Journal of Trace Elements in Medicine and Biology 31 (2015) 74–77

Contents lists available at ScienceDirect

Journal of Trace Elements in Medicine and Biology

journal homepage: www.elsevier.com/locate/jtemb

Toxicology

Do soft drinks affect metal ions release from orthodontic appliances?

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ARTICLE INFO

Article history:
Received 28 November 2014
Accepted 27 March 2015

Keywords:
Artificial saliva
Coca Cola®
Metal ions release
Orthodontic appliance
Stainless steel
Orange juice

ABSTRACT

Objective: The effect of orange juice and Coca Cola® on the release of metal ions from fixed orthodontic appliances.
Materials and methods: A continuous flow system designed for *in vitro* testing of orthodontic appliances was used. Orange juice/Coca Cola® was flowing through the system alternately with artificial saliva for 5.5 and 18.5 h, respectively. The collected samples underwent a multielemental ICP-OES analysis in order to determine the metal ions release pattern in time.
Results: The total mass of ions released from the appliance into orange juice and Coca Cola® (respectively) during the experiment was calculated (μg): Ni (15.33; 37.75), Cr (3.604; 1.052), Fe (48.42; $\geq$156.1), Cu (57.87, 32.91), Mn (9.164; 41.16), Mo (9.999; 30.12), and Cd (0.5967; 2.173).
Conclusions: It was found that orange juice did not intensify the release of metal ions from orthodontic appliances, whereas Coca Cola® caused increased release of Ni ions.

Introduction

Usually, scientific papers dealing with metal ions release from orthodontic appliances in *in vitro* conditions are performed in the environment of artificial saliva [1]. Saliva is known as one of the corrosion causing factors. All other factors present in the oral cavity, like temperature, microflora, saliva flow as well as the effect of the working parameters of the elements of the appliance, like to name just one can also be enhanced by the patient's dietary habits [2]. Corrosion is an electrochemical process whereby in the presence of an electrolyte (saliva), the orthodontic appliance starts to act as an electric cell, in consequence of which metal ions are released.

There is an observable in increase in the consumption of soft sugar-rich, acidic, drinks with some of them containing carbon dioxide, such as fruit juices or Coca Cola® especially among teenagers [3]. Orange juice has vitamins (*e.g.*, vitamin C), phenolic compounds and flavonoids [4]. These compounds have antioxidative properties and consequently may reduce the formation of the passivation layer [5]. Although the disadvantageous effect of these dietary habits on teeth (caries and erosion) has been known for some time now, only a very few reports concerning the effect of soft drinks on solubilization of metal ions from orthodontic appliances have been published [6,7]. The elements that constitute the orthodontic fixed appliances are usually manufactured from stainless steel, which contains approximately 8–12% Ni and 7–22% Cr [8]. Ni in turn is known to trigger more allergic reactions than all other metals [9].

The aim of the present work is the evaluation of soft drink effect on metal ions release from orthodontic appliances under *in vitro* conditions, in a continuous flow system.

Materials and methods

Materials

The evaluated material was a brand new orthodontic appliance consisting of 2 wires (0.017 × 0.025 in., Resilient Orthoform™ III Ovoid, 3M Unitek, Monrovia, CA), 4 bands (size 37+, Victory Series, 3M Unitek, Monrovia), 20 brackets (Victory Series Miniature Mesh Twin Bracket, 3M Unitek, Monrovia), and 20 elastic ligatures (Colored Unistick Ligatures, American Orthodontics). Wires, brackets, and bands were all made of stainless steel. The percentage of particular constituents of the chemical composition formed by the

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http://dx.doi.org/10.1016/j.jtemb.2015.03.007
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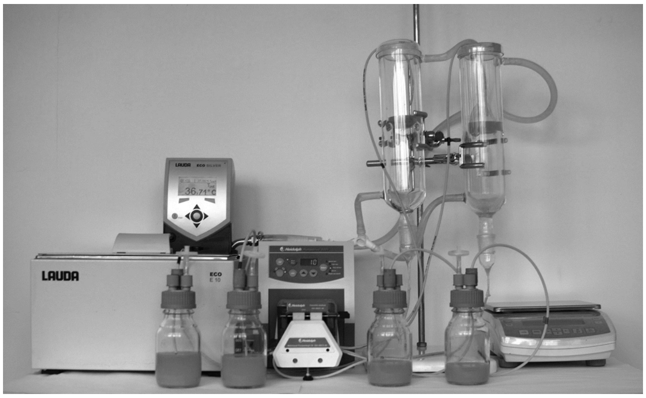

Fig. 1. Experimental system for evaluation of metal ions release from orthodontic appliances.

manufacturer was: brackets (70 Fe, 17 Cr, 4 Ni, 4 Cu, 1 Mn, 1 Si, 0.3 Nb + Ta), bands (65 Fe, 17 Cr, 12 Ni, 2.5 Mo, 2 Mn, 1 Si, 0.045 P, 0.03 C, 0.03 S), and wires (68 Fe, 20 Cr, 9 Ni, 2 Mn, 1 Si, 0.10 N, 0.07 C, 0.045 P, 0.03 S). The experiments were carried out with the use of commercial orange juice (Hortex Holding, Poland) or Coca Cola®, and modified artificial saliva solution as the media flowing through the system. The composition of the modified artificial saliva was described in previous studies [10]. The pH of orange juice and artificial saliva was measured with a pH-meter (SevenMulti, Mettler Toledo, Schwerzenbach, Switzerland) at room temperature.

Release of metal ions into in the vitro system

The *in vitro* system has been described in detail in previous studies [10]. The appliance was placed in a thermostated glass reactor (Fig. 1) with a cover and alternately orange juice/Coca Cola® and artificial saliva solution were made to flow through the system. Orange juice/Coca Cola® (330 mL) was flowing through the system at 37 °C for 5.5 h (1.0 mL min^{-1}) every day, and artificial saliva solution was flowing through the system with a flow rate reflecting the flow of saliva in the human mouth (0.5 mL min^{-1}) at 37 °C for the rest of the day (18.5 h). The experimental conditions of the *in vitro* test are reported in Table 1. The duration of the experiment was 28 days. The samples were collected at the following time intervals after days 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 18, 21, and 28. As a control, orange juice and artificial saliva was made to flow through the system under the same conditions under which the experimental set was operating, but without the orthodontic appliance.

Analytical methods

The samples of artificial saliva and the samples of orange juice and Coca Cola® were mineralized prior to being subjected to an analysis. The orange juice (10 mL) was digested with 5 mL of nitric acid (69% m m^{-1}, Suprapur, Merck, Darmstadt, Germany) in a microwave oven (Milestone, USA). The solution was diluted with re-demineralized water (Simplicity UV, Millipore, Molsheim, France) to 25 mL. The artificial saliva (25 mL) was mineralized with nitric acid (2.5 mL) before the analysis. The Coca Cola® (25 mL) was degassed and partially evaporated, and then digested with concentrated HNO_3 (10 mL). The digested mixture was boiled for 2 h in a covered flask, left to stand overnight, and diluted to 50 mL with re-demineralized water.

The digestion procedure was performed in the following way: (1) artificial saliva: 200 °C, 3 steps, 1000 W (8 min), 0 W (5 min), 1000 W (12 min), (2) orange juice: 200 °C, 3 steps, 1000 W (8 min), 0 W (5 min), 1000 W (12 min), 3) Coca Cola®: microwave digestion was not possible due to the very high calorific value of the material; sand bath digestion in an open system was performed (50 mL was evaporated to the volume of 10 mL; HNO_3 was added and the solution was boiled for 0.5 h and then diluted to 50 mL).

The samples were then analyzed directly by inductively coupled plasma optical emission spectrometry (ICP-OES Vista MPX Varian, Brisbane, Australia) with an ultrasonic nebulizer (U5000AT+, CETAC, Omaha, USA) for the concentration of Cd, Cr, Cu, Fe, Mn, Mo, and Ni ions according to PN-EN ISO 17025 in a certified laboratory (No. AB 696 by Polish Centre for Accreditation, ILAC-MRA). In order to control the stability of the instrument, the check standard procedure was used. CRM was Combined Quality Control Standard UltraScientific with the concentrations: 0.1 and 1 μg mL^{-1}. The detection limit for Cr was 0.00035 mg L^{-1}, and for Ni 0.0018 mg L^{-1}. The samples were analyzed in triplicates (the relative standard deviation of the measurements did not exceed 5%).

Table 1
Experimental setup.

	Orange juice	Coca Cola®	Artificial saliva
pH	3.765	2.465	6.752
Density (g mL^{-1})	1.0402	1.0384	0.9966
Average flow rate (experimental) (mL min^{-1})	1.01 ± 0.10	1.01 ± 0.10	0.51 ± 0.03
Average flow rate (control) (mL min^{-1})	1.01 ± 0.10	0.985 ± 0.110	0.51 ± 0.02
Total volume (experimental) (L)	9.37	9.40	15.8
Total volume (control) (L)	9.35	9.38	16.0

Results

The results of the experiment on the release of metal ions from the orthodontic appliance in time are reported in Fig. 2 (Cr ions) and 3 (Ni ions). The total mass of the released ions (in μg) is presented in Table 1. These data originate from the subtraction of the concentration obtained in the experimental samples (experimental setup with the orthodontic appliance) from the concentration present in the control samples (experimental setup without the orthodontic appliance).

The quantity of released metal ions into the orange juice and Coca Cola® in the present study was compared with the outcomes of previous experiments on artificial saliva [10]. The comparison of various metal ions release kinetics is presented in Figs. 2 and 3. The total mass of solubilized ions is shown in Table 2.

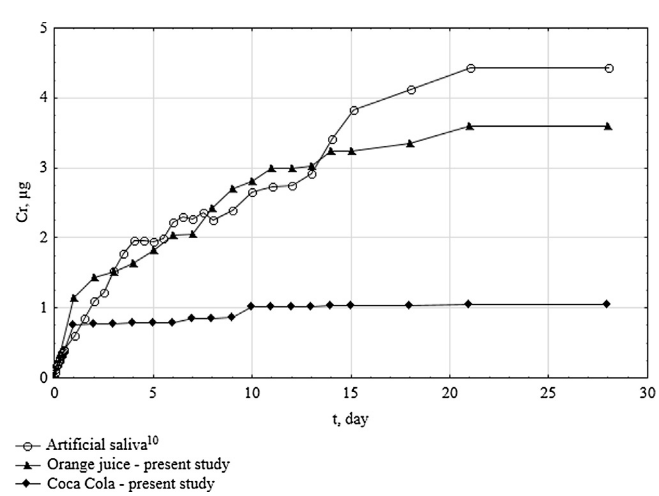

Fig. 2. Kinetics of release of Cr ions from the orthodontic appliance.