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Comparison of The Tensile Strength of The Nickel-Titanium Archwires Before and After Artificial Aging

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Abstract

Background: Comprehensive orthodontic treatment calls for archwires with exceptional strength, excellent springiness, and a lengthy range of motion during the initial alignment stage. Due to a number of reasons that could impair their effectiveness, these archwires and other components of fixed orthodontic appliances are susceptible to deterioration or corrosion inside the oral cavity. Therefore, the aim of this study was to compare the tensile strength of new conventional superelastic nickel titanium (NiTi) archwires to those after artificial aging.

Materials and methods: The total sample of 40 pieces of 0.016 inch round preformed NiTi archwire cutting into straight segments (30mm), 20 pieces of NiTi archwire as received wires which served as baseline and 20 pieces of NiTi archwire subjected to acid challenge experiment, and then subjected to the tensile strength.

Results: The mean tensile strength of group A (before aging) was lower than group B (after artificial aging). The independent T Test revealed a significant difference between the groups (P <0.05).

Conclusion: the NiTi archwire exhibited significantly the lowest force value at baseline, while after aging, the NiTi archwire provided the highest force value. Therefore, the NiTi archwires are more resistant to in vitro aging than at baseline condition.

Introduction:

The initial phase of comprehensive fixed orthodontic treatment consists of leveling and alignment, and the archwires used in this phase should have a good working range and supply mild, consistent forces for effective tooth movement (1). As a result, nickel titanium archwires have been recommended as the best choice for the alignment stage because they provide a force-bending curve with a defined baseline and a wider activation range(1,2).

These archwires can generally be divided into martensitic stabilized, martensitic active (thermoelastic), and austenitic active (superelastic) categories depending on their structural makeup (3). For an extended period of time, orthodontic appliances are typically subjected to the harsh conditions of the oral cavity, including chemical, thermal, and mechanical variables, all of which may affect the physical and mechanical characteristics of the orthodontic archwires(4,5). Although the thin passive oxide film on the surface of orthodontic alloys gave them resistance to corrosion in a variety of solutions, this protective layer is vulnerable to 11 corrosion because it can cause pitting and porosity on the surface of metal parts, which in turn increases friction between the archwire and the bracket slot (6).· To the best of our knowledge, there is little information on the impact of in vitro aging on the mechanical characteristics and surface topography of nickel titanium archwires. The majority of published results are only applicable to the as-received condition, despite the fact that clinicians have used the archwires for a few months under a variety of stresses and strains in the corrosive oral environment (7,8).

The literature showed that NiTi archwires in their unaltered state produced lighter tensile force values than NiTi archwires of the same size aged artificially (9-11).

This in vitro study's objective was to contr ast the tensile strength of nickel titanium a rch wires that had undergone artificial agin g and unaging.

Materials and Method

Materials

Archwires • 0.016-in prefabricated super elastic NiTi orthodontic archwires (Dentarum GmbH & Co.KG, Ispringen, Germany, No.988-476-00) are the materials employed in this investigation as shown in figure (1)

Methods

Samples grouping

Forty samples of arch wire totaled the sample, which were split into two groups as follows: Group A: Based on samples that were received as a baseline. Group B: Samples were put through an experiment involving an acid challenge. The samples from group (B) were cultured in DW (pH=7) for two months at 37 degrees Celsius to simulate the time between archwire replacements (every 6-8 weeks) (5). To prevent the distilled water from being saturated with corrosion products, it was changed every week(12). During the course of the study, the samples from group (B) were kept in the incubator at 37 °C as demonstrated in figure (2)

Using a digital vernier, a permanent marker, and a wire cutter, two straight portions measuring 30mm were cut from each piece of arch wire as illustrated in figure (3).

Preparation of acidic solution

Gloves and a mask were worn during the manufacture of the acidic solution to protect against the concentrated acid (1M HCL). With the use of buffer solutions (pH=4 and pH=7), the pH-meter was calibrated before each creation of an acidic solution. The electrode probe was then washed in DW and dried with blotting paper after immersion in each solution to remove any residue that would compromise the accuracy of the measurement. By progressively adding 1M HCL to a DW with an automated micropipette, a 500ml acidic solution (pH=2.5) was created. The DW was fitted with pH and temperature probes, and the pH-meter screen was continuously watched while the HCl acid was added. It was discovered that around 1.5ml of 1M HCl solution was needed to prepare 500ml of 2.5 pH acidic solution as shown in figure (4) (13).

In order to safeguard from the concentrated acid (1M HCL), gloves and a mask were worn during the production of the acidic solution. The pH-meter was calibrated before each production of an acidic solution using buffer solutions (pH=4 and pH=7). After immersing each solution, the electrode probe was then washed in DW and dried with blotting paper to eliminate any residue that would affect the measurement's precision. An automatic micropipette was used to make a 500ml acidic solution (pH=2.5) by gradually adding 1M HCL to a DW. The pH and temperature probes were installed in DW, and when the HCl acid was injected, the pH-meter screen was continually monitored. the amount of 1M HCl required to acidify 500 ml of 2.5 pH.

Acid challenged experiment

The wire segments from group (B) were subjected to the acid challenge experiment by immersion in the prepared acidic solution in accordance with the protocol of three sessions per day, five minutes each, with equal intervals of two hours. The samples were then kept in DW at 37 C for the remainder of the day to simulate the wet oral environment, after being washed and dried before and after each session. After each session, the DW and acidic solutions were refreshed (13).

Testing the samples

The wire of two groups were subjected to tensile strength testing at the University of Technology, Department of Materials Engineering as described by Sodar and Rafeeq 2021 and is in accordance with ISO 15841:2014. The force was exerted vertically at a crosshead speed of 2 mm./ min for 3 mm deflection through a rod mounted on the moving head of the machine. The loading forces were recorded as illustrated in figure (5) (14).

Results and Discussion

The means and standard deviation (SD) of the tensile strength are listed in table (1) and figure (7).

The mean tensile strength for the group A (before aging) was 111 (N/m^2), while the mean values for the group B(after aging) was the greatest 127.6(N/m^2). Moreover, the independent T Test revealed a significant difference between the groups ($P < 0.05$).

The majority of the information that has been published about the properties of orthodontic archwires is limited to new archwires in dry conditions, whereas clinicians use archwires in the corrosive oral cavity environment, typically over a period of months, during which they are subjected to various variables, including changes in intraoral temperature and acidity as well as the exposure to numerous mechanical stresses (6). The incubation temperature of 37°C represents the typical temperature of the oral cavity (15).

Lastly, both this trial and earlier investigations used an intense acid challenge procedure (13, 16) to simulate a situation in which an orthodontic patient drank an acidic beverage (pH 2.5) three times a day for two months, with each serving lasting roughly five minutes.

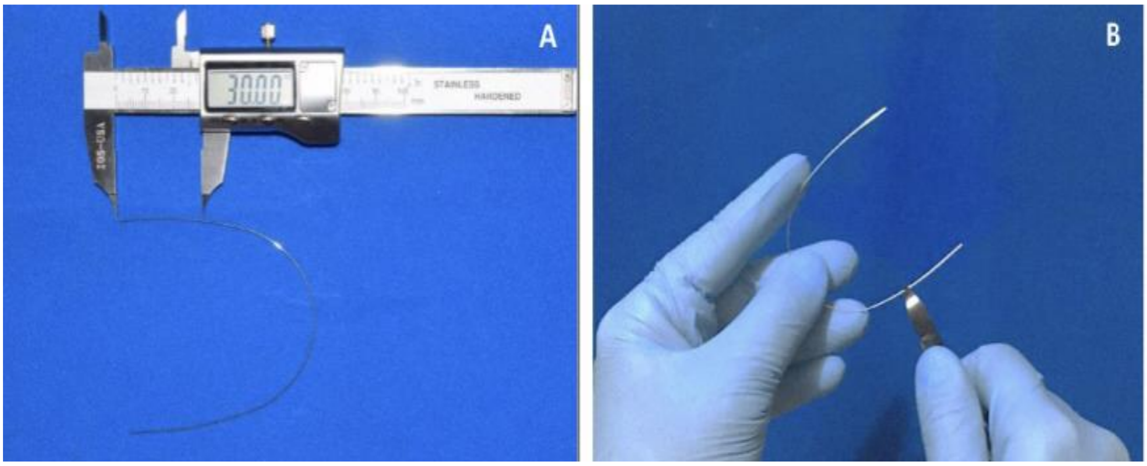
In the current investigation, NiTi archwire in the as received (group A) compared to NiTi archwire after artificial aging (group B) demonstrated significantly the lowest force value, whereas NiTi archwire in (group B) expressed the maximum force value. These findings are in line with numerous studies, including those by Sachdeva and Miyazaki (9), Wilkinson (10), Ramazanzadeh (5) and Aghili(11) which found that NiTi archwires in their unaltered state produced lighter tensile force values than NiTi archwires of the same size aged artificially. In actuality, it is important to emphasize that a number of technological factors, such as chemical composition, heat treatment, and hardness level, have a significant impact on the mechanical properties of NiTi alloy archwires.

Conclusions

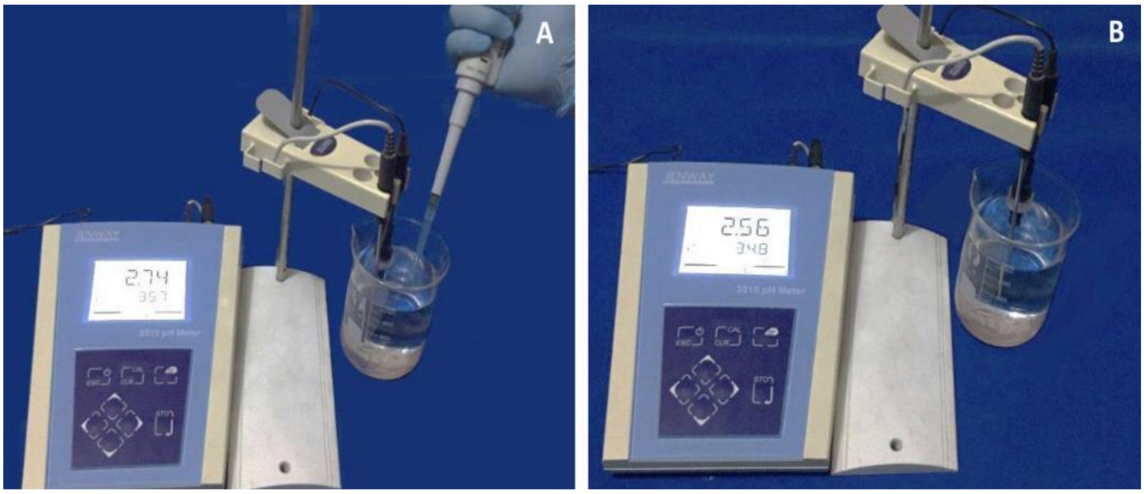
The NiTi archwire as received at baseline exhibited significantly the lowest force value, while NiTi archwires received the greatest force after artificial aging. More specifically, NiTi archwires are more resistant to in vitro- aging than NiTi archwire at baseline.

Figure (1) NiTi orthodontic arch wire

Figure(2): The samples stored inside the incubator at 37℃ during the period of study.



Figure(3): Sample preparation: A, measuring the archwire segment; B, Cutting 30mm from the distal part of the archwire.



Figure(4): Preparation of acidic solution: A, addition of HCL gradually into DW using automatic micropipette; B, 2.5 pH acidic solution has been prepared.

Figure (5) The samples during testing in the tensile strength test device.

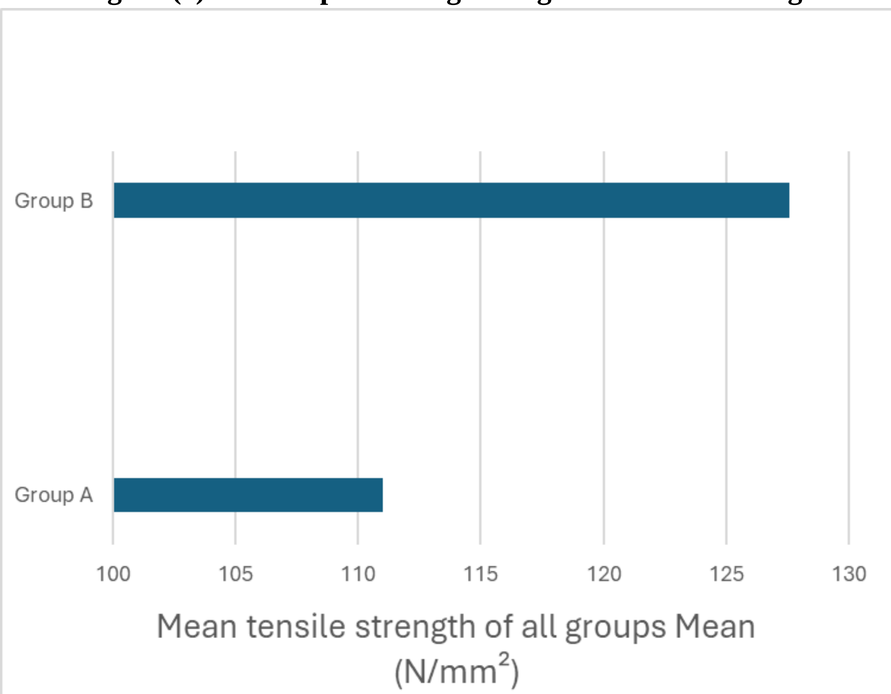


Figure 6. Bar chart showing mean values of tensile strength of all groups

Table (1): Descriptive statistics of the tensile strength of all groups

	Aging	Groups	Number	Mean (N/mm²)	Standard deviation	Minimum	Maximum	T Test	Significant
Tensile strength (N/mm^2)	Before	Group A	20	111	17.28	78	127	0.047	S *
	After	Group B	20	127.6	17.49	100	147		

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