Original Article

The Effects of the Duration of Use on Stiffness of Nickel-Titanium Orthodontic Wires

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Abstract

Aim and Background: The wire's stiffness might be changed over the usage time. The present in vivo study was conducted to investigate the effects of duration intervals on the stiffness of Nickel-Titanium (NiTi) orthodontic wires with different cross-sections to identify the appropriate size of wires. **Materials and Method:** The present clinical trial study was conducted on patients who were admitted to the Orthodontics Department of Tehran Dental Branch, Islamic Azad University. Totally, 90 samples of NiTi orthodontic wires, 30 samples with different sizes of 0.014, 0.016, and 0.018 inches were purchased. The measurement of the stiffness had been conducted before, after one month, and after two months of the treatment with 10 samples. The samples were taken to Razi Institute to evaluate archwires' stiffness, using a three-point bending test by Instron tester. Statistical analysis was conducted between and within-group differences using one-way ANOVA. **Results:** The stiffness of the 0.014, 0.016, and 0.018 inch-NiTi wires was insignificantly reduced from 64.0±0.8, 78.0±1.0, and 80.0±0.7 N/mm2 before being applied to the mouth to 63.0±3.0, 77.0±3.0, and 79.0±4.0 N/mm2 after one month and 62.0±2.0, 76.0±3.0, and 78.0±3.0 N/mm2 after two months of being used, respectively (P=0.8, P=0.8, and P=0.06, respectively). **Conclusion:** The stiffness of different cross-sections of NiTi wires did not show any significant changes during the 3 mentioned intervals.

Keywords: Stiffness, NiTi, Orthodontic wire, duration of use

Introduction

Successful orthodontic therapy depends on not only the manual skills and knowledge of treatment steps but also the knowledge and choice of materials used. One of the major components of fixed orthodontic therapy is the choice of wires [1]. One of the concerns of using orthodontic wires is its usage duration. Wires with different alloys including Nickel-Titanium (NiTi), stainless steel (SS), Cobalt-Chromium, and Beta-Titanium are commonly used in dentistry [2]. The NiTi alloy was first used by Buehler et al. in 1963 for space programs [3]. There is a wide range of biomedical applications of nickel-titanium due to its Shape Memory Effect (SMA) such as in the field of orthodontics and dentistry like in wires, distractors, palatal arches, endodontic files, etc. [4]. Since their introduction to orthodontics in 1971, NiTi wires have been remained popular due to their desirable properties, shape memory alloy (SMA), biocompatibility, environmental stability, stiffness, and elasticity. They are currently and mostly used during the first phase of orthodontic treatment [3]; although, this metal is subjected to different types of variations due to high masticatory forces in the mouth and may lose its strength and stiffness [5]. Indeed, orthodontic wires are exposed to saliva, water, and various beverages for a long time and have the potential to decrease the strength of fiber-reinforced composites [6, 7].

As we know, nickel-titanium wires have been widely used in orthodontic practice [8]. Their desirable mechanical properties and high costs force many clinicians to reuse NiTi wires after sterilization if contaminated [9]. In one study, the clinical recycling and cold sterilization of NiTi wires affected their bending abilities and surface properties. Similar changes are inevitable in the mechanical properties of NiTi wires regularly used in clinics and exposed to dry heat sterilization [10]. Oral environment corrosion is another major issue with

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orthodontic alloys due to the fact that the release of certain amounts of ions can have adverse health effects for patients and causes further friction of the wires [11]. However, the results of recent studies suggest that, at least, in the case of stable *in vitro* cultures, Titanium-Niobium (TiNb) SMAs are less toxic than NiTi SMAs. Overall, TiNb SMAs might be a promising solution for specific biomedical applications of NiTi [12].

Although most studies on the stiffness of NiTi orthodontic wires have been performed *in vivo*, no similar studies have yet been conducted in Iran [13]. Orthodontic wires are required to generate light and continuous biomechanical forces, communicated via brackets, resulting in tooth movement [14]. Given the well-known complications of stiff wires and in the light of an *in vitro* study of orthodontic wire stiffness, the present *in vivo* study was conducted to examine the mechanical and dynamic properties of NiTi wires. To improve their efficiency; the findings of the study can be an answer to both theoretical and applied questions and can facilitate the use of such wires at longer intervals of time so that orthodontic treatments can cost less, the patients' health can be promoted, and the knowledge on the subject can be improved.

Materials and Method:

The present clinical trial study was conducted on patients who were admitted to the Orthodontics Department of Tehran Dental Branch, Islamic Azad University. Wires with different cross-sections, made in the USA by American Orthodontic Company were purchased from a local market. Totally 90 samples, 30 samples with different sizes of 0.014, 0.016, and 0.018 inches, used in the clinic, were prepared and placed in the patients' mouth. The samples' stiffness was measured using an Instron tester at three times. The initial stiffness of the mentioned 30 samples was determined (before treatment) in the Research Center laboratory of Karaj Metallurgy, and the data were recorded in Data Form 1. The second measurement of stiffness was performed after the first interval of the treatment by removing those 30 wires from the patients' mouth during a one-month period. One month later and after the second interval of the treatment, the remaining 30 samples were removed from the patients' mouth and their stiffness was similarly measured. Both data related to the first and second intervals were recorded in Data Form 2. Between and within groups differences were analyzed using the one-way analysis of variance (ANOVA) while the Tukey test was used as Posthoc test. P<0.05 was considered significant.

Results:

The stiffness of the 0.014-inch NiTi wires was insignificantly reduced from 64.0±0.8 N/mm^2 before placing in the mouth to 63.0±3.0 N/mm^2 after one month and 62±2 N/mm^2 after two months (P=0.8). A similar insignificant decrease in the stiffness of 0.016 and 0.018-inch NiTi wires was also detected. The stiffness of the 0.016 and 0.018-inch NiTi wires insignificantly reduced from 78.0±1.0 and 80.0±0.7 N/mm^2 at the initial stage before its placement in the mouth to 77.0±3.0 and 79.0±4.0 N/mm^2 after one month and 76.0±3.0 and 78.0±3.0 N/mm^2 after two months of use, respectively (P=0.8 and P=0.6). In all three periods, the stiffness of 0.018-inch NiTi wire was higher than the other groups. Moreover, the stiffness of 0.016-inch NiTi wire was higher than 0.014-inch NiTi wire in all three periods of measurement (Table 1).

Table 1: Comparison of stiffness level based on different cross-sections and times of measurement (N/mm^2)

Intervals / Diameters	Before Treatment	After 1 Month	After 2 Months	P Value
0.014	64±0.8	63 ± 3	62±2	**P<0.8**
0.016	78±1	77±3	76±3	**P<0.8**
0.018	80±0.7	4±79	78±3	**P<0.6**

Discussion

In the present study, the effect of the use duration on the stiffness of NiTi wires with different cross-sections was evaluated. It was found that the stiffness of all wires with different cross-sections decreased over 2 months but the amount of these declines was not statistically significant. The highest stiffness yielded by the NiTi alloy was related to the 0.018-inch wire before placing in the mouth and the lowest was related to the 0.014-inch wire within a two-month period of use.

The strength, stiffness, and range of actions in a wire are important properties to carry out a specific function at different stages of treatment [15]. In addition, high spring-back, good formability, and low friction are desirable mechanical properties [16, 17]. Furthermore, the cross-section of the wire is an important factor, which affects the stiffness. It has been reported that the rectangular wire with larger dimensions had greater stiffness compared to the round wires [18]. Similar to our findings, it has been reported that the stiffness of 0.018-wires was more than 0.016-wires, and 0.016-wires were stiffer than 0.014-inch NiTi wires [18]. It seems that a long duration of use, high contact with different pH, and the oral cavity environment can be stressful conditions for orthodontic archwires. It has been reported that stress-induced Martensite formation with stress hysteresis, significantly reduced the elasticity and stiffness of NiTi wires [19]. In addition, Garrec and Jordan reported that the value of stiffness varied with different sizes of NiTi wires [20]. Based on our knowledge in the literature, no similar study exists with a focus on the effects of duration of use and stiffness of NiTi wires.

In 2008, Basafa and his colleagues evaluated the changes of load-deflection rate in 80 commercial NiTi mandibular archwires with a cross-section of 0.0014 inches after a single clinical application in three different crowding. Their samples were randomly divided into four groups of control, mild, moderate, and severe crowding groups. They found that in 1.5 mm bending, stiffness was 177, 34, 68, and 84 N/mm^2 in control, mild, moderate, and severe crowding groups, respectively [21]. The stiffness of 68 N/m^2 in moderate crowding groups in their study was close to the stiffness of 64±0.8 N/mm^2 observed in the 0.014-inch NiTi wire before placement in the mouth in our study. The difference in the results obtained from the two studies can be attributed to different mandibular crowdings and different manufacturers, while the present study only examined maxillary archwires. The distinguishing points and strength in our study include the use of different cross-sections of NiTi wire and different time intervals.

Shen and coworkers in 2013 evaluated the mechanical properties of the 0.014-inch NiTi wires used in the final treatment phase in simulated oral environments. They reported that in groups with 25°, 19°, and 13° deflection, stiffness increased and then decreased. Therefore, they concluded that the mechanical properties of NiTi wires were associated with time and the amounts of deflection and it could affect the treatment outcomes [22].

This study had certain limitations such as high costs of tests and approximately low sample size. Also, we only evaluated one type of wire alloy; although, different results may be achieved by different alloys.

Conclusion:

As their name implies, the use of fixed orthodontic appliances relies on their bonding to tooth structures [23]. In the current study, no significant reduction was observed in the stiffness of the NiTi wires with different cross-sections from the pre-treatment stage to the first and second months of the treatment during different tests. Future studies are recommended to be conducted on larger samples of NiTi orthodontic wires as well as on Stainless Steel orthodontic wires.

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