

An Investigation About The Effects Of Fizzy Drinks On The Mechanical Properties Of Orthodontic Archwires

Dr. Delaram Fazli¹, Dr. Ahmad Sheibani Nia^{2*}, Dr. Mustafa Fatemi³

¹ Orthodontist (Private practice) No. 9, 9th Neyestan St. Pasdaran Ave. Tehran/ Iran. P. O. Box: 19585175. Email: delaram.f@me.com

² Associate Professor, Fellowship of Orthosurgery, Department of Orthodontic, Islamic Azad University, Dental School, Tehran Branch, Tehran, Iran. Email: Asheibaninia@yahoo.com

³ Dr. Seyyed Mostafa Fatemi - assistant professor of Shaid Beheshti dental school. Email: drfatemi@gmail.com

*Corresponding Author:
Ahmad Sheibani Nia,

Associate Professor, Fellowship of Orthosurgery, Department of Orthodontic, Islamic Azad University, Dental School, Tehran Branch, Tehran, Iran, Email: Asheibaninia@yahoo.com

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Abstract

Background and aim: One of the problems in fixed orthodontic treatments is the changes that occur in the mechanical properties of the orthodontic wires. The presence of surface roughness on orthodontic wires can affect the corrosion, friction, dental movement, biocompatibility, and esthetic. On the other hand, changes in the mechanical properties of used arch wires can influence the final results; also, cause tips, torque, and unwanted dental movements. Thus, this study addresses the evaluation and the measurement of the influence of the fizzy (carbonated drinks) on the mechanical properties of nickel titanium and stainless steel wires.

Method and material: The research was done experimentally on a NiTi and stainless steel wires. To do this, ten-round-orthodontic wire packages, with a diameter of 0.014 inches, rectangular (0.016*0.022 inches) were purchased from American Orthodontics (AO) company and were prepared in 2.5 centimeters pieces. The samples were cleaned with alkaline solution and then mechanical properties of the wires such as yield strength, ultimate tensile strength and load deflection rate were tested by mechanical properties tensile testing machine and 3-point bending test. The samples were arranged in groups: 1- stainless steel rectangular 0.016*0.022. 2- stainless steel round 14. 3- Nickel titanium rectangular 0.016*0.022. 4- Nickel titanium round 14. The samples were chosen randomly. All the samples, initially, were inserted in plastic vial contains of 10 milliliter of carbonated drinks (pH = 2.74) for 5 minutes and then, were inserted in artificial saliva with pH = 7. The process was daily repeated for 30 days. Eventually, the same mechanical properties were re-evaluated and compared with the original amount, before the intervention.

Results: The statistical analysis of YS and LDR in the first group became significant ($P = 0.037$ and $P < 0.001$). In the second group, the YS and LDR was significant too ($P < 0.001$). The rate of changes on YS and LDR in the third and the fourth group were not significant. The rate of changes of UTS were not significant in any group ($P < 0.6$). Also, in intragroup comparison, the differences of YS, UTS, and LDR, before inserting the wires, in carbonated drinks showed that each variable in group 1 was more than the others. In group 2 was more than 3 and 4. In group 3 was more than group 4 significantly ($P < 0.001$). The findings were also the same, after placing, the samples in the carbonated drinks ($P < 0.001$).

Conclusion: It should be noted that limited studies were performed on the effects of fizzy drinks on the mechanical properties of the orthodontics wires. Based on the findings of this study, it can be concluded that the carbonated drinks can affect the mechanical properties and the treatment duration.

Keywords: Archwire, Mechanical Properties, Load Deflection Rate, Ultimate Tensile Strength, Yield Strength, Nickel Titanium, Orthodontic Treatment, Stainless Steel, Three-Point Bending Test.

INTRODUCTION

One of the problems in fixed orthodontic treatments is the change in the mechanical properties of orthodontic wires (1-3). Archwires are one of the components of orthodontic devices that are widely used for treatment today (4, 5). The presence of surface irregularities on orthodontic wires can affect corrosion, friction, tooth movements,

tissue compatibility and aesthetics(2, 3) . Also, any other changes in the mechanical properties of the used archwires can affect the final results of the treatment and cause tip or torque and unwanted dental movements (4, 6). The significant features that must be considered in orthodontic wires in order to apply optimal forces, during treatment, are: load deflection rate, yield strength and ultimate tensile strength (7-9). Additionally, dental materials must resist mechanical, chemical and thermal stresses in the patients' oral cavity and have sufficient compatibility with the aggressive environment in it (9). Although a number of studies have been focused on mechanical properties of transformational phases of NiTi, there is less information in those properties and most studies were concerned about, only, one property of them (10-12). Recently, due to the diversity of diets, drinks, containing preservatives and carbonated substances, mouthwashes and their chemical compounds, the mechanical properties of dental materials and orthodontic wires are affected (11, 12). Several studies have been conducted on the effects of mouthwashes and fluoride contained products on the mechanical properties of all types of wires and brackets and the amount of friction between the wires and the orthodontic bracket. These mouthwashes increase the surface roughness and friction between the wires and the brackets. Although there is not any detailed report about the changes in the level of surface roughness and the changes in the mechanical properties of orthodontic wires in the vicinity of these chemical solutions, foods and carbonated drinks in a period of one month (which is the usual time for arch replacement (13-15). Carbon dioxide is the main effective substance for carbonizing these drinks. This type of acid can cause corrosion in dental structures, dental materials, changes in the mechanical and chemical properties of orthodontic archwires(16, 17). Considering a high prevalence rate of addition to fixed orthodontic treatments in teenagers and a high consumption percentage of carbonated soft drinks in the country in recent years (18), the effect of this substance on the mechanical properties of orthodontic archwires is crucial (19). taking the importance of the foresaid matter and a trifle number of studies in this field, on the one hand, and price differences among wires from a variety manufacturing companies, on the other hand, the purpose of this research was to investigate the effects of carbonated fizzy on the mechanical properties of orthodontic archwires in the Faculty of Dentistry of Islamic Azad University in 2019-2021.

Materials and Methods:

This research is a single blind experimental study done on stainless steel wires with a size of 0.014 , 0.016 * 0.022 and nickel titanium wires with a size of 0.014 and 0.016 * 0.022 purchased from American Orthodontics (AO). To calculate the sample size, its formula used to compare multiple means. The alpha error considered 1% and the study power 90%. The sample size was calculated based on the study of Hafez et al. 9 people for each group. Eventually, taking a 10% chance of sample dropping into account, a sample size of 10 was considered for each group (16).

$$\begin{aligned} \bar{\mu} &= \frac{1}{k} \sum_{j=1}^k \mu_j^1 = \frac{1}{4} (12.29 + 5.07 + 6.23 + 5.47) = \frac{29.06}{4} = 7.26 \\ \Delta &= \frac{1}{\sigma^2} \sum_{i=1}^k (\mu_i - \bar{\mu})^2 \\ &= \frac{1}{4.14^2} ((12.29 - 7.26)^2 + (5.07 - 7.26)^2 + (6.23 - 7.26)^2 + (5.47 - 7.26)^2) \\ &= \frac{1}{4.14^2} (5.03^2 + 2.19^2 + 1.03^2 + 1.79^2) = \frac{34.35}{17.13} = 2.03 \\ n &= \frac{\lambda_{g,\alpha,1-\beta}}{\Delta} = \frac{17.43}{2.03} = 8.58 \sim 9 \end{aligned}$$

After going through the process of approving the project in the ethical scientific committee of Tehran Islamic Azad University of Medical Sciences, it received the ethics code (IR.IAU.DENT.REC.1399.088). 10 orthodontic-wire-Packages with the following features were purchased from American Orthodontics (AO) in Iran:

- 1) Material, nickel titanium and stainless steel.
- 2) Shape, circle with a diameter of 0.014 and rectangle with dimensions of 0.016 * 0.022.
- 3) Length, initially, 4-centimeter pieces were prepared from the flat parts of the arch wires, then they were reduced to 2.5 centimeters according to the proper distance between the device's legs.

The researchers' assumption, in this research, was the fact that, the process of making and polishing wires by the manufacturing factory was the same. In order for the tester not to notice the markings and coding on the wires, each wire was, first, prepared with a length of 4 cm. Then, we cleaned the samples with an alkaline solution to

remove spots of grease, mineral and organic substances. Before placing the samples in fizzy drinks, the mechanical properties of the wires such as strength, ultimate tensile strength and load deflection rate were measured by tensile testing machine (Instron model 3345-England) through three-point bending test. To prevent moving in the brackets, they were fixed by wax in the support. Then wires were held in the brackets with O-rings. Although a kind of friction will be produced in the brackets, it will be ignorable, since all the samples were put in them. To perform the three-point bending test, the chosen wire was placed on the support from both sides (Figure 1-3). To create a 3mm deflection in the samples, force was applied to the middle of the wire; Initial values (before the intervention) in 10 tested samples in each group were subjected to Cronbach's alpha test and the data distribution was normal.

First, 4-centimeter pieces of the flat part of the arch wires were prepared. They were immersed in a plastic vial containing 10 ml of fizzy drinks (Coca-Cola pH = 2.74) for 5 minutes. Then they were placed in artificial saliva made in the laboratory of dental materials of Tehran University with pH = 7 as a standard medium. The composition of this artificial saliva is as follows:

Sodium Chloride, Potassium Chloride, Disodium Hydrogen Phosphate, Urea, Calcium Chloride, 1-Hydrate Sodium sulfide, Distilled Water.

The process was repeated for 30 consequent days and the fizzy drinks were changed every day. It should be noted that the test process was carried out at a temperature of 37 degrees in an incubator. According to the appropriate distance between the bases of the machine, the samples were reduced to 2.5-centimeter pieces. The three-point bending test was performed again. The yield strength, ultimate tensile strength, and load deflection rate were measured with the same initial method and the value was compared with previous one, before the intervention.

In this research, the collected data of the measurement was coded first. The initial values (before the intervention) in 10 tested samples in each group were subjected to one-way analysis of variance. Then the normal distribution of the data and the esthetical analysis were analyzed and checked by using SPSS 21 software (IBM Crop., Armonk, NK, USA). Mean and standard deviation were used to describe quantitative variables. Also, qualitative variables were described based on the number and the percentage. The normal distribution of the quantitative data of the study was measured using skewness and crookedness values, Q-Q Plot. Shapiro and Wilk test was performed too. Then, according to the normality of the distribution of quantitative variables, ANOVA test and Bonferroni Post Hoc test were used to compare YS, LDR and UTS among study groups at each time point. Also, paired T-test was used to compare these three variables for different time points in each group. The significance levels of the tests were considered ($P < 0.05$).

Results:

In this study, the effects of fizzy drinks on the mechanical properties of 40 orthodontic wires were studied. 10 stainless steel orthodontic wires 0.016 * 0.022 for the first group, 10 stainless steel orthodontic wires 0.014 for the second group, 10 nickel titanium wires 0.016 * 0.022 for the third group and finally, 10 nickel titanium wires 0.014 for the last group. Initial values (before intervention) in 10 tested samples in each group were subjected to Cronbach's alpha test and the data distribution was normal. The amount of change in YS and LDR, in the first and second group, was significant ($P > 0.001$) (Table 4-2). These two variables were not decreased significantly in the third and the fourth group ($P = 0.437$, $P = 0.161$, $P = 0.070$ and $P = 0.110$). the changes in UTS were not significant in any group ($P = 0.751$, $P = 0.527$, $P = 0.707$, $P = 0.848$) (Table 1).

All three variables were significant among the first, second, third and the fourth group before and after being exposed to fizzy drinks ($P > 0.001$). In a way that, the first group was significantly more than the other groups, the second group was significantly more than the third and the fourth, and finally, in the third group, it was significantly more than the fourth group (Table 1).

Table1: The amount of change in the characteristics of stainless steel and nickel titanium wires according to the indicators, by wire size and stages

Mechanical Properties		Yield strength (MPa)	Load deflection rate (MPa)	Ultimate tensile strength (MPa)
Stages				
.016*0.022 SS	Before	2935.06 ± 3.82	133230.6 ± 862.96	3344.22 ± 3.85
	After	2900.66 ± 6.66	132739.1 ± 861.16	3310.84 ± 5.13
	Changes	34.4 ± 2.84	491.5 ± 1.80	33.37 ± 1.28
	Test	0.037	<0.001	0.751
0.014 SS	Before	±1881.02 2.01	111925.5 ± 428.88	2253.19 ± 1.68
	After	1876.46 ± 3.68	111815.7 ± 432.85	2230.88 ± 3.44
	Changes	4.56 ± 1.67	±109.8 4.03	22.31 ± 2.36
	Test	0.001	<0.001	0.527
016*0.022 NiTi	Before	917.27 1.45±	23053.2 ± 65.38	1324.27 1.44±
	After	886.75 ± 4.28	22763.3 130.41±	1288.5 3.78±
	Changes	30.51 ± 2.83	289.9 ± 65.03	35.76 ± 2.34
	Test	0.437	0.161	0.707
0.014 NiTi	Before	±323.84 0.64	±6745.3 22	±544.21 0.54
	After	305.36 ± 4.36	6236.2 57.15±	2518.06 ± 1.64
	Changes	18.47 ± 3.72	28.18±509.1	1.10±26.14
	Test	0.070	0.110	0.848

Discussion:

In this study, the effects of fizzy drinks on the mechanical properties of 40 orthodontic wires were studied. The first group consisted of 10 stainless steel orthodontic wires with a diameter of 0.016 * 0.022, the second group had 10 stainless steel orthodontic wires with a diameter of 0.014, The third group was composed of 10 nickel titanium wires with a diameter of 0.016 * 0.022 and the fourth group had 10 nickel titanium wires with a diameter of 0.014.

The prepared wires were examined with an assumption that the process of manufacturing and finishing them, by the manufacturing factory, was the same. In order to evaluate the correlation of the initial values related to the mechanical properties of the wire samples of all 4 groups, they were subjected to Cronbach's alpha test. Considering the fact that all the evaluated parameters in 4 groups of wires are $\alpha > 0.9$, it can be concluded that there is no significant difference among the wires. The amount of change in YS and LDR in the first and the second group was significant ($P < 0.001$). These two variables were not decreased significantly in the third and the fourth

group ($P=0.437$, $P=0.161$ and $P=0.070$, $P=0.110$). The rate of UTS was not significant in any group ($P=0.6$). All three variables were significant among the first, second, third and the fourth group before and after being exposed to fizzy drinks ($P>0.001$). In a way that, in the first group it was significantly more than other groups. In the second group, significantly more than the third and fourth groups, and in the third group significantly more than the fourth group. By evaluating the effects of biological decomposition on the released ions on the mechanical properties of 4 types of orthodontic wires, Metwally et al concluded that by immersing the wires in 6 different solutions, the microhardness and modulus of elasticity of all types of wires were decreased, which was related to the release of metal ions found as the result of immersion in acidic solutions (20). The possible cause considered, in this study, is the same as the current research. In the study by Sharma et al., who investigated the effects of different types of fruit juice and chloride ions on the stainless steel wires' corrosion, it is said that all types of juice and chloride ions can increase the corrosion of stainless steel wires. The possible mechanism of this phenomenon expresses the absorption of acid molecules on the surface of steel wires (21). The findings of this study are based on the recent research and is related with the decreased mechanical properties of SS wires. By evaluating the effects of chemicals on the mechanical properties of YS, LDR, and UTS of SS and NiTi wires, Pops et al concluded that NiTi wires have better compatibility with the dentoalveolar tissue than SS wires with a rectangular cross-section through continuous force generation. They concluded that the YS and UTS of SS wires were higher than NiTi in both rectangular and round shapes (22). These results are in line with the findings of the current studies and the study of Hafez et al (16). By evaluating the effects of different types of non-alcoholic beverages on the mechanical properties of orthodontic archwires, Hafez et al concluded that the use of these fizzy drinks causes corrosion by keeping the pH concentration below the critical limit while hydrogen is trapped on the surface. It can be the cause of changes in the mechanical properties of the wires (16). The mechanism considered in this study is related to the reduction of mechanical properties and is in line with the current research. The data analysis of the current research showed that the YS and LDR of the samples decreased after being placed in fizzy drinks compared to the beginning of the experiment. In confirmation with this finding that the mechanical properties are reduced under the influence of chemical factors, Hafez and his colleagues observed that tea and Coca-Cola also decrease the elastic modulus (16). As the slope of the stress-strain diagram decreases, YS and UTS also decrease (16). The studies of Rapijko et al. and Parenti et al. claimed that these drinks do not have significant effects on the modulus of elasticity of orthodontic wires (12, 23). Since different factories produce a variety of orthodontic wires with different sizes, it can be the evidence for showing the differences among different studies. In the present study, the analysis showed that the reduction of YS in the first and second group was statistically significant ($P=0.037$) ($P=0.001$) but not significant in the third and fourth group ($P=0.437$) ($P=0.070$). Also, the average reduction of LDR in the first and second group was statistically significant ($P<0.001$) ($P<0.001$) but not significant in the third and fourth group ($P=0.110$) ($P=0.161$). It means that the reduction of YS and UTS, after placing NiTi samples in fizzy drinks, was not significant while the statistical analysis of Hafez and his colleagues; also, Metwally and his colleagues in 2013 and 2018, respectively, showed that the reduction of YS and UTS was significant for both NiTi wires and SS wires (16, 20). The findings of Marques et al (24), Yu et al(25) and Abalos et al (26) confirmed the findings of Hafez et al. The differences between the findings of the current study and Hafez et al and Metwally et al may be due to the differences in the study design (16) (20). In both studies, the size of the used wires was different from the current study, and both of wires had the size of $0.019 * 0.025$. Also, unlike our study, the samples were placed in fizzy drinks for 3 minutes (16, 20). The differences among the data of the present study and the studies of Marques et al, Yu et al and Abalos et al may be due to the different studied solutions. In the present study the samples were put in fizzy drinks with a PH of 2.74 while the studies of Marques et al, Yu et al, and Abalos et al, the samples were placed in a solution containing fluoride (24-26).

It should be noted that if we keep the orthodontic wires in a dry environment, the characteristics of the wire will not change, at least for several months. In contrast with these conditions, if we the wires are put in the same conditions with the mouth, for at least 1 month, the destructive changes of the wires are clearly evident and its mechanical properties, including YS, LDR, and UTS, will be reduced (27).

Since fluorides are widely used to promote oral health and prevent and control carries, and systemic fluoride enters the body through tea, nutritional supplements, and fluoridated water bottles. Orthodontic wires are in contact with a moderate amount of fluoride (28). This issue caused investigations about the effects of fluoride on orthodontic wires among researchers. In this regard, Watanabe et al, in 2003, stated that the surface changes and color changes caused by fluoride-containing prophylactic materials on titanium-based orthodontic wires were clearly evident

after 1 and 24 hours of immersing the samples in this solution (1). In confirmation with this claim, in the years after Walker et al' study, Watanabe et al investigated the effects of fluoride on the mechanical properties of nickel-titanium orthodontic wires. After performing the three-point bending test, they observed that fluoride had a definite effect on the mechanical properties of nickel-titanium wires (29). Continuing to find the response, Walker et al designed another study and investigated the mechanical properties and surface properties of SS and titanium beta wires after topical fluoride treatment. Their results showed that the use of topical fluoride materials with beta titanium and SS can reduce the mechanical properties of wires and will potentially lead to a long-term orthodontic treatment (4). These studies concluded that the decrease in the mechanical properties of orthodontic wires, after being placed in a solution, containing fluoride is caused by visible changes in the quality of the surface topography of the wires. In other words, under the influence of fluoride, the surface layer of the wires undergoes changes that lead to changes in its mechanical properties (4). Regarding the effects of the pH of fluoridated solution on surface changes and mechanical properties, it should be noted that the solution pH is one of the important factors in the degradation of alloys; although, it should be noted that surface changes and the reduction of mechanical properties can be also seen at neutral pH (4). In fact, the importance of acidic pH on the corrosion of orthodontic wires, in clinical conditions, is less compare to laboratory studies (20). From the other side and in the current study, we found that the average reduction of UTS in all 4 groups was not statistically significant ($P=0.751$) ($P=0.527$) ($P=0.707$) ($P=0.848$). While, Keerthana et al evaluated the UTS nickel-titanium wires after being placed in a fluoridated mouthwash solution and observed that the fluoridated solution caused significant decrease in UTS (14). This difference is probably caused by the differences in chemical substances (fluoride in the study by Keerthana et al and the acidic content of fizzy drinks in the present study) and the duration of exposure for 3 months in the study by Keerthana et al and 1 month in the current study. Also, the difference in the types of the measuring device. In that study the device was TA.XTplusC-Stable microsystems and in the present study, it was Universal Testing Machine(13), while in the study of Keerthana et al the wires were evaluated intra-orally, but in the current research, the wires were examined in a laboratory (13). The occurred errors in the transfer and comparison of information from clinical conditions to laboratory ones are unavoidable (20). Also, it should be considered that the three-point bending test method, used in the laboratory, cannot completely recreate mouth clinical conditions in the laboratory and accurately simulates the occluso-gingival movements. In fact, the three-point bending test was designed to focus on the biomechanical and physical characteristics of wires in a way that other studies can be repeated again (30). One of the limitations of this study is its in-laboratory nature. Despite many efforts to replicate oral and laboratory clinical conditions, the differences between these two environments cannot be ignored. Considering the fact that in the mouth real conditions, three-point bending test will be applied to a part of a bow, which the radius of it, is different in different parts of the mouth. It is done with great precision and using clinical information. New models of the three-point bending device have been invented, designed and built. Firstly, the three main points of the test are not in the same line, but on the standard U-shaped arc, and secondly, it is possible to choose all three points of this standard arc for any amount of desired bending. Unfortunately, the mentioned device could not be found in Iran's research centers. It is recommended to conduct an in-vivo study and use a more accurate device with a newer technology to simulate the oral environment as much as possible and to increase the efficiency of archwires in fixed orthodontic treatments. Considering the fact that, in the sliding system, rectangular SS wires and NiTi wires for initial arrangement may be kept in the patient's mouth for more than a month, it is recommended to conduct studies in a longer period of time to obtain more accurate results. From the other side and according to the results, the clinician should control the nutrition and the health care of the patients and tries to shorten the period of using archwires, especially in the final stages and during the use of steel wires.

Conclusion:

It seems that the acidic environment can affect the mechanical properties of SS orthodontic wires and thus the length of treatment.

Running title: Effects of fizzy drinks on the mechanical properties

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