing the amount of hair collected from participants.

Preformed crowns for restoration of primary teeth are used in various treatments. Because they are frequently used in clinical practice, there are concerns about accumulation of components released from such crowns. Some heavy metals can cause severe damage to the human body when absorbed and accumulated in large amounts. However, various trace elements, including heavy metals, have essential roles in human physiologic functions. In particular, abnormalities in the metabolism of trace elements in children affect various functions related to growth and development. An increase in the level of lead in blood can cause intellectual disabilities (12) and affect the physical growth of adolescent girls (13). As for the components of preformed crowns, Fe is necessary for the synthesis of hemoglobin in blood, and Cr is involved in the metabolism of sugars, lipids, proteins, and connective tissues. Ni, which is absorbed only in small amounts in the small intestine, stabilizes ribonucleic acid (RNA), promotes iron absorption, and activates some enzymes. Therefore, maintaining the balance of trace elements in the body is vital for the growth and development of children.

Oxygen, carbon, hydrogen, and nitrogen together make up 96% of the human body; the remaining 4% is composed of a large number of trace elements. Ni, Cr, and Fe account for only a small proportion of the body. In this study, the level of Cr (a component of the 3M Stainless Steel Primary Molar Crown) in scalp hair samples was significantly higher in the crown group than in the control group. However, Cr level was within the allowable range for hair mineral analysis in all participants. Although there was no statistically significant difference between groups in the levels of Ni or Fe, levels tended to be higher in the crown group than in the control group. Nevertheless, Ni and Fe levels in both groups were within allowable ranges. These findings suggest that the effects of components released from preformed crowns were small, but that the number of preformed crowns used in restoration of primary teeth and the duration of use should be considered.

Of the 26 trace elements analyzed in this study, the levels of 25 were within allowable ranges. The V level in the present participants was significantly higher than the allowable range, but the levels of other trace elements were below the mean of allowable ranges. The high level of V may be related to the fact that most participants in this study had spent their entire lives in Kanagawa Prefecture. The main source of tap water in this area is located at Mt. Fuji and is rich in V (14, The main source of water; www. pref. kanagawa.jp/).

The present results suggest that accumulation of trace elements released from preformed crowns used in restoration of primary teeth (3M Stainless Steel Primary Molar Crowns) does not affect the body. Rather, environmental conditions seem to have a larger effect on systemic accumulation of these elements.

Acknowledgments

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