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## The Effects of Hot and Cold Sterilization on The Tensile Strength of Orthodontic Wires” (An in-vitro study)

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### Abstract:

*Aims: The purpose of this study was: (1) To determine the effect of different methods of sterilization such as dry heat, autoclave, ethylene oxide and 2.45% glutaraldehyde on tensile strength of Beta-Titanium, Nickel-Titanium and Stainless steel wires. (2) To compare the difference in the tensile strength between different wires and between different methods of sterilization. (3) To evaluate the changes in tensile strength values caused by repeated cycles of sterilization.*

*Methods and subjects: In this study a total of 135 wires of dimension 0.016” diameter and 7 inches length were used, which were divided in 3 groups of 45 wires each in 0.016” Stainless Steel, 0.016” Nickel Titanium and 0.016” Beta Titanium. These groups were further divided into 9 subgroups. The sterilization methods used in this study were: Autoclave, Hot air oven, Ethylene Oxide and 2.45% Glutaraldehyde. An Instron Universal Testing machine was used to record the tensile strength.*

*Result: On comparison of the results it is concluded that for reuse of orthodontic wires tested none of the sterilization methods used, significantly altered the physical properties of the wires.*

*Conclusion: Sterilization of the wires prevents cross contamination without decreasing the ultimate tensile strength of the wires, making the practice more cost effective.*

*Keywords: Stainless steel, Nickel Titanium, Beta Titanium, Tensile strength, Sterilization, recycling.*

### Introduction

As overhead costs are increasing, orthodontists are continuously searching for ways to reduce costs. One such method pointed out is recycling of wires which not only reduces cost but also decreases the concern of waste disposal and environmental damage. Beta Titanium wires are approximately three times more expensive than stainless steel arch wires, while Nickel Titanium wires are twice as expensive.

When considering reuse of these wires one must evaluate the effect of sterilization on the physical properties of wires; especially like the ultimate Tensile Strength.

Nickel Titanium (NiTi) wires offer several advantages over previous wires especially during initial leveling and aligning of crowded teeth. Shape memory and super elastic properties of these wires were found to be extremely advantageous during initial leveling and aligning. Austenitic stainless steel by

virtue of its formability, corrosion resistance, and high stiffness, low cost and low friction as compared to other wires finds its place during retraction phase of treatment.

Beta Titanium alloy wires have the advantage of being supplied in a more formable state. According to **Burstone and Goldberg<sup>1</sup>** Beta Titanium wires have high spring back, low stiffness and high formability. As a consequence of both the cost factor and indispensable desired mechanical properties clinicians are prompted to sterilize and reuse these wires.

According to **Pernier C et al<sup>2</sup>** orthodontic wires are frequently packaged in individual sealed bags in order to avoid cross-contamination. The instructions on the wrapper generally advise autoclave sterilization of the package and its contents if additional protection is desired. However, sterilization can modify the surface parameters and the mechanical properties of many types of material.

Investigation of the effects of sterilization on orthodontic wire properties has been limited. **Mayhew and Kusy<sup>3</sup>** determined the tensile strengths of Nickel Titanium wires after sterilization by three methods: dry heat, autoclaving and chemical vapour after three cycles. None of the sterilization methods appeared to have altered the tensile strengths of the Nickel Titanium wires.

**Buckthal and Kusy<sup>4</sup>** investigated the effect of cold sterilization solutions on Nickel Titanium wires. Again, they found no change in the physical properties of the wires following three cycles of sterilization. In the past many orthodontic offices have used cold sterilization solutions for pliers, wires and

other orthodontic items. However, since items frequently were placed in the solutions only long enough to achieve disinfection (a few hours) rather than sterilization (10.5 hours), this standard has changed. Dry heat and/or autoclaving are now accepted as the best methods of sterilization for metal items.

Previous studies have concentrated on rectangular Nickel Titanium wires and on its properties. No investigation has been done on round stainless steel, Nickel Titanium & Beta Titanium wires.

According to **Crotty OP et al, Kapila S et al<sup>5</sup>** NiTi wires are the most reused wires because of their good flexibility, spring back and their excellent use in alignment without any loops but with the disadvantage of being costly.

If clinical use and subsequent sterilization significantly alter the physical properties i.e. the ultimate tensile strength of the wire it may lead to delivery of substandard care and thus be ethically wrong. According to **Shovelton D<sup>6</sup>** most effective method of sterilization in an orthodontic office is autoclaving. However, if the effect of type of sterilization and number of cycles are predictable & insignificant then the decision on reuse of arch wire becomes a moral and ethical decision.

The purpose of this study is to determine the effect of different methods of sterilization on tensile strength of Beta Titanium, Nickel Titanium and Stainless steel wires, to evaluate changes and to compare difference in tensile strength between different wires and different methods of sterilization.

## Materials and methods

In this study a total of 135 wires of dimension 0.016" in diameter and 7 inches length were used. One hundred and thirty five wires were divided in 3 groups of 45 wires each in 0.016" Stainless Steel, 0.016" Nickel Titanium and 0.016" Beta Titanium. These groups were further divided into 9 subgroups: Each subgroup consisted of 5 wires of each variety. All the wires used in the study were having similar dimension and were from following manufacturers. 0.016 inch Stainless Steel wires, 0.016 inch Nickel Titanium wires (ORTHO ORGANIZERS), 0.016 inch Beta Titanium wires (ORMCO). The sterilization methods used in this study were - AUTOCLAVE (NAT ) (2500 F for 20 min- 1 Cycle) - Subgroups 2 and 3 in each of the group of wires represent 1 cycle and 5 cycles of sterilization i.e. wires were sterilized at 2500 F for 20 min and at 2500 F for 100min respectively. The temperature was kept same in both 1 and 5 cycles of sterilization. During 5 cycles of sterilization the samples were not removed from the autoclave, and the samples were sterilized continuously for 100 min. Similarly, the different wires in other subgroups were sterilized by following methods of sterilization to achieve 1 and 5 cycles of sterilization i.e. by - HOT AIR OVEN (UNI-TECH SALES ) (3750F for 20 min -1 Cycle), ETHYLENE OXIDE (3M) (4 hrs- 1 Cycle), COLD DISINFECTANT SOLUTION (2.45% Glutaraldehyde - CIDEX) (10 hrs-1 Cycle). The Instron Universal Testing Machine was used to measure the ultimate tensile strength. The ultimate tensile strength of the wire is the peak of the curve in the plastic range. It is the maximum stress of force a material can withstand.

The jig assembly (Fig 1) consisted of an upper and lower member which were attached to the Instron Universal Testing machine. The wires were attached to the jig by turning them around the threaded screw and securing them with the help of the bolt. The machine used a load cell of 10,000 pounds and the cross head speed of the testing machine was 0.5 mm/min. This was kept constant for all the wires tested. The tensile strength recorded was the maximum stress value in Pounds per square inch just prior to fracture of the test wire i.e. the Ultimate Tensile Strength was recorded. This was repeated for all the wires in each subgroup. The readings were recorded from a computer connected to the Instron Machine.

ANOVA test was done for each sterilization procedure of each type of wire using the data from zero, one and five cycles of sterilization. ANOVA test is used to find out if there is a significant difference between three or more group means. To find out between which means there is a significant difference, a post hoc analysis needs to be done. The Tuckey's Honestly Significant Difference (HSD) Test is a post hoc test designed to perform a pair wise comparison of the means to see which difference is significant.

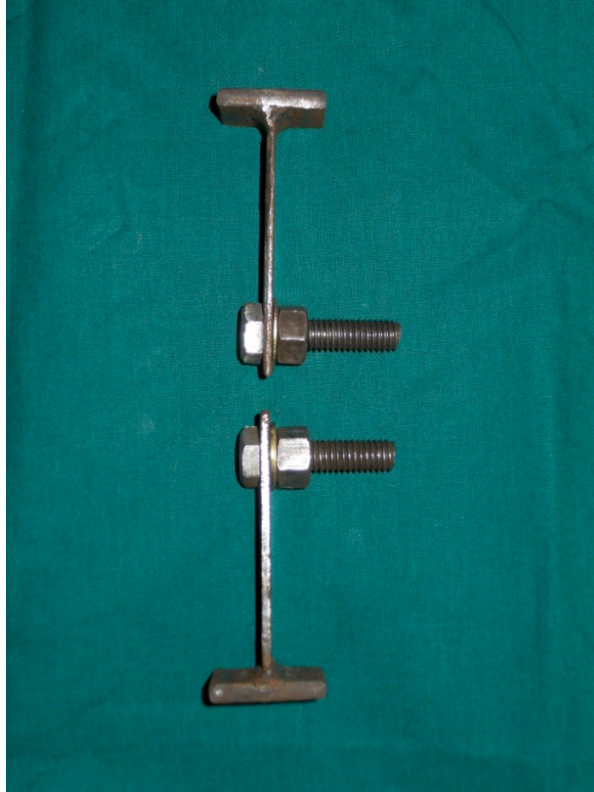


Fig 1: Jig assembly

## Result

The ANOVA test evaluating the tensile strength of **stainless steel** wires showed that the values of ratio in all types of methods of sterilization which were used i.e. **dry heat**, **autoclave**, **ethylene oxide** and **2.45% glutaraldehyde** were found to be 2.35, 0.09, 0.06 and 3.64 respectively, which is less than 3.88, the critical value of F (at  $p=0.05$ ). Therefore, it was concluded that statistically there is no significant difference in the tensile strength of stainless steel wires after zero, one and five cycles of sterilization by different methods.

The ANOVA test evaluating the tensile strength of **Nickel Titanium** wires sterilized by **dry heat** has showed a significant increase in F ratio i.e. 7.32 (which is  $>3.88$ ). On further evaluation with Tuckey's test, the

tensile strength of NiTi wires significantly increased from zero to one cycle of sterilization.

NiTi wires which were sterilized by **autoclave** method showed a significant increase in the F ratio i.e. 17.26 (which is  $>3.88$ ). On further evaluation with Tuckey's test an increase in the tensile strength of NiTi wires after sterilization with autoclave produced a significant increase in tensile strength from zero to one cycle of sterilization and five cycles of sterilization.

**Ethylene oxide** sterilization of NiTi wires demonstrated a significant increase in the F ratio at  $p=0.05$  i.e. 6.70 (which is  $>3.88$ ). Further evaluation with Tuckey's test revealed an increase in the tensile strength after five cycles of sterilization. No significant difference in tensile strength of NiTi wires after one cycle of sterilization with Ethylene oxide was found.

**Glutaraldehyde** sterilization of NiTi wires demonstrated no significant differences in ATS and ANOVA test evaluation after zero, one and five cycles of sterilization..

The results of ANOVA tests evaluating **TMA wires** sterilized by **dry heat** revealed an increase in the critical value of F at  $p=0.05$  i.e. 109.89 (which is  $>3.88$ ). On further evaluation with Tuckey's test an increase in the tensile strength of TMA wires from zero to one cycle of sterilization with dry heat was noted. Statistically, no increase in the tensile strength of TMA wires was found after five cycles of dry heat sterilization.

**Autoclave** sterilization of TMA wires showed an increase in the critical value of F at  $p=0.05$  i.e. 13.71 (which is  $>3.88$ ) after ANOVA

evaluation. On further evaluation with Tuckey's test an increase in tensile strength from zero to one and zero to five cycles of sterilization was noted.

**Ethylene oxide** and **2.45% Glutaraldehyde** methods of sterilization showed no change in the tensile strength of TMA wires after zero, one and five cycles of sterilization. Standard deviations of the tensile strength and ANOVA test results are summarized in Tables 1 and 2.

| STANDARD DEVIATION OF AVERAGE TENSILE STRENGTH OF WIRES.<br>( Lbs/sq inch) |                      |          |         |          |
|----------------------------------------------------------------------------|----------------------|----------|---------|----------|
| Wire                                                                       | Sterilization Method | 0 Cycles | 1 Cycle | 5 Cycles |
| Stainless Steel                                                            | Dry Heat             | 465.1    | 913.8   | 260.2    |
| Nickel Titanium                                                            | Dry Heat             | 295.2    | 428.4   | 470.3    |
| TMA                                                                        | Dry Heat             | 368.4    | 138.1   | 212.0    |
| Stainless Steel                                                            | Autoclave            | 465.1    | 794.5   | 683.3    |
| Nickel Titanium                                                            | Autoclave            | 295.2    | 454.1   | 422.6    |
| TMA                                                                        | Autoclave            | 368.4    | 199.9   | 178.7    |
| Stainless Steel                                                            | Ethylene Oxide       | 465.1    | 431.5   | 897.0    |
| Nickel Titanium                                                            | Ethylene Oxide       | 295.2    | 291.7   | 220.0    |
| TMA                                                                        | Ethylene Oxide       | 368.4    | 288.1   | 86.4     |
| Stainless Steel                                                            | Glutaraldehyde       | 465.1    | 436.5   | 505.8    |
| Nickel Titanium                                                            | Glutaraldehyde       | 295.2    | 937.3   | 198.8    |
| TMA                                                                        | Glutaraldehyde       | 368.4    | 432.5   | 791.8    |

Table 1: Standard deviation

| Wire            | Sterilization Method | F Ratio | Conclusion      |
|-----------------|----------------------|---------|-----------------|
| Stainless Steel | Dry Heat             | 2.35    | Not significant |
|                 | Autoclave            | 0.09    | Not significant |
|                 | Ethylene Ox.         | 0.66    | Not significant |
|                 | Glutaraldehyde       | 3.64    | Not significant |
| Nickel Titanium | Dry Heat             | 7.62*   | Significant     |
|                 | Autoclave            | 17.26*  | Significant     |
|                 | Ethylene Ox.         | 6.70*   | Significant     |
|                 | Glutaraldehyde       | 1.00    | Not significant |
| Beta Titanium   | Dry Heat             | 109.89* | Significant     |
|                 | Autoclave            | 13.71*  | Significant     |
|                 | Ethylene Ox.         | 3.18    | Not significant |
|                 | Glutaraldehyde       | 1.27    | Not significant |

Table 2: ANOVA test result  
(Critical Value of F at  $p=0.05$  is 3.88)

## Discussion

The results of this study suggests that sterilization of the orthodontic wires does not alter the ultimate tensile strength as expected. The data of this study showed that the mean tensile strength of **Beta Titanium** did increase significantly after one cycle of the **dry heat sterilization**. **Autoclave sterilization** demonstrated an increase in the mean tensile strength of Beta Titanium wires after one and five cycle of sterilization statistically. **Ethylene oxide** and **Glutaraldehyde** methods of sterilization showed no statistical difference in the tensile strength.

The mean tensile strength of the **Nickel Titanium** wires showed highly significant difference from zero to one cycle of **dry heat sterilization**. The mean tensile strength of

Nickel Titanium wires showed a significant increase from zero to one cycle and zero to five cycle of **autoclave sterilization**. **Ethylene sterilization** after 5 cycles showed an increase in mean tensile strength from zero to five cycles of sterilization. **Glutaraldehyde sterilization** of NiTi wires demonstrated no significant differences in the tensile strength of wires after 0,1 and 5 cycles of sterilization.

No significant differences in the tensile strength of **stainless steel wires** was demonstrated following 0, 1 and 5 cycles of sterilization by any methods of sterilization. A study done by **Staggers et al<sup>7</sup>**, also showed similar results regarding the tensile strength of stainless steel wires after using same methods of sterilization methods for the same duration of time as used in this study.

**C. Pernier et al<sup>2</sup>** conducted a study to determine the influence of one of the most widely used sterilization processes, autoclaving on the surface parameters and mechanical properties stainless steel, nickel-titanium, neo sentalloy and TMA wires. The alloys were analysed on receipt and after sterilization. The results showed no adverse effects on the surface parameters or on selected mechanical properties. This supports the possibility for practitioners to systematically sterilize wires before placing them in the oral environment.

In a study conducted by **Glen and Fraunhofer<sup>8</sup>**, they used various sterilization protocols on three types of Nickel Titanium, one type of Beta Titanium and stainless steel wires. No clinically significant differences were found between new and used wires. Our present study demonstrated an advantage i.e., autoclave sterilization of Beta Titanium wires showed an increase in mean tensile strength

and a statistically significant difference from zero to one cycle and zero to five cycle in tensile strength after autoclave sterilization, for which further investigations can be carried out for the finalization of this new advantage.

A study was conducted by **Staggers et al<sup>7</sup>**, stating the effects of sterilization on tensile strength of orthodontic wires by using dry heat, autoclave and ethylene oxide as sterilization methods. They found an increase in tensile strength of TMA wires after 1 cycle of dry heat sterilization. A significant increase in tensile strength of Nickel-Titanium wires was demonstrated under dry heat and autoclave sterilization after one and five cycles of sterilization. Ethylene oxide sterilization did not demonstrate any significant differences in tensile strengths after following 0, 1 and 5 cycles of sterilization of NiTi wires. There were also no significant differences in the tensile strength of stainless steel wires following 0, 1 and 5 cycles of sterilization. But, our present study presented two advantages, firstly an increase in Average Tensile Strength of TMA wires after five cycles was noticed, and also demonstrated a significant increase after statistical evaluation. Secondly, Nickel Titanium also demonstrated an increase in the tensile strength after 5 cycles of sterilization with ethylene oxide, and further investigations can be carried out for the finalization of these advantages.

Another study conducted by **Mayhew and Robert<sup>3</sup>** to determine the effects of sterilization on the mechanical properties and the surface topography of Nitinol and Titanal arch wires. Within the confines of the present sterilization experiments no detrimental changes were observed.

**James E. Buckhtal** and **Robert Kusy**<sup>4</sup> determined the effects of cold disinfectants on the mechanical properties and surface topography of Nickel Titanium arch wires. They used 2% acidic glutaraldehyde, chlorine dioxide and iodophor. No detrimental changes were detected in the mechanical properties or surface topography of Nickel Titanium wires after disinfectant treatment

**Sung Ho Lee et al**<sup>9</sup> investigated the changes in mechanical properties, surface topography, and frictional forces of three types of 0.016 X 0.022-inch rectangular Nickel Titanium wires after recycling. The results showed that there were no statistically significant differences between the wires in maximum tensile strength, elongation rate, modulus of elasticity, and bending fatigue but recycling increased the surface roughness and friction coefficients, that seemed to have limited clinical significance.

## Conclusion

Arch wires are not the only orthodontic items that may be recycled, brackets may also be reused. However, recycling orthodontic wires and brackets does raise some ethical questions. Scientific research can evaluate the quality of recycled orthodontic materials, yet monitoring the effectiveness of sterilization in private practice is not as easily accomplished. Certainly the use of disposable items minimizes the chance of cross contamination between patients and most orthodontic materials are disposable. Yet one must consider whether reduction of overhead achieved through recycling outweighs the risk of contamination between patients. One must also consider the patient's opinion about recycling as some patients may not be

receptive to recycled appliances or wires in mouth.

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