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Article

Release of Nickel and Chromium from Metallic Orthodontic Appliance in Patients' Saliva

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Abstract

Introduction: **Malocclusions** are often treated with appliances made of metal alloys. These alloys biodegrade in oral cavity and release toxic metals such as nickel and chromium. This study aimed to assess nickel and chromium content in the saliva of patients wearing fixed orthodontic appliances. **Materials: and methods:** This was a cross-cutting study aiming at assessing nickel and chromium content in saliva. A survey was conducted to record socio-demographic characteristics and clinical signs due to the wearing of orthodontic appliances. A 10mL saliva sample was used to measure salivary pH and assess nickel and chromium concentrations using atomic emission spectrophotometry. A Student's T-test compared saliva metal levels in non-wearers and wearers of metal orthodontic appliances. **Results:** On the whole, 92 participants, among whom 46 without appliance and 46 wearing appliance were received during the study period. Their mean age was 17.05±6.46 years. Patients' mean saliva pH was 6.97±0.44. Mean nickel concentration was 4.39±4.01µg/l in the saliva of non-appliance wearers and 20.41±18.56µg/l in the saliva of appliance wearers, respectively. Chromium mean concentration was 1.3±1.33µg/l for non-appliance wearers and 9.38±19.49µg/l and for appliance wearers. **Conclusions:** Metal orthodontic appliances release nickel and chromium in saliva. It is necessary to monitor the risk of intolerance and optimize treatment duration.

Keywords: nickel; chromium; saliva; orthodontic appliance

1. Introduction

Correcting dental misalignment enables the dentition to fulfill its occlusal wedging, centering and guiding functions. At the end of orthodontic treatment, oral functions such as chewing, phonation, swallowing and breathing are easily performed. Facial aesthetics and smile improve. Also, growth potential is optimal for the young person.

To achieve these therapeutic goals, the multi-attachment metal alloy appliance is usually used. It includes molar bands or tubes, brackets, arches and binding wires stuck to the teeth. These components are made of metals with varying rates of iron, nickel, chromium, molybdenum, cobalt, copper, cadmium or titanium [Error! Reference source not found.].

Unfortunately, in the oral environment, these various metals are subject to variations due to saliva pH, oral temperature and the actions of enzymes or bacteria in dental plaque, food and then oral hygiene products [2–4]. The consumption of food or drinks with acidic or alkaline pH varies the pH of the oral cavity [5], increasing the formation of an oxide layer on the surface of dental alloys.

A series of oxidation and reduction reactions occur on the metals surface. Also, various mastication forces cause mechanical abrasion of orthodontic appliances and potentially release metal

ions [9,10]. This biodegradation of fixed orthodontic appliances leads to the release of metal ions (nickel, chromium, iron, copper) in the oral cavity [11,12].

Food habits and oral hygiene methods vary from one individual to another. In rice, corn, peanuts, dried fish and tomatoes consumed in Burkina Faso, *Bazié et al.* found varying levels of nickel, chromium, lead, zinc, cadmium, manganese, mercury and arsenic [6]. The local context is also marked by the use of homemade cooking utensils made of metal alloys (aluminum, silicon, copper, zinc, chromium, etc.) which contaminate food during cooking [7,8].

These metals add to those potentially released by orthodontic appliances in patients. Metals released in saliva go through the digestive tract and reach the bloodstream of exposed subjects and accumulate mainly in some organs such as the liver or kidneys.

In their studies on the release of toxic components by orthodontic appliances, authors found variable amounts of nickel, chromium or bisphenol A in the saliva of patients wearing orthodontic appliances [4,10,11,13]. According to *Ousehal et al.* [12] fixed orthodontic appliances release fairly high concentrations of nickel during the first days of their fitting in the oral cavity. As for *Al-Rawe et al.* [14], the increase in the release of metal ions is mainly due to the consumption of food containing acidic pH.

Furthermore, nickel and chromium cause more toxicological effects than other metals in dental alloys. Allergic reactions, contact dermatitis, and gingival hyperplasia are regularly reported in clinical practice [15,16]. The prevalence of nickel allergy is estimated at 28.5% of the general population by *Zigante et al.* [15]. Mutagenic and carcinogenic effects are reported due to the bioaccumulation of metals in the oral cavity, due to the length of orthodontic treatments [1,17,18].

High prevalence of orthodontic anomalies combined with the fact that alternative appliances such as aligners or resin braces also release toxic components such as bisphenol A or methyl methacrylate monomer, fixed metal braces are still widely used [9,19]. They are fairly less expensive.

Despite this interest in metal orthodontic appliances, their toxicity remains a health concern. This issue has raised the interest in investigations to characterize the risk of patient exposure to metals during orthodontic treatment. We report the results of a study which general objective was to assess nickel and chromium content in the saliva of Burkinabe patients wearing fixed metal orthodontic appliances.

2. Material and Methods

2.1. Context, Type and Duration of the Study

This prospective cross-cutting study was conducted from July 21 to October 10, 2025. Data collection involved subjects received during consultation at Yalgado Ouédraogo University Hospital, at Eras dental clinic and at clinic Frany. Sample analysis was performed in the Laboratory of Environment, Toxicology and Health (LATES), University Joseph KI-ZERBO, Ouagadougou.

2.2. Population Studied and Sampling

The study covered two groups of patients. Group 1 included subjects who did not wear orthodontic appliances. Group 2 consisted of subjects who wore multi-bracket metal orthodontic appliances. The sample size was decided for convenience. Each group included 46 participants who met the same inclusion criteria. After obtaining their informed consent, they were included when they came for consultation.

2.3. Inclusion and Non-Inclusion Criteria

Subjects included in this study were non-smokers and were not under medical treatment. Also, they were carefully examined for any oral disease, systemic disease, oral piercing, metallic dental restorations, dentures or welding on orthodontic appliances (diabetes, renal or hepatic insufficiency,

Parkinson, antidepressant, antihistamine, antihypertensive). Patients with a known allergy to jewelry, watches or any other source of nickel were excluded.

The control group of subjects who did not wear orthodontic appliances was formed based on the same inclusion criteria. They were selected among patients who came in initial consultation.

2.4. Variables Studied

Using a clinical examination form, we reported the socio-demographic profile of the subjects selected for the study and their initial malocclusions according to the dental health component table of the Index Of Orthodontic Treatment Need (IOTN). Then, we identified the clinical signs of appliance toxicity in patients and listed their food habits. Lastly, we measured pH in each saliva sample as well as nickel and chromium quantities.

2.5. Appliances

2.5.1. Orthodontic Appliance

The fixed orthodontic appliance for each patient comprised twenty brackets (BK Unix Roth .022 B704 22021HK) bonded with 3M transbond XT composite on the incisors, canines and premolars and four bands (B704 22092HK BWP Washplus) cemented with Fuji One glass-ionomer cement on the first molars, two preformed maxillary and mandibular orthodontic arches ligated with a chain or elastomeric ligatures. This medical device was made by Orthoplus (Paris-France).

2.5.2. Laboratory Appliances

PerkinElmer® Optima™ 8000 inductive coupling plasma atomic emission spectrometer was used for metal quantification. It uses a dual-spectrum optical system with a range of 160 to 900nm and a resolution of 0.009 to 200nm. It enables simultaneous multi-element analysis and equipped with a dual-view detector.

A 190-L LG freezer was used to store saliva samples at -20 °C before transferring them to the laboratory for analysis. A Voltcraft PH-100 ATC series pH meter was used to measure pH in saliva. It was calibrated every Monday morning to ensure the reliability of the measurements.

2.5.3. Small Materials, Substances and Reagents

A set of small materials or reagents were used for the study. Sterile 50 milliliter polypropylene Falcon tubes were used to facilitate the access of the pH meter probe to saliva. Artificial saliva with a pH of 6.8 was used as a reference to calibrate the pH meter weekly.

2.5.4. Saliva Collection and Sample Incubation

Saliva sampling was made two hours after any oral hygiene protocol and at least thirty minutes after any food intake. The mouth was previously rinsed with 15 mL of distilled water for 30 s. Saliva was collected without any stimulation.

The patient was at rest with his mouth closed for 5 min and then directly spit up to 10 mL of saliva in a sterilized 50 mL polypropylene tube. The tube was pre-washed with nitric acid to dissolve any traces of metals and rinsed with demineralized water. Then, samples were anonymously labeled and placed in the freezer at -20 °C to ensure sample stability after saliva pH measurement.

2.5.5. Saliva pH Measurement Technique

The pH was measured immediately after saliva collection (maximum 30 min). The measurement was made using a Voltcraft portable electronic pH meter, pH-100 ATC series. After each measurement, the pH meter probe was rinsed with distilled water contained in a rinse bottle equipped with a soft pouring plastic spout and then dried with a soft, lint-free cloth.

2.6. Ethical Considerations

Participants were informed of the study objectives and how it will be conducted. They gave their informed consent in writing. Throughout the study, patient anonymity was respected and the confidentiality of the data collected was ensured. This study received authorization from the Health Research Ethics Committee (CERS) through its deliberation no. 2024-06-181.

2.7. Data Processing and Analysis

Data collected were processed with SPSS 21 and Word 2016 software. The significance threshold p was set at 0.05. To highlight the interaction of orthodontic appliances in saliva, Student's T test was used to compare the averages of nickel and chromium in the saliva of subjects wearing and not wearing orthodontic appliances. Our variables are described by their mean and standard deviation.

3. Results

On the whole, 92 patients participated in this study, divided into two groups: 46 patients equipped with a multiband appliance and 46 people without any appliance. Participants were mainly pupils and students living in the Ouagadougou city as shown in Table I. The average age was 16.26 ± 5.85 years for those without appliance and 17.84 ± 7.07 years for those equipped with appliance. Their food habits were dominated by sweet foods (see Table II).

These patients consulted mainly for aesthetic reasons due to dental malpositions summarized in Table III which also lists the clinical signs observed after the appliance was placed in the mouth and the procedure performed just before saliva sampling.

The results showed that the pH (see Table IV) was on average 6.97 ± 0.44 in participants wearing appliances and slightly higher in those who did not wear appliances. As shown in Table V, on average nickel and chromium in patients were respectively 20.41 ± 18.56 and 9.38 ± 19.49

Table I. Participants' socio-demographic characteristics.

Variables	With appliance	Without appliance	Total
Participant number (n)	46	46	92
Age (average and standard deviation)	16.26±5.85	17.84±7.07	17.05±6.46
Gender (n/%)			
Male	27	18	45(51.09)
Female	19	28	47(48.91)
Residence (n/%)			
Ouagadougou	43	40	83(90.22%)
Others	3	6	9(9.78%)
Occupation			
Pupil	30	26	56(60.87)
Student	16	17	33(35.87)
Computer scientist	0	1	1(1.09)
Engineer	0	1	1(1.09)
Pharmacist	0	1	1(1.09)

Table II. Distribution of participants per types of food eaten just before saliva sampling.

Favorite drink	Frequency	Rate
Soft pop	37	40.22%
Water	6	6.52%
Natural juice	49	53.26%
Food taken before saliva sampling	Frequency	Rate
Rice	42	45.65%
Pasta	15	11.96%

To	11	6.52%
Bean	6	4.35%
Couscous	4	4.35%
Bread with eggs	4	4.35%
Bread and meat	2	2.17%
Thea	2	2.17%
Atiéké	2	2.17%
Porridge	1	1.09%
Yam	1	1.09%
Milk coffee	1	1.09%
Potato	1	1.09%
Total	92	100%

Table III. Participants distribution according to clinical aspects.

	Frequency	Rate
Diagnosed orthodontic anomalies		
Deepbite	7	15.21%
Overbite	5	10.87%
Missing tooth	1	2.17%
Retained tooth	2	4.35%
Diastema	4	8.70%
Dental crowding	15	32.61%
Crossbite	4	8.70%
Overjet	8	17.39%
Clinical signs due to the orthodontic appliance placement (n=14)		
Pruritus	1	7.14%
Irritation	6	42.46%
Metallic taste	5	35.71%
Burning	2	14.29%
Clinical procedure performed before saliva sampling (n=46)		
Archwire replacement	16	34.78%
Bracket bonding	3	6.52%
Ring sealing	1	2.17%
Chain replacement	12	26.08%
Ligature replacement	38	81.61%

Table IV. Distribution according to saliva pH.

Saliva pH	Without appliances (n/%)	With appliances (n/%)
[6-6.5[	2(4.35%)	8(17.39%)
[6.5-7[	16(34.78%)	14(30.43%)
[7-7.5[	27(58.70%)	17(36.96%)
[7.5-8[	1(2.1%)	7(15.22%)
Total	46(100%)	46(100%)
Saliva pH average	7.03±0.32	6.97±0.44

Table V. Quantities of nickel ions released from the fixed orthodontic appliance.

Metal(µg/L)	Without appliance (n=46)		With appliance (n=46)		p-value
	Frequency	Rate	Frequency	Rate	
Nickel					0.0002
<2	13	28.26%	2	4.35%	
2 to 10	30	65.22%	18	39.13%	
11 to 20	3	6.52%	11	23.91%	

>20	0	0.00%	15	32.61%
Total	46	100%	100.00%	100.00%
Nickel average	4.39±4.11		20.41±18.56	
Chromium				0.0031
<2	41	89.13%	17	36.96%
2 to 10	5	10.87%	22	47.83%
11 to 20	0	0.00%	4	8.70%
>20	0	0.00%	3	6.52%
Total	46	100%	46	100.00%
Chromium average	1.30±1.33		9.38±19.49	

4. Discussions

The results of this study show nickel and chromium release in patients’ saliva. Saliva seems to be a biological sample easier to study than blood, urine, hair, nails or skin. Sampling this biological fluid is less invasive than serum, easier to analyze than urine or hair samples.

The use of the freezer ensured the stability of the saliva samples before their analysis. Nickel and chromium concentrations in saliva samples remain stable for 6 months if stored at -20°. The pH is measured immediately, within thirty minutes after collection to avoid any change due to loss of CO² or temperature fall. Since the sample is taken at least thirty minutes after having eaten, saliva buffering capacity brings the pH back to an equilibrium value close to neutral. Yet, we noticed that the device reduces salivary pH.

Furthermore, the spectrometer used had a quantification limit of 2 µg per liter of saliva. Below this limit, the exact value of nickel or chromium was unknown. This limited the accurate reading of minute levels of trace elements, particularly in the saliva of participants who do not wear appliances.

Most of participants in this study were pupils and students lining in the Ouagadougou city. Female participants were more numerous. Indeed, they seek orthodontic treatment for aesthetic reasons, as they are more concerned with their physical appearance. Orthodontic treatment with a multi-bracket metal device is indicated after the eruption of permanent teeth, generally above twelve years.

This type of treatment is most often for adolescents whose food system is rich in fermentable sugars. 93.48% of the subjects surveyed consumed soft drinks and sweetened natural juices. Soft drinks and sugar affect saliva pH, which becomes acidic and increases the corrosion of dental alloys [20].

The presence of metals in subjects without orthodontic appliances shows that there are other sources of exposure to metals. Hence the need for an individual approach by taking into account other potential sources of metal exposure for each participant to orthodontic treatment with metal appliances. Metal levels in in-vivo studies could be altered by factors such as food, drinks, air, or tooth brushing [13].

There are many sources of food exposure: meat, chocolate, cocoa, dried fruits (hazelnuts, almonds), cereals, legumes, tea, coffee, spinach. Canned goods can also be contaminated by the migration of metals from the container. Similarly, some stainless steel or homemade aluminum kitchen utensils widely used in our context can contribute to this contamination during cooking. Drinking water can also be contaminated by metals. The WHO guideline values for drinking water currently tolerate nickel concentration up to 70 µg/mL and chromium concentration up to 50 µg/mL [21].

Occupational sources of exposure to nickel and chromium include metalworking jobs (welder, factory), industries (automotive, jewelry, watchmaking, electrical, chrome plating). Preventive measures must be taken by wearing personal protective equipment, ventilating work areas, and regularly monitoring ambient air. All these sources contribute to oral exposure which increases the doses of metals in patients wearing metal orthodontic appliances.

Given these potential risks, alternatives to metal components during orthodontic treatment can be ceramic brackets or aligners. Ceramic brackets are made of zirconium oxide or aluminum oxide.

They are more stable in saliva but their cost is high and their implementation more delicate; easily breakable during treatment and their removal is very difficult. Indeed, the polished surface of the ceramic is less smooth compared to that of the metal, which facilitates the retention of dental plaque. The adhesive capacity of the composite is important in the ceramic interface, the breakage during removal refers to the tooth-composite interface. Enamel fractures regularly occur during the removal of ceramic brackets. All these drawbacks tend to limit the use of ceramic brackets.

The use of aligners is currently flourishing, notably among adult patients, due to their aesthetic appeal. They are designed using artificial intelligence. The cost of orthodontic treatment with aligners is higher compared to that of treatment using metal brackets. In addition, orthodontic aligners release bisphenol A, an endocrine disruptor, into saliva. It affects hormones and fertility by affecting spermatozooids and ovaries health [11].

Ultimately, the presence of the appliance significantly increases nickel and chromium in saliva. This corroborates the results found by some authors who have highlighted the increase of these metals in saliva after wearing orthodontic appliances [4,10,16,19]. Values obtained remain lower than those found by *Ousehal et al.* [12]. Bonding brackets, changing orthodontic arches or sealing molar bands increase metal release.

By considering a patient who swallows one liter of saliva per day, according to the results of this study, he could swallow nearly twenty micrograms of nickel and ten micrograms of chromium per day. Since orthodontic appliances are made of several metals, the combination of both becomes a serious concern for the human body. As *Sawadogo et al.* [8] point out, other metals such as aluminum intervenes and could become a set of toxic metals for patients. The doses released are minimal, below the daily safety limit of 600 µg per day which corresponds to the toxicity threshold of nickel [20].

However, this was a cross-cutting study with minimal assessment in saliva with pH nearly null. A longitudinal study on larger cohorts before, during, and after orthodontic treatment would enable to better monitor the kinetics of metal release in saliva and long-term biological effects.

5. Conclusion

This study highlights the release of metals in saliva environment by the metallic orthodontic appliance consisting of rings, brackets, maxillary and mandibular arches. The main results show that nickel and chromium significantly increase in saliva after the fitting of metallic orthodontic appliances. Clinical signs report a sensation of metallic taste upon the fitting of the appliance.

While wearing fixed orthodontic appliances, it would be advisable to avoid foods with extreme alkaline and particularly acidic pH levels. As a preventative measure, it also seems necessary to reduce the duration of wearing metal orthodontic appliances to the bare minimum. Quantities released remain tolerable under sound clinical practice that takes into account the risks of sensitization and intolerance to metals, particularly nickel.

Conflicts of Interest: The authors declare having no conflict of interest.

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