A COMPARATIVE EVALUATION OF EFFECTS OF DIFFERENT KINDS OF STERILIZATIONS ON MODULUS OF ELASTICITY AND SURFACE TOPOGRAPHY OF COPPER NITI WIRES - AN INVITRO STUDY

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ABSTRACT: Copper NiTi wires were the latest innovation in the evolutionary scale, giving us the opportunity of choosing the force level by choosing the temperature at which the wires will deliver its optimum force level. With so many advantages and their ability to return to their original form coupled with the high cost of copper NiTi, many clinicians started reusing the wire. This raises concern about disinfecting/sterilizing the wire before using in another patient for prevention of cross infection. Hence, various sterilization procedures like cold sterilization using 2% acidic Glutaraldehyde, dry heat sterilization and autoclaving were used to prevent this cross infection. Aim: The main aim of this study is to evaluate the effects of different kinds of sterilization on Modulus of elasticity and surface topography of the 0.016 copper NiTi wires before and after sterilization procedure.

Materials and Methods: In the present study, Three point bending test along with tensile test was performed to evaluate the modulus of elasticity. Scanning electron microscope pictures were used to evaluate surface topography changes.

Results: Pretreatment and post treatment values were statistically analyzed by one way ANOVA test. No detrimental changes were detected in tensile properties of copper NiTi wires after single cycle of sterilization with any of the stated sterilants. Very minimal non significant changes occurred during the second cycle of sterilization procedure. There was no changes in surface topography of the wire either with dry heat or autoclaving. However, on second treatment cycle with 2% glutaraldehyde, some amount of surface pitting was seen.

Conclusion: Dry heat sterilization and autoclaving have been found to have very minimal changes on the tensile properties of these wires after one or two cycles of sterilization procedures, but not statistically significant. No detrimental effect was found on surface topography with dry heat or autoclaving. Results support the use of these sterilization procedures as part of infection control process, if the clinician select to reuse these wires for one time only. However, of late, since there is easy availability and modest cost of these wires it is recommended to use new wires which are supplied sealed sterilized packs for each patient to comply with present admissible standard of hygiene and sterilization.

KEYWORDS: Copper NiTi wires, Sterilization, Surface Topography, Modulus of elasticity

INTRODUCTION

Man’s long history of technologic development has been marked by a continuing search for improved materials. This has resulted in an array of new materials which have affected nearly every aspect of contemporary orthodontics. Rapid strides have been made in the field of archwire materials, resulting in a plethora of archwires varying widely in material, geometry, configuration, manufacturing process and physical properties.

Orthodontic therapy is a force management procedure largely based on the use of metal wires for storing and distributing therapeutic forces. Archwires are an important constituent of modern orthodontic appliances, as they directly determine the characteristics of force generation and consequently, of the tooth movement. Two new arch wire materials with a major component of titanium became available in the 1970’s. The first Nickel titanium (NiTi) orthodontic alloy, introduced by ANDREASEN, was known as Nitinol (NiTi - Nickel Titanium Nol - Naval ordinance laboratory) were based on the original research of BUEHLER who developed special NiTi alloy having two remarkable properties that were unique in dentistry—shape memory and super elasticity.”

In the nineties nickel titanium archwires like copper NiTi and Neosentalloy, that are superelastic and
thermodynamic were introduced. By taking advantage of the body temperature and setting the alloy transformation temperature (Af) for the martensitic transformation, precise control of the memory phenomenon can be effected. This is called “Varying transformation temperature Orthodontics”.

Copper NiTi alloy wires, a quaternary alloy of Copper, Nickel, Titanium and chromium is a recent introduction in the family of NiTi alloy wires with active austenitic grains. They were introduced by ROHIT SACHDEVA AND SUCHIO MIYASAKI in 1994 and have distinct advantage over Nickel-Titanium alloys2.

The copper NiTi are more resistant to permanent deformation and generate a more constant force over longer activation spans than NiTi alloy wires, and also a nearly constant force for very small activations. Incorporation of a smaller ratio of copper combined with more sophisticated manufacturing and thermal treatment processes made it possible, for the fabrication of different copper NiTi archwires with precise and constant transformation temperatures at 150, 270, 350 and 400°C. This along with its low deflection rates has made copper NiTi the best among the contemporary aligning archwires. Their high cost, however, has hampered their universal appeal especially in countries like India.

As a consequence of both the cost factor and need for retention of elastic properties after clinical usage, it has prompted some clinicians to reuse these archwires. This raises the concerns about the treatment of wires between patients for prevention of cross-infection. Few studies exist concerning the reuse of the copper- NiTi wires following treatment with currently accepted sterilization techniques.

The aim of this study was to compare and evaluate the effects of three different types of sterilization procedures on Modulus of elasticity, and surface topography of Copper NiTi wires (ORMCO-Fig.1 and Fig.2).

Materials and Methods

The study was designed to evaluate the effects of three different types of sterilization procedures on Modulus of elasticity, and surface topography of Copper NiTi wires (ORMCO-Fig.1 and Fig.2).

Experimental design:

For each test, 56, 51mm wire segments each obtained from the manufacturer were used. Out of these 8, wires were removed and kept as control group and the remaining 48 wires of each were divided randomly into two groups.

Group-I: Consist of 24 wires out of which

- 8 wires receive 2% glutaraldehyde – 10 hrs without dilution
- 8 wires receive dry heat sterilization – 1 hrs 160°C
- 8 wires receive steam autoclave – 121°C, 15-20psi for 20 minutes.

Group-II: Consists of 24 wires out of which

- 8 wires receive 2% glutaraldehyde – 20 hrs without dilution
- 8 wires receive dry heat sterilization – 2 hrs 160°C
- 8 wires receive steam autoclave – 121°C, 15-20psi for 40 minutes.

Base line data was obtained on control wires. Control wires did not receive any sterilization treatment. Group I and Group II were tested after one and two sterilization cycles and were compared with control group.

Modulus of elasticity:

The modulus of elasticity was determined by using the three point test. The deflection obtained for the respective loads were plotted on a graph.

Three point bending test:

The jig (Fig.3) consisted of an upper member with two steel poles and a lower member with one steel pole. The steel poles were of 5mm diameter. Two 0.022 inch standard edgewise stainless steel medium twin brackets were bonded with super glue (Sun Medical Co. Japan) to the steel poles on the upper member and the distance between the poles adjusted such that the mid axis of the two brackets were 14mm apart. The upper member was then attached to the load cell, while the lower member was attached to the cross head of the testing machine (Instron-4487 Universal Testing Machine Co. Mass –(Fig.4) such that the single pole of the lower member was midway between and just above the level of the two brackets. A straight buccal segment of each wire was ligated to the two brackets with elastic modules (Elastiks, Unitek Corp, Calif). The crosshead of the testing machine was activated such that, the lower member of the jig moved downwards at a rate of 1mm/min, deflecting the wire as it moved for a total distance of 1.5mm. The cross head was reversed, maintaining the same speed as the wire was unloaded. The readings were noted at intervals of 0.3mm, from 0 mm to 1.5mm during loading, and from 1.5mm to 0mm during unloading. Mean loads were plotted against deflection on
an X-Y recorder. After each run, the wire was removed, a new wire was ligated to the bracket, and the procedure repeated.

A tangent to the steepest initial straight line portion of load deflection curve was drawn and the modulus of elasticity calculated by using the formula.

\[ E = \frac{L^3 M}{4 b d^3} \]

where

- \( E \) – modulus of elasticity
- \( L \) – support span
- \( b \) – width of the beam
- \( d \) – depth of the beam
- \( M \) – slope of the tangent to the initial straight line portion of load deflection curve.

Surface Topography

The surface topography of the wire was evaluated with the help of a scanning electron microscope. The specimens of about an inch long were mounted on the specimen studs using silver paste with an electrically conducting adhesive. The studs with the specimens was later placed inside the vacuum chamber of the scanning electron microscope. The accelerating voltage, the angle of the tilt and the aperture were adjusted to optimize the quality of the micrograph. The surface of the wire was scanned and observed on screen at various magnifications. Scanning electron micrograph pictures were taken at 1500X magnification.

Statistical Analysis of Data

All the data obtained was statistically analyzed by using one way ANOVA test.

Results

Elastic modulus: (Table.1). (Graph-1)

Modulus of elasticity of copper NiTi ranged between 2.3 Msi to 4.1 Msi. In the present experiment, the modulus of elasticity for copper NiTi treated with 2% glutaraldehyde showed a change of 6.6% and 7.8% change after first and second cycles, when compared with control group. With autoclave group, the change was 8.2% and 9.9% when compared to control group. With dry heat sterilization, the values were 7.9% and 12% respectively.

Surface topography: (Fig.5 to Fig.11)

Detailed study of surface topography of copper NiTi is a much interesting aspect because we know that, it is more porous when compared with nitinol, which is...
attributed to copper content of the wire. Results of surface structure before and after treatment with sterilizing agents were represented by scanning electron microscope pictures of respective groups.

Table 1: Mean values of Modulus of Elasticity for the Studied groups

<table>
<thead>
<tr>
<th>Study Group</th>
<th>Mean ± SD</th>
<th>p_value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>3.4571 ± 0.3155</td>
<td>0.1289</td>
</tr>
<tr>
<td>Group I—2%</td>
<td>3.2286 ± 0.2498</td>
<td></td>
</tr>
<tr>
<td>Glutaraldehyde</td>
<td>3.1750 ± 0.10351</td>
<td></td>
</tr>
<tr>
<td>Group I—Auto Clave</td>
<td>3.1833 ± 0.22286</td>
<td></td>
</tr>
<tr>
<td>Group II—2%</td>
<td>3.1857 ± 0.2854</td>
<td></td>
</tr>
<tr>
<td>Glutaraldehyde</td>
<td>3.1143 ± 0.23401</td>
<td></td>
</tr>
<tr>
<td>Group II—Auto Clave</td>
<td>3.0174 ± 0.2690</td>
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It was generally observed that the experimental groups when compared to control group showed increased level of loading and unloading forces at any given point of deflection, but, statistically significant values are seen only when Group II dry heat and Group II Autoclave were compared to control group. The control group showed an overall greater values of other parameters like yield strength, UTS, percent elongation and elastic moduli, than the corresponding wires in experimental group. However, it did not show any statistically significant difference. Bar diagrams showing changes of modulus of elasticity (Graph-I), yield strength (Graph-II), Ultimate Tensile Strength (Graph-III), percent elongation (Graph IV) after sterilization as compared to control group are depicted.

Discussion

Orthodontic therapy is a force management procedure largely based on the use of metal wires for storing and distributing therapeutic forces. The mechanical properties of arch wires are important considerations in the construction of an orthodontic appliance.

The technological advancements in material science have led to the discovery of newer arch wire material, that apply lighter and lighter forces, which play a very important part in day to day practice. Nickel – Titanium alloys occupy the pride of place amongst the newer arch wire alloys. No doubt, super elasticity and shape memory properties of nickel titanium has added advantage and it is relatively easy to tie into crowded arch segment, when the wire is below its transformation temperature. But, it frequently failed to deliver consistent forces at an adequate level for desired tooth movement. A major cause of this deficiency is the hysteresis that severely limits the working range of super elastic archwires. Another difficulty lies in setting consistent transformation temperature. Some wires work effectively while, some lack adequate force to move the teeth.

The new alloy copper NiTi, developed by Rohit Sachdeva and Sachio Miyasaki has an added advantage over Nitinol alloy wire. The new alloy copper NiTi does not exhibit any hysteresis, thus providing equal loading (engaging) and unloading (tooth driving) forces. This makes it easier to insert large sized rectangular as well as round wires without patient discomfort. It also generates more consistent tooth movement as the wire is active longer in optimal force range. Copper NiTi develops approximately 20% less loading force, hence creates less trauma and patient discomfort. Around the rest position, however, the decrease of force generated in copper NiTi is less than that of nickel titanium alloys. This explains the clinical efficiency of copper NiTi to continue working even as teeth near their intended position.

Numerous physical and mechanical properties can be used to describe orthodontic wires. The intent of any such list is to characterize clinically significant parameters. Therefore, load deflection changes, ultimate tensile strength, yield strength, percent elongation, modulus of elasticity, and surface topography are important, not only because they are basic material properties which can be measured with standardized laboratory procedures, but also, because they are closely associated with appliance property.

The present study was undertaken to evaluate the effects of three different types of commercially available sterilants on selected mechanical properties of copper NiTi wires. The mechanical properties evaluated were modulus of elasticity and surface topography. These above properties determine the wire behaviour.

Three point bending test as described by Miura et al and modified by Kapila was used to determine the load deflection characteristics and tensile loading test was used to determine other mechanical properties of orthodontic wires. The bending and tension test were conducted primarily to determine the fundamental stiffness and inherent strength. The stiffness and strength are necessary to calculate elastic property ratio on basis of following relationship

\[ \text{Strength} = \text{stiffness} \times \text{range}. \]

Only if the strength and stiffness changes after treatment will the elastic property ratio change, thereby indicating a change in clinically important wire mechanical properties. The scanning electron microscopic picture of surface topography before and after storage or treatment provide a picture of any onset of tarnish or corrosion because of recycling.
Fig. 5: SEM picture of copper NiTi – Control Group.

Fig. 6: SEM picture of copper NiTi – Group I: 2% Glutaraldehyde

Fig. 7: SEM picture of copper NiTi – Group II: 2% Glutaraldehyde

Fig. 8: SEM picture of copper NiTi – Group I: Autoclave

Fig. 9: SEM picture of copper NiTi – Group II: Autoclave

Fig. 10: SEM picture of copper NiTi – Group I: Dry heat.

Fig. 11: SEM picture of copper NiTi – Group II: Dry heat
The stress-strain curves in bending can be obtained by following cantilever bending test as with a Tinius Olsen stiffness tester or a torquemeter, or by the three point bend test as designed by MIURA\textsuperscript{4} or by the four point bending test as proposed by KUSY\textsuperscript{5} or by five point bending test as suggested by NIKOLAI. Out of these, here we used three point bending test proposed by MIURA as this method of testing is claimed to have the following characteristics:

- The results are reproducible and repeatability is maintained.
- It accurately differentiates between wires possessing super elastic features.
- It actually simulates the application of wire pressure on the tooth in the oral cavity.

NIKOLAI et al states that the three point bending test is in essence a pair of mirror imaged modified cantilever test as specified in ADA specification no:32. In the present study, the three point bending test involved the use of Instron universal testing machine at a cross head speed of 1mm/min. The loading and unloading forces were registered by the load cell and plotted against displacement on X-Y recorder for each specimen. These values were recorded at intervals of 0.3 mm, from 0 mm to 1.5mm during loading, and from 1.5mm to 0mm during unloading. This was a slight deviation from what was earlier done by Kapila S.\textsuperscript{6} Wherein they recorded the values at 0.2mm intervals, this was done only for better convenience. Mean loads were plotted against deflection for all samples. Loading and unloading characteristics were analyzed separately for the wires, since these two characteristics represent the potential clinical behaviour of the wire during activation and deactivation respectively. Such a distinction in analysis of these two characteristics helped to simplify the interpretation of findings and in relating the findings to the changes expected in the clinical performance of the wire.

Tensile bending test was also performed with an Instron Universal Testing Machine. The specimen was slowly loaded along its long axis and the load was plotted as a function of specimen extension. From the load deflection data, modulus of elasticity was calculated. The wire sample tested in the present study were of diameter 0.016 inch copper NiTi (ORMCO corp, California)

**Modulus of Elasticity:**

The Young’s modulus is a property that is constant for any given material and is normally taken to be structure insensitive.

The new ADA specification no.32 for orthodontic wires not containing precious metals determines this property in Orthodontics from bending moment angular...
deflection graph. However, it is considered impossible to measure the true modulus of elasticity in bending, because the bending deformation is considered as containing both elastic and plastic components which cannot be distinguished or separated. In the tensile test, the entire piece reaches the elastic limit at the same time, whilst in bending the outer fibers of the wires are strained (compressed/stretch) more than the inner fibers so that these areas reach the elastic limit first. In our experiment, three point bend test was utilized to determine the elastic modulus of the copper NiTi for the following reasons:

1. It closely stimulates the clinical application of wires.
2. The results are stated to be more reproducible.
3. It accurately differentiates the wires that do not possess superelastic properties.

The average modulus of elasticity for Copper NiTi was found to be in the range of 3.15x106 to 3.50 x 106 - Msi for the fresh wire.

The orthodontic relevance of this measure is that a wire with a high modulus of elasticity will have a small range of deflection for engaging a malaligned tooth, otherwise the wire will plastically deform or too great a force will be applied to the tooth. That means, ideally orthodontic wire should have low modulus of elasticity.

The control means for the Copper NiTi ranged from 3.2 to 4.1 Msi before storage, and from 2.3 to 4.1 Msi after storage. The uniformity of values indicates that there were no “storage effects” on wire stiffness. In addition, the elastic moduli were not affected by the sterilization and no changes occurred after 1 or 2 cycles.

The F Probability value for modulus is 0.1289 (P>0.05) showing that the changes are statistically non significant.

Surface topography: (Fig-5 to Fig 11).

The surface topography is seen to effect the working characteristics of the wire. It is of important consideration in friction and this entity is characteristic of the material itself and its manufacturing process.

Friction:

When one moving object contacts another, friction at their interface produces resistance to the direction of movement. The frictional force is proportional to the force with which the contacting surfaces are pressed together and is affected by the nature of the surface at the interface i.e., rough or smooth, chemically reactive or passive, modified by lubricants etc.

The relative roughness of two surfaces in contact is an important consideration in friction and this is largely dependent upon the absolute roughness of the individual surfaces. Surface roughness is characteristic of material itself the manufacturing process (polishing, heat treatment etc) shelf life or use time, as the surface has imperfect resistance to deterioration, corrosion, creep relaxation etc.

Friction of a bracket on an arch is a consideration, whenever a tooth must be moved by sliding it along the wire. The frictional force is always parallel to the surface in contact and its magnitude is dependent up on the amount of normal (perpendicular) force pushing the two surfaces together. Since it operates in the opposite direction to the mobile body, it is important that such forces be eliminated or minimized, when orthodontic tooth movement is being planned.

Scanning electron microscopic pictures of the copper NiTi represents that it is quite porous and rough. Addition of copper seems to have increased the surface roughness of the wire. Both in vivo and in vitro studies suggests that Nitinol is susceptible to a pitting type of corrosion attach. Most chemicals used for disinfection or sterilization are corrosive and attach metals that are immersed in them.

The comparison of scanning electron microscopic pictures of copper NiTi control group with that of wires subjected to disinfection sterilization procedure shows considerable deviation in surface structure of the wire before and after treatment.

SEM picture of glutaraldehyde treated wire in second cycle shows considerable amount of surface pitting. However friction developing within the bracket depend on many other factors including material properties, surface condition, and test condition, all of which may effect the coefficient of friction, which needs further investigation.

Although the present results support the use of sterilization as a method of preventing cross infection during reuse, there are certain limitations when treating wires with chemical disinfectants as it is difficult to control the adequate immersion time and the changing of solutions when required. Unlike heat sterilization, disinfectants (chemical) take several hours to sterilize and cannot be verified for sterilization in the office.

To ensure destruction of all pathogens, heat sterilization or autoclaving are the method of choice, and it does not seems to effect the properties of the wire on one cycle of treatment but caution should be exercised using it for two cycles. Though the use chemical solutions to disinfect or sterilize arch wires does not alter the elastic properties much, the surface topographies appear to be compromised. However, because of easy availability and modest cost it is recommended to use new wires, which are supplied in sealed sterilized packs, for each patient to comply with the present admissible standards of hygiene and sterilization.
CONCLUSION

The perceived relative high cost of NiTi wires and their ability to return to their original form has led to their reuse.

Finally the following conclusions can be drawn from the present study:-

- Dry heat sterilization and autoclaving have been found to have very minimal changes on the tensile properties of these wires after one or two cycles of sterilization procedures, but not statistically significant.
- Slight changes in the surface topography of the wires was found after second cycle with 2% glutaraldehyde. However no detrimental effect was found on surface topography with dry heat or autoclaving.
- Results support the use of these sterilization procedures as part of infection control process, if the clinician select to reuse these wires for one time only. However, of late, since there is easy availability and modest cost of these wires it is recommended to use new wires which are supplied sealed sterilized packs for each patient to comply with present admissible standard of hygiene and sterilization.

References