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Effect of Some Beverages on the Mechanical Properties of Force and Tension of Orthodontic Archwires: *in vitro* Study

Efecto de Algunas Bebidas sobre las Propiedades Mecánicas de Fuerza y Tensión de los Arcos de Ortodoncia - Estudio *in vitro*

Anna Marina Teixeira Rodrigues Neri; Anna Carollina Pereira Barroso; João Victor Fernandino Sales Diniz Campos; Larissa Doalla de Almeida e Silva; Ângelo Fonseca Silva; Carolina Carvalho de Oliveira Santos; Thiago Fonseca-Silva

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ABSTRACT: The aim of this study was to analyze the mechanical behavior of orthodontic archwires when exposed daily to beverages. During clinical practice, orthodontists constantly observe the biodegradation of orthodontic appliances. The components of orthodontic wires, as they are permanently in contact with the oral cavity, can undergo biochemical changes caused by saliva, beverages, and foods. A sample of 550 orthodontic CrNi steel archwires that were divided into 5 groups according to their caliber, experimental exposure and follow-up time. Each group had a sample of 10 arches (n = 10). The arches were packed in Petri dishes, immersed in artificial saliva and stored in an oven at 37ºC. After 24 hours, they were subjected to daily exposures of 20 minutes in 5 different solutions (artificial saliva, milk, Coca-Cola, lemon juice and coffee). Mechanical tests were performed at three different times: on the first day of the experiment (T0); on the fifteenth day of the experiment (T15); and on the thirtieth day of the experiment (T30). The comparison between the groups for the results of the force and tension tests was adjusted in a Unidirectional Analysis of Variance model and subsequently submitted to the Post-Hoc test for multiple comparisons, adopting a significance level of 95 % ($p<0.05$). Archwires without exposure to food solutions showed higher mean values of force and tension when compared to archwires exposed to the solutions in both T15 and T30 groups. It was observed that orthodontic CrNi archwires, in contact with different solutions, decrease their strength and tension. The orthodontic CrNi steel archwires daily to different beverages showed decrease in the mechanical properties of force and tension of these materials.

KEY WORDS: beverages, orthodontic wires, orthodontics.

INTRODUCTION

Orthodontic treatment performed in the shortest possible time and without causing discomfort to the patient is an ideal condition to obtain satisfactory results in the initial phase of the therapy and, consequently, to achieve success in the results of the treatment (Nimeri *et al*., 2013). The literature emphasizes that it is essential for the orthodontist to have full knowledge of the materials to be used and their mechanical properties to enable the patient to have the best indication for this appliance (Hepdarcan *et al*., 2016).

Orthodontic archwires have been used since the early days of orthodontics. These can be made of various metal alloys, such as silver, gold, and stainless steel. Over the years, there has been a growing evolution in the use of these materials, concomitant with technological advances and the need to increase the efficiency of orthodontic movement (Kapila & Sachdeva, 1989). Stainless steel has long been the material of choice for making orthodontic archwires due to its stiffness, corrosion resistance, and low cost (Srinivasan & Krishnan, 2023). However, this metal alloy did not show good elasticity and, for this reason, it was necessary to discover new alloys to replace it, thus giving rise to chromium-cobalt, nickel-titanium (NiTi), beta-titanium and multifilament alloys (Kusy, 1997).

Postgraduate Program in Dentistry; School of Biological and Health Sciences; Universidade Federal dos Vales do Jequitinhonha e Mucuri – UFVJM; Diamantina, MG, Brazil.

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Currently, nickel-titanium (NiTi) and chromium-nickel (CrNi) alloys, with their variations during the manufacturing process, have been used as eligible materials to manufacture orthodontic archwires. The wires are used in conjunction with the brackets to create orthodontic forces, however, their alloys become unstable in the long run, releasing corroded material into the oral cavity (Ba˛cela *et al*., 2020).

During clinical practice, orthodontists constantly observe the biodegradation of orthodontic appliances (Braun *et al*., 1999). The components of orthodontic wires, as they are permanently in contact with the oral cavity, can undergo biochemical changes caused by saliva. Studies indicate that this medium is a potential agent of corrosion of metal alloys due to the action of electrolytes present in the saliva, such as sodium, potassium, chloride and bicarbonate, as well as their organic components, such as enzymes, immunoglobulins, glycoproteins and albumins (Tahmasbi *et al*., 2015). In addition, the oral cavity has several specific characteristics that favor the biodegradation of metal alloys due to their ionic, thermal, microbiological and enzymatic conditions (Velasco-Ibanez *et al*., 2020).

The patient's diet causes temperature and pH variations in the oral environment, which can be important factors related to the clinical behavior of orthodontic materials (Nanjundan & Vimala, 2016).

Thus, the literature indicates that orthodontic devices in constant contact with acidic beverages undergo an accelerated dissolution of the metal oxide surface layer, caused by thermodynamic instability and the release of iron, zinc, silver, nickel and chromium ions, generating the destruction of the surface of the materials and the occurrence of corrosion (Kim & Johnson, 1999; Amini *et al*., 2008).

In this context, the objective of the present study was to analyze the mechanical behavior of orthodontic archwires when exposed daily to different types of beverages.

MATERIAL AND METHOD

Study design and sample. The present experimental *in vitro* study included a sample of 550 orthodontic CrNi archwires of 0.012", 0.014", 0.016", 0.018", 0.020". The archwires were divided into 5 groups according to their caliber (0.012", 0.014", 0.016", 0.018", 0.020") and redistributed into 5 new groups according to experimental exposure (artificial saliva, milk, Coca-Cola®, fresh lemon juice and coffee). To identify each arch gauge in each group as a function of the experimental exposure, they were marked with a colored line, where each caliber used had a specific line color. Each experimental group had a sample of 10 arches (n = 10). The sample size was defined using the ISO15841:2014 Dentistry - Wires for use in orthodontics.

The orthodontic archwires were packed in petri dishes, immersed in artificial saliva and stored in an oven at 37ºC. After 24 hours of immersion, the archwires were subjected to daily exposures of 20 minutes (Beattie & Monaghan, 2004) in 5 different solutions: saliva, milk, Coca-Cola®, fresh lemon juice and coffee, renewed daily. After daily exposure to the solutions, the arches were washed in artificial saliva and, once more, immersed in new artificial saliva, and stored in an oven at 37ºC, until the next day's test was performed. The mechanical analyses were performed at three different times: group T0, in which the tests were performed on the first day of the experiment, where the orthodontic archwires had not been exposed to any solution; group T15, in which the tests were performed on the fifteenth day of the experiment; and group T30 in which the tests were performed on the thirtieth day of the experiment.

Conditions of the solutions. The preparation of the solutions used in the present study was standardized and maintained under the same conditions of packaging and temperature during all days of the study. The solutions that needed to be prepared were prepared prior to all the experiments, such as fresh lemon juice and coffee.

The composition of the artificial saliva used in the experiment was: methylparaben 2 %, vegetable USP glycerin 10 %, base syrup 40 % and 120ml of CMC gel 0.25 % (Rosa *et al*., 2018). Pasteurized milk (Itambé®, Pará de Minas – MG) has in its formulation whole milk, stabilizers, sodium triphosphate, sodium citrate, monosodium monophosphate, dihydrogen diphosphate and lactose. Coca-Cola® is composed of carbonated water, sugar, kola nut extract, caffeine, IV caramel coloring, phosphoric acid acidulant, and natural flavoring. Fresh lemon juice is composed of alkalizing tonic, vitamin C, bioflavonoids, pectin and potassium and was prepared in the proportion of 50 ml of lemon juice (Citrus aurantifolia) and 200 ml of water (Klimek-Szczykutowicz *et al*., 2020), without added sugar. Coffee (3 Corações®, Santa Luzia – MG) is a roasted and ground coffee bean containing caffeine, chlorogenic acid, caffeic acid, kahweol and antioxidants (de Melo Pereira *et al*., 2020) and was prepared in 250ml of water for 21g of coffee powder. The coffee water was boiled to a temperature of 100ºC, measured with a thermometer, and then the coffee was strained. When it reached 60ºC, the orthodontic archwires were inserted into the solution. The other solutions analyzed were used at room temperature (25ºC).

Specimen making and mechanical testing. To carry out the mechanical tests, two blocks of acrylic resin of 16.6 mm each were made so that the brackets could be bonded later. After the polymerization of the acrylic resin, an Edgewise-type steel bracket, .022mm slot (Morelli®, Sorocaba, São Paulo) was glued to the upper region of each specimen so that the two brackets were parallel to each other, 33 mm apart. The specimens were prepared by a single duly calibrated researcher.

For the mechanical test, the orthodontic archwires were adapted to the brackets parallel to the base of the specimen and stabilized on the specimen with the aid of elastic ligatures. Then, the archwires were subjected to mechanical tests to analyze the force and stress quantities using the EZ-Test-Shimadzu universal testing machine. With the aid of a chisel, located exactly in the middle of the distance between the two brackets (16.5 mm), a load cell of 200 Kgf (kilogram force), and a speed of 1 mm/min in the vertical direction (from top to bottom), the archwires were subjected to stress until they reached bilateral deflection at 45º, with 1 cycle for every 10 wires. As well as the preparation of the specimens, the mechanical tests were also performed by a single previously calibrated researcher (intra-examiner Kappa 0.93-0.98).

Data analysis. The collected data were assessed using SPSS 17.0 for Windows. Normality tests were performed (Kolmogorov-Smirnov). The comparison between the groups for the results of the force and tension tests was adjusted in a Unidirectional Analysis of Variance model and subsequently submitted to the Post-Hoc test for multiple comparisons. The level of significance adopted in the tests was 95 % ($p<0.05$).

RESULTS

The normality test (Kolmogorov-Smirnov) showed that the data from the sample of this study had a normal distribution. The descriptive results of the mechanical tests are shown in Table I. Archwires without exposure to food solutions showed higher mean values of resistance (strength test) and tension when compared to archwires exposed to food solutions in both the T15 and T30 groups.

T0 vs T15 comparison. The comparative results of the mechanical tests were performed using the One-Way ANOVA test and are presented in Table II. When comparing the T0 group with the T15 group, a reduction in the tension of the 0.012-inch arches was observed when exposed to artificial saliva, milk, Coca-Cola®, lemon juice and coffee ($p<0.05$).

The 0.014-inch arches showed reduced strength when exposed to artificial saliva, milk, Coca-Cola®, lemon juice and coffee ($p< 0.05$). The alloy tension was reduced in the presence of artificial saliva and coffee ($p<0.05$).

The 0.016-inch arches showed reduced strength when exposed to artificial saliva ($p<0.05$). The alloy tension was reduced in the presence of artificial saliva, Coca-Cola®, lemon juice, and coffee ($p< 0.05$).

The 0.018-inch arches showed reduced strength when exposed to coffee ($p<0.05$). Arch tension was reduced in the presence of artificial saliva, milk, Coca-Cola®, lemon juice, and coffee ($p< 0.05$).

The 0.020-inch arches showed reduced strength when exposed to artificial saliva, milk, Coca-Cola®, lemon juice, and coffee ($p<0.05$). The alloy tension was reduced in the presence of artificial saliva, Coca-Cola®, lemon juice, and coffee ($p<0.05$).

T0 vs T30 comparison. The comparative results are presented in Table III. When comparing the T0 group with the T30 group, a reduction in the tension of the 0.012-inch arches was observed when exposed to artificial saliva, milk, Coca-Cola®, lemon juice and coffee ($p< 0.05$).

The 0.014-inch arches showed reduced strength when exposed to artificial saliva, milk, Coca-Cola®, lemon juice and coffee ($p< 0.05$). The alloy tension was reduced in the presence of artificial saliva and coffee ($p<0.05$).

The 0.016-inch arches showed reduced strength when exposed to artificial saliva and Coca-Cola® ($p< 0.05$). The alloy tension was reduced in the presence of artificial saliva, milk, Coca-Cola®, lemon juice, and coffee ($p< 0.05$).

Table I. Descriptive analysis of the strength and tension of CrNi orthodontic archwires exposed to different food solutions at T15 and T30.

	ANALYSIS IN T15				ANALYSIS IN T30			
		Arch	Mean	Standard deviation		Arch	Mean	Standard deviation
MAXIMUM FORCE	**No exposure**	0.012”	5.698	2.613	**No exposure**	0.012”	5.698	2.613
		0.014”	8.846	1.265		0.014”	8.846	1.265
		0.016”	8.396	0.825		0.016”	8.396	0.825
		0.018”	11.381	1.278		0.018”	11.381	1.278
		0.020”	17.667	1.216		0.020”	17.667	1.216
	Artificial saliva	0.012”	3.050	2.000	**Artificial saliva**	0.012”	2.875	2.000
		0.014”	4.425	2.000		0.014”	4.275	2.000
		0.016”	5.400	2.000		0.016”	5.350	2.000
		0.018”	8.950	2.000		0.018”	7.550	2.000
		0.020”	12.425	2.000		0.020”	13.700	2.000
	Milk	0.012”	3.400	2.000	**Milk**	0.012”	2.650	2.000
		0.014”	5.275	2.000		0.014”	4.700	2.000
		0.016”	7.925	2.000		0.016”	6.350	2.000
		0.018”	10.425	2.000		0.018”	9.025	2.000
		0.020”	14.150	2.000		0.020”	14.500	2.000
	Coca-Cola	0.012”	3.475	2.000	**Coca-Cola**	0.012”	3.125	2.000
		0.014”	5.125	2.000		0.014”	4.800	2.000
		0.016”	6.000	2.000		0.016”	5.575	2.000
		0.018”	9.525	2.000		0.018”	8.150	2.000
		0.020”	12.700	2.000		0.020”	13.075	2.000
	Lemon juice	0.012”	3.150	2.000	**Lemon juice**	0.012”	2.625	2.000
		0.014”	4.775	2.000		0.014”	4.700	2.000
		0.016”	6.375	2.000		0.016”	6.450	2.000
		0.018”	9.500	2.000		0.018”	9.975	2.000
		0.020”	13.475	2.000		0.020”	16.450	2.000
	Coffee	0.012”	3.025	2.000	**Coffee**	0.012”	2.850	2.000
		0.014”	4.300	2.000		0.014”	4.525	2.000
		0.016”	5.650	2.000		0.016”	6.175	2.000
		0.018”	8.425	2.000		0.018”	9.200	2.000
		0.020”	11.325	2.000		0.020”	14.275	2.000
MAXIMUM TENSION	**No exposure**	0.012”	8.128	1.715	**No exposure**	0.012”	8.128	1.715
		0.014”	9.277	3.164		0.014”	9.277	3.164
		0.016”	13.018	3.799		0.016”	13.018	3.799
		0.018”	18.926	2.287		0.018”	18.926	2.287
		0.020”	20.977	3.948		0.020”	20.977	3.948
	Artificial saliva	0.012”	3.877	2.000	**Artificial saliva**	0.012”	3.654	2.000
		0.014”	5.625	2.000		0.014”	5.434	2.000
		0.016”	6.864	2.000		0.016”	6.800	2.000
		0.018”	11.377	2.000		0.018”	9.597	2.000
		0.020”	15.794	2.000		0.020”	17.415	2.000
	Milk	0.012”	4.322	2.000	**Milk**	0.012”	3.368	2.000
		0.014”	6.705	2.000		0.014”	5.974	2.000
		0.016”	10.074	2.000		0.016”	8.072	2.000
		0.018”	13.252	2.000		0.018”	11.472	2.000
		0.020”	17.987	2.000		0.020”	18.432	2.000
	Coca-Cola	0.012”	4.417	2.000	**Coca-Cola**	0.012”	3.972	2.000
		0.014”	6.514	2.000		0.014”	6.101	2.000
		0.016”	7.627	2.000		0.016”	7.089	2.000
		0.018”	12.108	2.000		0.018”	10.360	2.000
		0.020”	16.144	2.000		0.020”	16.621	2.000
	Lemon juice	0.012”	4.004	2.000	**Lemon juice**	0.012”	3.336	2.000
		0.014”	6.070	2.000		0.014”	5.974	2.000
		0.016”	8.103	2.000		0.016”	8.199	2.000
		0.018”	12.076	2.000		0.018”	12.680	2.000
		0.020”	17.129	2.000		0.020”	20.911	2.000
	Coffee	0.012”	3.845	2.000	**Coffee**	0.012”	3.622	2.000
		0.014”	5.466	2.000		0.014”	5.752	2.000
		0.016”	7.182	2.000		0.016”	7.849	2.000
		0.018”	10.709	2.000		0.018”	11.695	2.000
		0.020”	14.396	2.000		0.020”	18.146	2.000

Statistically significant values (p<0.05).

Table II. (CrNi T0-T15): Comparative analysis of the resistance and shear stress between orthodontic archwires exposed to different food solutions over a 15-day interval.

				Confidence interval (95 %)	
MAXIMUM FORCE		**Mean**	**"p" value**	**Minimum**	**Maximum**
No exposure 0.012''	Artificial saliva 0.012''	2.6485333	0.146	-0.501754	5.798821
	Milk 0.012''	2.2985333	0.311	-0.851754	5.448821
	Coca-Cola 0.012''	2.2235333	0.365	-0.926754	5.373821
	Lemon juice 0.012''	2.5485333	0.182	-0.601754	5.698821
	Coffee 0.012''	2.6735333	**0.139**	-0.476754	5.823821
No exposure 0.014''	Artificial saliva 0.014''	4.4210000*	**0.001**	1.588427	7.253573
	Milk 0.014''	3.5710000*	**0.009**	0.738427	6.403573
	Coca-Cola 0.014''	3.7210000*	**0.007**	0.888427	6.553573
	Lemon juice 0.014''	4.0710000*	**0.003**	1.238427	6.903573
	Coffee 0.014''	4.5460000*	**0.001**	1.713427	7.378573
No exposure 0.016''	Artificial saliva 0.016''	2.9964000*	**0.029**	0.225128	5.767672
	Milk 0.016''	0.4714000	1.000	-2.299872	3.242672
	Coca-Cola 0.016''	2.3964000	0.124	-0.374872	5.167672
	Lemon juice 0.016''	2.0214000	0.311	-0.749872	4.792672
	Coffee 0.016''	2.7464000	0.053	-0.024872	5.517672
No exposure 0.018''	Articial saliva 0.018''	2.4310000	0.129	-0.397699	5.259699
	Milk 0.018''	0.9560000	1.000	-1.872699	3.784699
	Coca-Cola 0.018''	1.8560000	0.508	-0.972699	4.684699
	Lemon juice 0.018''	1.8810000	0.479	-0.947699	4.709699
	Coffee 0.018''	2.9560000*	**0.037**	0.127301	5.784699
No exposure 0.020''	Artificial saliva 0.020''	5.2426000*	**0.000**	2.410541	8.074659
	Milk 0.020''	3.5176000*	**0.010**	0.685541	6.349659
	Coca-Cola 0.020''	4.9676000*	**0.001**	2.135541	7.799659
	Lemon juice 0.020''	4.1926000*	**0.002**	1.360541	7.024659
	Coffee 0.020''	6.3426000*	**0.000**	3.510541	9.174659
MAXIMUM TENSION					
No exposure 0.012''	Artificial saliva 0.012''	4.2516733*	**0.003**	1.338730	7.164617
	Milk 0.012''	3.8067667*	**0.007**	0.893823	6.719710
	Coca-Cola 0.012''	3.7114533*	**0.008**	0.798510	6.624397
	Lemon juice 0.012''	4.1245667*	**0.004**	1.211623	7.037510
	Coffee 0.012''	4.2834667*	**0.003**	1.370523	7.196410
No exposure 0.014''	Artificial saliva 0.014''	3.6523400*	**0.027**	0.309845	6.994835
	Milk 0.014''	2.5718300	0.237	-0.770665	5.914325
	Coca-Cola 0.014''	2.7625233	0.161	-0.579972	6.105019
	Lemon juice 0.014''	3.2074333	0.066	-0.135062	6.549929
	Coffee 0.014''	3.8112400*	**0.020**	0.468745	7.153735
No exposure 0.016''	Artificial saliva 0.016''	6.1538300*	**0.001**	2.585247	9.722413
	Milk 0.016''	2.9440333	0.163	-0.624550	6.512616
	Coca-Cola 0.016''	5.3911233*	**0.002**	1.822540	8.959706
	Lemon juice 0.016''	4.9144233*	**0.004**	1.345840	8.483006
	Coffee 0.016''	5.8360300*	**0.001**	2.267447	9.404613
No exposure 0.018''	Artificial saliva 0.018''	7.5491333*	**0.000**	4.488671	10.609596
	Milk 0.018''	5.6741333*	**0.000**	2.613671	8.734596
	Coca-Cola 0.018''	6.8182333*	**0.000**	3.757771	9.878696
	Lemon juice 0.018''	6.8499333*	**0.000**	3.789471	9.910396
	Coffee 0.018''	8.2165333*	**0.000**	5.156071	11.276996
No exposure 0.020''	Artificial saliva 0.020''	5.1828667*	**0.003**	1.554936	8.810797
	Milk 0.020''	2.9899667	0.164	-0.637964	6.617897
	Coca-Cola 0.020''	4.8332667*	**0.006**	1.205336	8.461197
	Lemon juice 0.020''	3.8480667*	**0.033**	0.220136	7.475997
	Coffee 0.020''	6.5811667*	**0.000**	2.953236	10.209097

Statistically significant values (p<0.05).

Table III. (CrNi T0-T30): Comparative analysis of the resistance and shear stress between orthodontic archwires exposed to different food solutions over a 30-day interval.

				Confidence interval (95%)	
MAXIMUM FORCE		Mean	"p" value	Minimum	Maximum
No exposure 0.012''	Artificial saliva 0.012"	2.8235333	0.100	-0.326754	5.973821
	Milk 0.012"	3.0485333	0.062	-0.101754	6.198821
	Coca-Cola 0.012"	2.5735333	0.172	-0.576754	5.723821
	Lemon juice 0.012"	3.0735333	0.059	-0.076754	6.223821
	Coffee 0.012"	2.8485333	0.095	-0.301754	5.998821
No exposure 0.014''	Artificial saliva 0.014"	4.5710000*	**0.001**	1.738427	7.403573
	Milk 0.014"	4.1460000*	**0.003**	1.313427	6.978573
	Coca-Cola 0.014"	4.0460000*	**0.003**	1.213427	6.878573
	Lemon juice 0.014"	4.1460000*	**0.003**	1.313427	6.978573
	Coffee 0.014"	4.3210000*	**0.002**	1.488427	7.153573
No exposure 0.016''	Artificial saliva 0.016"	3.0464000*	**0.026**	0.275128	5.817672
	Milk 0.016"	2.0464000	0.293	-0.724872	4.817672
	Coca-Cola 0.016"	2.8214000*	**0.044**	0.050128	5.592672
	Lemon juice 0.016''	1.9464000	0.373	-0.824872	4.717672
	Coffee 0.016"	2.2214000	0.191	-0.549872	4.992672
No exposure 0.018''	Artificial saliva 0.018"	3.8310000*	**0.005**	1.002301	6.659699
	Milk 0.018"	2.3560000	0.154	-0.472699	5.184699
	Coca-Cola 0.018"	3.2310000*	**0.020**	0.402301	6.059699
	Lemon juice 0.018"	1.4060000	1.000	-1.422699	4.234699
	Coffee 0.018"	2.1810000	0.235	-0.647699	5.009699
No exposure 0.020''	Artificial saliva 0.020"	3.9676000*	**0.004**	1.135541	6.799659
	Milk 0.020"	3.1676000*	**0.023**	0.335541	5.999659
	Coca-Cola 0.020"	4.5926000*	**0.001**	1.760541	7.424659
	Lemon juice 0.020"	1.2176000	1.000	-1.614459	4.049659
	Coffee 0.020"	3.3926000*	**0.014**	0.560541	6.224659
MAXIMUM TENSION					
No exposure 0.012''	Artificial saliva 0.020"	4.4741633*	**0.002**	1.561220	7.387107
	Milk 0.020"	4.7601700*	**0.001**	1.847227	7.673113
	Coca-Cola 0.020"	4.1563600*	**0.003**	1.243417	7.069303
	Lemon juice 0.020"	4.7919633*	**0.001**	1.879020	7.704907
	Coffee 0.020"	4.5059567*	**0.002**	1.593013	7.418900
No exposure 0.014''	Artificial saliva 0.014"	3.8430333*	**0.019**	0.500538	7.185529
	Milk 0.014"	3.3027467	0.054	-0.039749	6.645242
	Coca-Cola 0.014"	3.1756400	0.070	-0.166855	6.518135
	Lemon juice 0.014"	3.3027467	0.054	-0.039749	6.645242
	Coffee 0.014"	3.5252333*	**0.035**	0.182738	6.867729
No exposure 0.016''	Artificial saliva 0.016"	6.2173500*	**0.001**	2.648767	9.785933
	Milk 0.016"	4.9461500*	**0.004**	1.377567	8.514733
	Coca-Cola 0.016"	5.9286333*	**0.001**	2.360050	9.497216
	Lemon juice 0.016''	4.8190433*	**0.005**	1.250460	8.387626
	Coffee 0.016"	5.1686367*	**0.003**	1.600054	8.737220
No exposure 0.018''	Artificial saliva 0.018"	9.3288333*	**0.000**	6.268371	12.389296
	Milk 0.018"	7.4538333*	**0.000**	4.393371	10.514296
	Coca-Cola 0.018"	8.5661333*	**0.000**	5.505671	11.626596
	Lemon juice 0.018"	6.2461333*	**0.000**	3.185671	9.306596
	Coffee 0.018"	7.2313333*	**0.000**	4.170871	10.291796
No exposure 0.020''	Artificial saliva 0.020"	3.5620667	0.056	-0.065864	7.189997
	Milk 0.020"	2.5450667	0.375	-1.082864	6.172997
	Coca-Cola 0.020"	4.3565667*	**0.013**	0.728636	7.984497
	Lemon juice 0.020"	0.0662667	1.000	-3.561664	3.694197
	Coffee 0.020"	2.8310667	0.220	-0.796864	6.458997

Statistically significant values ($p<0.05$).

The 0.018-inch arches showed reduced strength when exposed to artificial saliva and Coca-Cola® ($p < 0.05$). Thread tension was reduced in the presence of artificial saliva, milk, Coca-Cola®, lemon juice, and coffee ($p < 0.05$).

The 0.020-inch arches showed reduced strength when exposed to artificial saliva, milk, Coca-Cola® and coffee ($p < 0.05$). The alloy tension was reduced in the presence of Coca-Cola® ($p < 0.05$).

DISCUSSION

To achieve a successful orthodontic treatment, it is important that the materials used during this process maintain their properties and distribute forces and reactions on the teeth in a controlled way (Nanjundan & Vimala, 2016). In the present study, it was observed that orthodontic CrNi archwires, in contact with different solutions, decrease their strength and tension compared to archwires that did not suffer such exposure.

It is believed that the ingestion of food solutions may be associated with the corrosion of orthodontic archwires and, consequently, generate changes in their physicomechanical properties, resulting in a reduction in the strength, tension and deformability of the wires. As demonstrated in a previous study, corrosion of brackets and orthodontic archwires was associated with exposure to beverages with varying levels of acidity, including Pepsi® soft drink, in which as the acidity increased with the consumption of the liquid, the pH of the artificial saliva decreased, generating breakage of the surface of the materials, and increasing frictional forces (Nanjundan & Vimala, 2016).

Another relevant factor is the presence and action of metal ions on the orthodontic archwires. The exposure of the wires to soft drinks, such as Coca-Cola®, causes the release of metal ions, especially Ni ions, which results in the activation of cathodic corrosion and the consequent oxidation reaction of the arches. In this context, the passive oxide layer undergoes an additional action of protons in the acidic environment, resulting in the extraction of metal ions and, consequently, the reduction of the resistance of the wires (Mikulewicz *et al*., 2015).

The results analyzed when exposing the orthodontic archwires to artificial saliva, where there was a decrease in force and tension in all wire diameters used, can be explained by the fact that the oral cavity provides an environment that allows aqueous corrosion in metals and alloys to occur easily (Amini *et al*., 2008). Saliva has a neutral pH (between 6.8 and 7.2), presenting itself as an electrolyte and a medium for chemical reactions between metals that can lead to the formation of corrosion, which affects the surface properties of the wires, such as roughness and texture (Hobbelink *et al*., 2015). In addition, artificial saliva can cause an increase in surface roughness and, thus, accelerate arch corrosion (Huang *et al*., 2003).

Although saliva has a pH that tends to be neutral, the fact that there are welding points in the arches contributes to corrosion since these structures tend to emit electrogalvanic currents along with artificial saliva, causing the release of metal ions (House *et al*., 2008). In addition, it is known that artificial saliva has elements such as phosphorus and calcium, which favor the occurrence of a greater corrosive attack, as shown by its constituents and the residues of the welding of orthodontic archwires (Tahmasbi *et al*., 2015, 2017).

Shahabi *et al*. (2011) compared the corrosion of brackets exposed to artificial saliva with solutions of lemon juice, Coca-Cola®, and vinegar. Coca-Cola® produced a higher and faster corrosion compared to lemon juice, which presented insignificant corrosion in the first week, which accelerated and remained constant in the following weeks (Hobbelink *et al*., 2015). In this study, there was no significant difference between the pH of lemon juice (2.7) and the pH of Coca-Cola® (2.5), which indicates that parameters other than acidity may be involved with the corrosion process and should be investigated, such as the concentration of fluoride ions in the solution. The pH of milk is slightly acidic, ranging between 6.6 and 6.8, and the pH of coffee has an average of 4.9 and 5.1, also considered acidic (Sivetz & Desrosier, 1979). These solutions have a superhydrophobicity against some metals, which is defined when the angle of contact with water is greater than 150º with a sliding angle of less than 10º (Yuan *et al*., 2020). In addition, since they are acidic beverages, their behavior can be compared with that of the other solutions that were analyzed, where a greater and more accelerated corrosion process of the orthodontic archwires is observed due to their properties.

When the wires are exposed to different acidic or alkaline substances, there are chemical changes in the surface and structure that affect the clinical efficacy of the metal alloys (Pop *et al*., 2017). No scientific evidence was found on the influence of the ingestion of food solutions with an impact on the mechanical properties of orthodontic archwires and the consequences on time and efficiency of orthodontic movement, however, there are indications that food solutions can interfere with the mechanical efficiency of the wires and consequently generate negative repercussions on the treatment, such as the loss of optimal strength to stimulate tooth movement. The findings of the present study suggest that there is a need to change orthodontic archwires more frequently, with shorter time intervals, to prevent corrosion from impacting the expected mechanical result.

The limitations of the present study are related to the study design itself and the reduced spectrum of food solutions tested. In addition, the substances were used in isolation, which does not simulate a real oral environment since the exposure products come into contact with the mouth and wires along with other solutions and food. Because it does not simulate a real oral environment, another limitation of this study is that the results are underestimated since it cannot be said that they are consistent with clinical reality. Therefore, it is important to emphasize that in vivo studies and clinical trials should be carried out to determine the impact of mechanical alteration of the archwires exposed to the oral environment on the efficiency of orthodontic treatment.

CONCLUSION

It is concluded that when the orthodontic CrNi arch wires are exposed daily to different beverages, there is a change in the mechanical properties of the force and tension of these materials.

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NERI, A. M. T. R.; BARROSO, A. C. P.; CAMPOS, J. V. F. S. D.; E SILVA, L. D. A.; SILVA, A. F.; SANTOS, C. C. O. & FONSECA-SILVA, T. Efecto de algunas bebidas sobre las propiedades mecánicas de fuerza y tensión de los arcos de ortodoncia - estudio *in vitro*. *Int. J. Odontostomat., 18(4)*:393-401, 2024.

RESUMEN: El objetivo de este estudio fue analizar el comportamiento mecánico de los arcos de ortodoncia cuando se exponen diariamente a bebidas. Durante la práctica clínica, los ortodoncistas observan constantemente la biodegradación de los aparatos de ortodoncia. Los componentes de los alambres de ortodoncia, por estar en contacto permanente con la cavidad oral, pueden sufrir cambios bioquímicos provocados por la saliva, bebidas y alimentos. Se utilizó una muestra de 550 arcos de acero CrNi para ortodoncia, que se dividieron en 5 grupos según su calibre, exposición experimental y tiempo de seguimiento. Cada grupo contó con una muestra de 10 arcos (n=10). Los arcos fueron empacados en placas Petri, sumergidos en saliva artificial y almacenados en estufa a 37 ºC. Luego de 24 horas, fueron sometidos a exposiciones diarias de 20 minutos en 5 soluciones diferentes (saliva artificial, leche, Coca-Cola, jugo de limón y café). Las pruebas mecánicas se realizaron en tres momentos diferentes: el primer día del experimento (T0); el decimoquinto día del experimento (T15); y el trigésimo día del experimento (T30). La comparación entre los grupos para los resultados de las pruebas de fuerza y tensión fue ajustada en un modelo de Análisis de Varianza Unidireccional y posteriormente sometida a la prueba Post-Hoc para comparaciones múltiples, adoptando un nivel de significancia del 95 % ($p<0{,}05$). Los arcos sin exposición a soluciones alimenticias mostraron mayores valores medios de fuerza y tensión en comparación con los arcos expuestos a las soluciones en los grupos T15 y T30. Se observó que los arcos de ortodoncia CrNi, en contacto con diferentes soluciones, disminuyen su fuerza y tensión. Los arcos de ortodoncia de acero CrNi expuestos diariamente a diferentes bebidas mostraron disminución en las propiedades mecánicas de fuerza y tensión de estos materiales.

PALABRAS CLAVE: bebidas, alambres de ortodoncia, ortodoncia.

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Corresponding author:
Prof. Dr. Thiago Fonseca-Silva
D.D.S. M.Sc. Ph.D.
Department of Dentistry
Division of Orthodontics
School of Biological and Health Sciences
Universidade Federal dos Vales do Jequitinhonha e Mucuri – UFVJM
Rua da Glória, 187
Diamantina
Minas Gerais 39100-000
BRAZIL

E-mail: thiagofonsecasilva@gmail.com