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Research Article

# Effects of Temperature Changes on the Tensile Property of Nonlatex Intra-Arch Elastics (Power Chains): An *In Vitro* Study

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## Abstract

**Background:** The use of intra-arch elastics (power chains) is a common practice in current orthodontics and the loss of mechanical properties of the power chains, including tensile strength, has been a topic of discussion among scientists and clinicians.

**Objective:** The aim of this study was to evaluate the effect of temperature changes on the tensile property of nonlatex power chains.

**Material and Methods:** Twenty-four medium sized power chains were used. Tests were performed by immersing identical lengths of the elastic chains in distilled water at various temperatures (37oC, 15oC and 55oC) to simulate ambient mouth temperature and ingestion of cold or hot drinks, respectively. The elastic chains were stretched from 8 cm to approximately 12 cm and immersed in the water for 8 min and the process was repeated 3 times per day for 4 weeks. A universal testing machine read the tensile strength weekly.

**Results:** The analysis focused on differences in the tensile properties between control and experimental groups. A decrease in tensile strength was observed in all groups. The control group exhibited more tensile strength than did the experimental groups. The differences between groups were statistically significant in the first and fourth weeks only.

**Conclusion:** All power chains tested showed a significant change in tensile strength related to the temperature in the first and fourth weeks. The tensile property of the elastics decreased due to temperature changes.

***Keywords:*** *Tensile Property; Orthodontics; Temperature; Stretching; Power Chain*

## Introduction

A series of elastic bands connected to each other and used to pull teeth together is called a power chain. There are several types of power chains: open (short and long) and closed. Closed chains produce the biggest initial force. Less force is exerted by open type chains, as the chain links are separated by short connectors [1]. The uses of power chains range from the closure of small residual gaps to retraction in extraction cases [2]. The chains can be transparent, gray, or other-colored [3]. The most common disadvantages of the power chains include difficulties in oral hygiene, increased dental plaque retention and a loss of color through the absorption of fluid and dye from food [4].

The elastics commonly used in current orthodontics are made of either latex (natural rubber) or polyurethane (a synthetic nonlatex polymer). Several properties of latex and nonlatex elastics have been evaluated [5,6]. Latex elastics are used because they present improved properties, such as lower cost, biocompatibility, greater flexibility and capacity of returning to the original dimensions after undergoing deformation [7-9]. In spite of latex being a biocompatible material, Santos, Pithon, Martins, Romanos and Ruellas [10] suggested that, latex elastics might present a risk of cytotoxicity. Some authors reported that sterilization significantly increased the cytotoxicity of elastics, as the increase in cytotoxicity varied according to the sterilization method used [11].

The use of nonlatex orthodontic elastics has become more popular, in part because latex may cause allergies [12]. Both types of elastics show loss of strength with an increase in treatment time, but nonlatex elastics become more "deformed" with use than do latex elastics [13]. Nonlatex elastics can replace latex elastics if they are changed more frequently [14].

The loss of mechanical properties of the power chain, including tensile strength, has been the topic of discussion among scientists and clinicians. The oral environment can decrease elastic forces due to temperature alterations inside the oral cavity [9], ranging from ice cold to very hot [15]. Also, chemical interactions among materials in the oral cavity can modify the molecular structure of the elastics, favoring their degradation [16].

The routine use of power chains in orthodontics makes it important for orthodontists to be aware of the tensile strength of the materials used and the effects of the oral environment on the materials.

## Aim of the Study

The aim of this study was to evaluate the effects of temperature changes on the tensile properties of nonlatex intra-arch elastics *in vitro*.

## Materials and Methods

### Study sample

The sample comprised 24 nonlatex intra-arch colorless elastics with uniform size and length. Colorless elastics were used to prevent any effect due to pigmentation in the elastic materials [17]. A length of 8 cm was used (power chain medium size). The samples were obtained from reels of the same type/brand and were divided into two categories, Control and Experimental (N = 12 each).

### Data collection

Tests were performed in distilled water at specific temperatures -37°C, 15°C and 55°C to simulate ambient mouth temperature and ingestion of cold and hot drinks, respectively [15]. The examiner checked the temperatures using an accurate thermometer. Each chain specimen was stretched to 50% of its original length, then attached to mandrels and immersed in a water bath. Chains in the control group were immersed in a water bath at 37°C and maintained at this temperature throughout the test period. Chains in the experimental group were immersed in a water bath kept at a constant temperature of 55°C then in a water path at 15°C for 8 minutes per each, which is the mean time of drinking beverages [5]. This cycle was repeated three times daily simulating the three meals (breakfast, lunch and dinner) up to 4 weeks.

The tensile test was performed weekly for four weeks. After being removed from the water, the stretched chains were removed from the mandrels and cut in the middle. The tensile strength test was performed on each cut chain by using the Universal Testing System machine.

### Statistical analysis

The tabulated data from the tensile strength tests were analyzed using SPSS version 21. Median values and interquartile ranges (IQRs) were determined. The Mann-Whitney U test was to compare the two independent groups (control and experimental). Values of $p \leq 0.05$ were considered statistically significant.

## Results

The analysis focused on differences between control and experimental groups in the tensile strength of the chains relative to temperature changes. The results of the tensile strength tests for both control and experimental groups are shown in table 1. Time spent submerged in the test water continuously decreased the tensile strength of both groups and the biggest decreases were registered after the fourth week. The control group consistently exhibited greater tensile strength than did the experimental group and the differences were statistically significant after the first and fourth weeks. These results confirm direct association between the temperature changes and the tensile strength evaluated.

| | 1 Week | 2 Weeks | 3 Weeks | 4 Weeks |
|---|---|---|---|---|
| Control | 0.107 (0.106 - 0.0.108) | 0.091 (0.083 - 0.097) | 0.072 (0.068 - 0.073) | 0.058 (0.055 - 0.059) |
| Experimental | 0.092 (0.091 - 0.098) | 0.085 (0.077 - 0.086) | 0.070 (0.06 - 0.072) | 0.042 (0.027 - 0.046) |
| p value | 0.0495* | 0.2752 | 0.5127 | 0.0495* |

***Table 1:*** *Median (IQR) tensile strength (MPa) of control and experimental groups.*

**p ≤ 0.05 was considered statistically significant.*

## Discussion

Force relaxation of power chains is an issue of interest for many investigators because of the clinical significance of the material's performance. Reducing the tensile strength of the power chain reduces the efficacy needed to retract the teeth, which is the basic purpose of the elastics. Josell, Leiss and Rekow [18] studied power chains from several different manufacturers and demonstrated that all the power chains lost some tensile strength rapidly during the first hour of use and that the loss continued over two to four days.

Stretching the power chain material to its elastic limit causes unfavorable permanent deformation. The amount of the impairment depends greatly on the strength and the speed used to stretch the material. Stretching the elastics 300% or more of their original length may lead to tearing of the material [19], while stretching the material 50% causes less force decay than stretching it 100% [20].

The environment plays a major role in the total life of the power chains. Synergistic effects may arise from stretching, loading, temperature changes and water, leading to reduced fatigue limits [21]. Ash and Nikolai [22] found that elastics also lost their properties when artificial saliva was used. The deformation process can be modified by plasticizing agents, such as water and oral fluids and is also dependent on the intraoral exposure period [23].

In this study, changes in tensile strength of the power chains relative to changes in temperature were studied. The test conditions were chosen to mimic a single day of exposure to different thermal conditions, approximating those encountered with consuming three meals daily. The results of this study suggest that as early as one week following a 50% fixed elongation of the power chains in distilled water, the chains will present an unfavorable deformation, even with no change in ambient temperature.

The results in this study also demonstrated correlation between the temperature changes and the tensile strength of the power chains. There were statistically significant differences identified after the first and the fourth weeks between the control and experimental groups. These may be explained as: 1) high stress resulting from temperature changes applied on the material for the first week; 2) steady changes for both groups (control and experimental) through the second and third weeks; 3) fatigue in both groups through the fourth week, but greater fatigue in the experimental group due to temperature changes.

The results of this study clearly show that the extreme temperature changes, such as those from eating or drinking hot or cold food and beverages, can amplify the reduction in tensile strength of the power chains over time. In general, at low temperatures, the elastic material behaves like a stiff body, because the chain segments cannot be mobilized and slippage is absent, while at with high temperatures, the material becomes more pliable [24,25]. The results confirm the need to exchange the power train every four weeks to maintain a constant force being applied to the teeth. It is better to choose power chains with high tensile strength to avoid premature rapture.

## Conclusion

- All power chains tested showed a significant change in tensile strength over the four-week period.
- After the first and fourth weeks, power chains subjected to extreme temperature changes (mimicking daily consumption of food and drinks) showed greater loss of tensile strength than did those exposed to a constant temperature.
- Considering the amount of tensile strength lost over four weeks, power chains need to be changed after this period.

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