**ORIGINAL ARTICLE** **DENTISTRY**

Journal of Contemporary Medicine and Dentistry
www.jcmad.com

ISSN [P-2347-4513]
ISSN [O-2349-0799]
Year: 2020
Volume: 8
Issue: 1
36-42

# Effects of Autoclave Sterilization on the Surface Parameters and Mechanical Properties of Different Composition of Five Orthodontic Arch Wires – An in Vitro Study

**Ramamurthy Suresh [1], Priya Kalidass[2]**

1. Senior Assistant professor, Department of Dental surgery, Thanjavur Medical College and Hospital
2. Reader, Department of Orthodontics, SRM Dental College, Ramapurum

## Abstract

***Objectives*** *of the present study were to determine the effects of autoclave sterilization on the surface parameters and mechanical properties of five different compositions of orthodontic arch wires.* ***Methods:*** *Preformed orthodontic arch wires of stainless, Nickel titanium, Neo sentalloy with Ion guard, Titanium molybdenum alloy and Timolium were tested before and after sterilization with scanning electron microscopy, Atomic force microscopy and load deflection character.* ***Results*** *The results obtained were statistically analyzed by Paired 't' test and ANOVA followed by Tukey HSD test. Surface parameters were classified from smoothest to roughest as Stainless steel (Rq 71.50), Nickel Titanium super elastic & Timolium (Rq 210.00), TMA (Rq 275.93) and Neo sentalloy with Ion guard (Rq 352.34). Load deflection requirement from lowest to highest as Neo sentalloy with Ion guard (2.90 N), Nickel Titanium super elastic (4.48N), TMA (18.13N), Timolium (21.77N) and Stainless Steel (27.73N).* ***Conclusion*** *The study results showed that autoclave sterilization of selected orthodontic wires does not affect surface characters and mechanical properties.*

***Keywords***: *Orthodontic arch wire, Surface parameters, Atomic force microscopy, Load deflection*

**Address for correspondence:** Dr. Ramamurthy Suresh, 18A, Teachers colony, N.K Road, Thanjavur-613006. Email: sureshortho11@gmail.com

**Date of Acceptance: 21/02/2020**

## Introduction

Sterilization of dental instruments prevent cross contamination with infectious pathogens among dentists, office staff, laboratory technicians and patients. Current practices of sterilization and disinfection across the world focus on total elimination of pathogens and spores. The time frame needed for total sterilization undergoes continuous evaluation in research laboratories and the protocols are made universal after approval by the official bodies. The desirable mechanical properties of Nickel Titanium alloy wires and their relatively high cost had prompted many clinicians to recycle these wires [1]. Recycling involves repeated exposure of the wire for several weeks or months to the mechanical stresses and elements generated in the oral environment, as well as sterilization between uses. The combined effects of repeated clinical use and sterilization may subject the wire to corrosion and cold working, with a resultant alteration in its properties [2]. The increasing popularity of heat sterilization in modern orthodontic practice and the potential susceptibility of some types of Nickel Titanium alloy wires to heat treatment indicate a need to evaluate the changes in properties of these wires when subjected to clinical recycling combined with sterilization. Several studies have been undertaken to investigate the possibility of changes in orthodontic wires, resulting from sterilization. The results obtained have been contradictory; some concluding that sterilization results in the alteration of the mechanical properties, while others noted no differences [3-

6]. Most studies were done on Nickel Titanium wires; other wires were not much studied. It is important to know, sterilization of different orthodontic wires have any adverse effect on surface structure and mechanical properties. The purpose of this study was to determine the effects of autoclave sterilization on the surface parameters and mechanical properties of different composition of five orthodontic wires.

## Materials and Methods

The present study was carried in Govt Dental College, Chennai, Tamil Nadu and the study of Atomic force microscopy study done in IIT Madras. Institutional Ethical committee permission was obtained for the study.

***Wires and their designation***

The wires tested included the five different commercially available preformed 19×25inch orthodontic arch wires were

**Group I**

Stainless steel (3M, Unitek, Monrovia, USA)

**Group II**

Super elastic NiTi (3M, Unitek, Monrovia, USA)

**Group III**

Neo Sentalloy with Ion guard (Bioforce, GAC International, Inc., New York, USA)

**Group IV**

TMA (Ormco Corp, Glendora, California, USA)

**Group V**

Timolium (TP Labs, Indianapolis)

Each group consists of ten samples and tested for surface parameters and load deflection behavior

***Sterilization technique***

Ultrasonically cleaned sample of five wires of each group were Autoclaved for 18 minutes at 134c and another five samples of wires were kept as such[7].

***Surface parameters***

The surface parameters of each group of wires were examined before and after sterilization by scanning electron and atomic force microscopy.

***Scanning electron microscopy***

From each sample, one centimetre of arch wire was sectioned and placed on the stub for photo micrographic examination. For each alloy, five different surface areas were observed before and after sterilization. The enlargements selected are ×500 and ×1000, at 30 KV acceleration tension. The scanning electron microscopy used was JEOLJSM- 6360, Japan electronics limited.

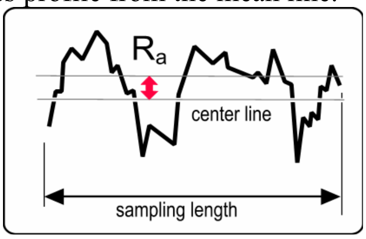
***Atomic Force Microscopy (AFM)***

In this study, Auto probe CP (NANOSCOPE IV Digital version, Veeco Company) with 0.6µm cantilevers was used. It was equipped with PSI Pro Scan version 1.5 software for capturing and processing images which helps in allowing 3D reconstructions and measurements of the surface parameters were calculated on the scanned surface.

Though there are many different roughness parameters in use, $R_a$ is by far the most common followed by Rq, Rz, and Rsk. By convention every 2D roughness parameter is a capital R followed by additional characters in the subscript. The subscript identifies the formula that was used and the R means that the formula was applied to a 2D roughness profile.

**$R_a$**

It is the arithmetic mean of the departures of the roughness profile from the mean line.




**Rq**

Root- mean – square (rms) roughness is the average of the measured height deviations taken within the evaluation length or area and measured from the mean linear surface. Rq was the rms parameter corresponding to $R_a$.

This research focused on one of the these parameters the Rq (root mean square), where

$$R_q = \sqrt{\frac{1}{N}\sum_{i=1}^{N} Z_i^2},$$

The roughness profile contains n ordered, equally spaced points along the trace and Zi is the vertical distance from the mean line to the $i^{th}$ data point. Height is assumed to be positive in the up direction, away from the bulk material.

From each sample, one centimeter of arch wire was sectioned and specimen was fixed to a scanned piezo with three translator degrees of freedom. A very fine tip served as a probe, scanning the surface of the specimen. For each groups of wires, five different surface areas were observed before and after sterilization. Surface scan was taken with an area of 100 µm × 100µm. the RMS roughness of these surface areas was determined and the mean and standard deviation were calculated from these values.

***Three-point bending test***

The load deflection characteristics of specimens from each group were evaluated with the help of the modified three-point bending test as described Peter Wilkinson et al;[8].

Acrylic block measuring 80mm×15mm×15mm was used, with a cut made in the centre of the block with a depth of 10mm to allow the deflection of wire samples. Two 0.022 inch standard medium twin edgewise brackets 3.5mm wide with 0 torque and angulation (American Orthodontics) were placed 14mm apart.

From each group of wires, a 25mm long piece was cut from the nearly straight, posterior section of the individual arch wire. The specimens were tested in orthodontic bending with an Instron Universal Testing Machine (Autograph model, Shimadyu Corporation, Japan) fitted with a 500 kg compression load cell calibrated on the 2 kg range with a 2 kg standard weight traceable to the National Bureau of standards. The deflecting rod of the Instron machine was fitted with the common tie-tucker instrument, to stimulate a clinical condition.

The deflections studied were 1mm for stainless steel, 1.5mm for Titanium- molybdenum and Timolium and 2mm for Nickel Titanium super elastic and Neo sentalloy with Ion guard at a speed of 1mm/min. These distances were chosen to avoid entering the plastic range of the wire and causing permanent deformation[9]. This study was carried out on ten wires of each group, when tested before and after sterilization. Force exerted was recorded in Newton's and results were tabulated.

**Figure 1:** Scanning electron picture of orthodontic wires before and after sterilization

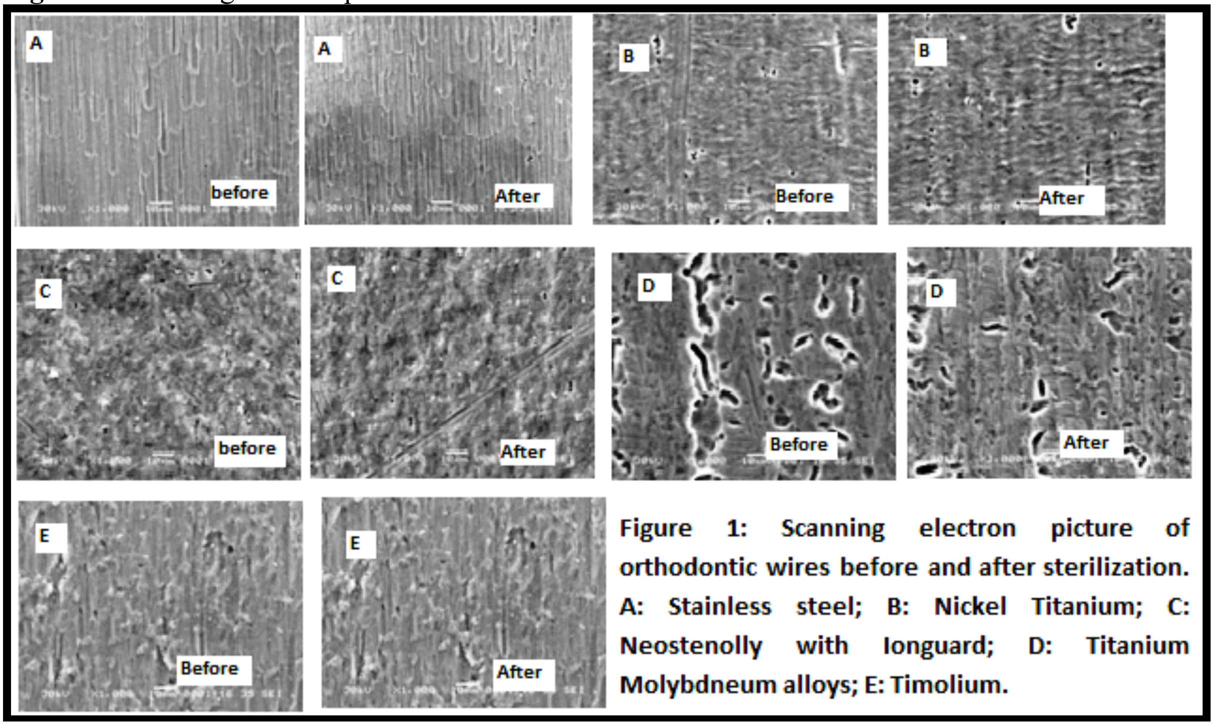



**Figure 1: Scanning electron picture of orthodontic wires before and after sterilization. A: Stainless steel; B: Nickel Titanium; C: Neostenolly with Ionguard; D: Titanium Molybdneum alloys; E: Timolium.**

**Figure 2**: Atomic force microscopy picture of orthodontic wires before and after sterilization

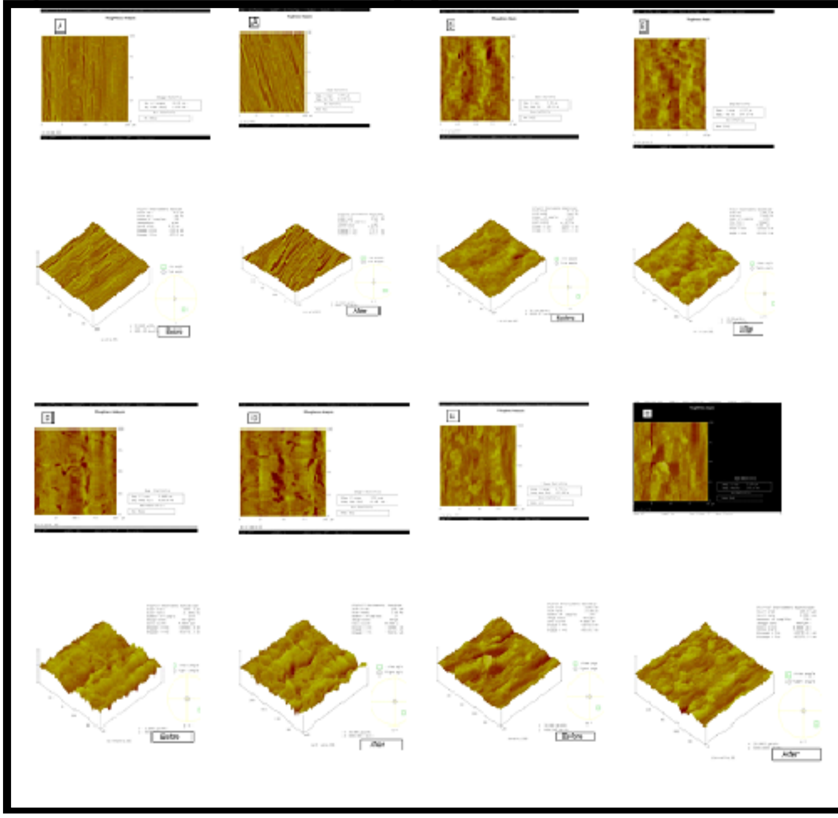


**Figure 2: Atomic force microscopy picture of orthodontic wires before and after sterilization.**

**A: Stainless steel; B: Nickel Titanium; C: Neosentalloy with Ionguard; D: Titanium Molybdneum alloys; E: Timolium**

## Results

The results obtained were statistically analyzed by paired 't' test and ANOVA followed by Tukey HSD test. Paired 't' test was performed to compare the results before and after sterilization. ANOVA followed by Tukey HSD test was performed to compare the results obtained among the five groups I – V.

ANOVA followed by Tukey HSD test was used for comparison of surface roughness between groups I, II, III, IV and V were listed in Table I. Statically significant difference was found between groups I-V ('p' value < 0.001). The statistical analysis student's paired "t" test was used for comparison of surface roughness, before and after sterilization of groups I – V and these were listed in Table II. Before and after sterilization of groups I - V, showed no statistically significant difference for surface roughness (P' value is > 0.001).

The statistical analysis ANOVA followed by Tukey HSD Test was used for comparison of load deflection behavior between groups I, II, III, IV and V were listed in Tables III. Statically significant difference was found between groups I-V ('p' value < 0.001). The Students paired "t" test was used for comparison of load deflection behavior, before and after sterilization of groups I – V were listed in Tables IV. Before and after sterilization of groups I - V, showed no statistically significant difference for load deflection behavior (P' value is > 0.001).

**Figure 3**:Average roughness of wires, before and after sterilization

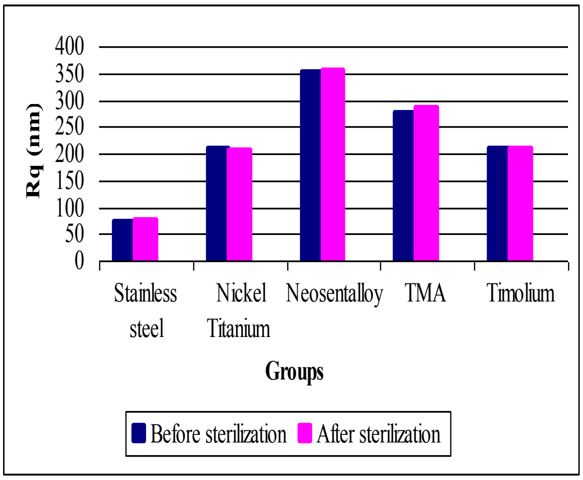


**Figure 4**:Load deflection behavior of wires, before and after sterilization

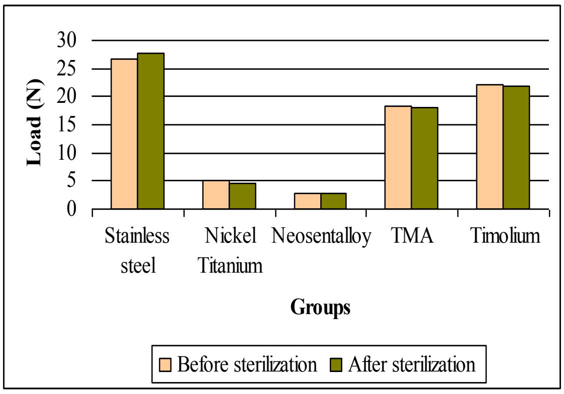



**Table 1**: ANOVA followed by Tukey HSD Test for comparison of surface roughness between groups I, II, III, IV and V

| Groups | Before sterilization | | After sterilization | |
|---|---|---|---|---|
| | **Mean** | **SD** | **Mean** | **SD** |
| Groups I | 71.50[a] | 9.00 | 77.26[a] | 7.55 |
| Groups II | 210.00[b] | 7.59 | 207.57[b] | 12.16 |
| Groups III | 352.34[d] | 19.99 | 356.61[d] | 14.56 |
| Groups IV | 275.93[c] | 17.08 | 284.92[c] | 23.31 |
| Groups V | 208.83[b] | 6.45 | 208.39[b] | 7.31 |
| P value | <0.001** | | <0.001** | |

Note ** denotes statistical significance at 1% level
Different alphabet between groups denotes significant at 1% level

**Table 2:** Student's paired "t" test for surface roughness, before and after sterilization of groups I – V

| Groups | Before Sterilization | | After Sterilization | | P value |
|---|---|---|---|---|---|
| | **Mean** | **SD** | **Mean** | **SD** | |
| Groups I | 71.50 | 9.00 | 77.26 | 7.55 | 0.379 |
| Groups II | 210.00 | 7.59 | 207.57 | 12.16 | 0.727 |
| Groups III | 352.34 | 19.99 | 356.61 | 14.56 | 0.764 |
| Groups IV | 275.93 | 17.08 | 284.92 | 23.31 | 0.445 |
| Groups V | 208.83 | 6.45 | 208.39 | 7.31 | 0.932 |

Since 'P' value is > 0.001, denotes no statistical significance

**Table 3**: ANOVA followed by Tukey HSD Test for comparison of load deflection behavior between groups I, II, III, IV and V

| Groups | Before sterilization | | After sterilization | |
|---|---|---|---|---|
| | **Mean** | **SD** | **Mean** | **SD** |
| Group I | 26.64[e] | 1.76 | 27.73[e] | 1.76 |
| Group II | 4.99[b] | 0.63 | 4.48[b] | 0.56 |
| Group III | 2.71[a] | 0.41 | 2.90[a] | 0.63 |
| Group IV | 18.43[c] | 1.68 | 18.13[c] | 1.39 |
| Group V | 22.17[d] | 1.73 | 21.77[d] | 1.25 |
| P value | <0.001** | | <0.001** | |

Note ** denotes statistical significance at 1% level
Different alphabet between groups denotes significant at 1% level

**Table 4**: Students paired "t" test for load deflection behavior, before & after sterilization of groups I – V

| GROUPS | Before sterilization | | After sterilization | | P value |
|---|---|---|---|---|---|
| | **Mean** | **SD** | **mean** | **SD** | |
| Group I | 26.64 | 1.76 | 27.73 | 1.76 | 0.065 |
| Group II | 4.99 | 0.63 | 4.48 | 0.56 | 0.076 |
| Group III | 2.71 | 0.41 | 2.90 | 0.63 | 0.489 |
| Group IV | 18.43 | 1.68 | 18.13 | 1.39 | 0.683 |
| Group V | 22.17 | 1.73 | 21.77 | 1.25 | 0.554 |

Since 'P' value is > 0.001, denotes no statistical significance.

## Discussion

Surface topography of arch wires was important for corrosion behavior, mechanical properties and optimal performance during sliding mechanics. Surface topography can critically affect both the aesthetics and the performance of working orthodontic components [10]. Scanning electron microscopic picture of as received wires of Stainless steel appeared uniform with small elevation and depression. Nickel Titanium super elastic wire surface exhibited irregularity with small oval pores was present. Neo sentalloy with ion guard had exhibited a surface that appeared like dry sand grains. The surface of TMA appeared irregular with large pores, whereas that of Timolium appeared having uniformly irregular surface. SEM analysis also demonstrated no change in surface topography after sterilization of wires [Fig.1]. A similar SEM finding of as received and autoclaved wires was reported by Pernier et al; [7]

The stylus technique, known as surface profilometry, which had been the principal method of surface analysis for years, due to increasing demands for non – destructive or non – contact techniques have paved the way for the development of Atomic force microscopy. Atomic force microscopy to be most suitable for the investigation of surface topography as it offers the greatest variability in defining measuring areas [10]. The two dimensional image obtained by Atomic force microscopy were similar to SEM. To obtain a more objective numerical value for surface roughness, a three dimensional image was used to calculate Rq. Rq describes the optical finishing status of the surface and is an important of statistical data, because it express the standard variation of the specimen's surface (Fig.2) [11].The results enabled the classification of groups according to their average roughness, from the smoothest to the roughest, as follows: Stainless steel (Rq 71.50), Nickel Titanium super elastic &Timolium (Rq 210.00), TMA (Rq 275.93) and Neo sentalloy with Ion guard (Rq 352.34) (Fig.3). Our study results were in accordance with findings of Pernier et al; Kusy et al; had reported that, Stainless Steel appeared the smoothest, followed by Cobalt – chrome, Beta Titanium and Nickel Titanium [7,12]. According to Lee and Chang recycling of nickel titanium alloy wires increased the surface roughness and frictional coefficients, but these seemed to have limited clinical significance [11]. Grosgogeat et al; reported that TMA wires have higher friction coefficient and hardness than those of NiTi, whereas roughness was lower. Autoclave sterilization process induced no significant modification of the tribological properties of TMA and NiTi wires [13]. Buckthal and Kusy found that no detrimental changes were detected in the surface topography of nickel titanium wires after disinfectant treatment [1]. Mayhew and Kusy also concluded neither the sterilization procedure nor multiple cycling had any apparent effect on the surface topography of nickel titanium wires [14]. Prososki et al; found that Stainless Steel appeared smoothest, followed by Cobalt – chrome and TMA & Nickel Titanium. No significant difference in surface roughness of TMA and Nickel Titanium were found in his study [15]. But his finding differed markedly from those of Kusy et al; Vinod Krishnan and Jyothindra Kumar reported that Stainless steel appeared smoothest surface followed by Timolium and TMA [16].

The mechanical properties of wires were essential for clinical performance and any alteration in its properties, will give suboptimal results. The mechanical properties of orthodontic wires are determined from different type of bending test, as this mode of deformation is considered more represented of clinical conditions than the tension test that is conventionally used for metals. The cantilever bending test performed with the Olsen stiffness tester is more complicated, because the fixed end of the specimen rotates while the other end of the test span is deflected by a bending plate [17]. Three point tests are relatively simple to perform in the laboratory and stimulate better clinical inter-bracket distances, so it was used to study the load deflection behavior of wires [9].

The results allowed the classification of the groups according to their load requirement for deflection, from the lowest to highest value. It can be summarized as follows: Neo sentalloy with Ion guard (2.90 N), Nickel Titanium super elastic (4.48N), TMA (18.13N), Timolium (21.77N) and Stainless Steel (27.73N) (Fig.4). According to Crotty et al; the tensile and flexural properties of super elastic nickel titanium wires showed no significant change, when subjected to autoclave sterilization [3]. According to Smith et al;load/deflection and tensile testes showed no clinically significant difference between as received and used then disinfected/ sterilized Nickel Titanium wires.

Mayhew and Kusy found that, neither the heat sterilization nor multiple cycling procedures had a deleterious effect on the elastic moduli or tensile properties of Nickel Titanium wires [14]. Buckthal and Kusy reported that, no significant changes were detected in the fundamental stiffness or inherent strength of the Nickel Titanium wires after multiple disinfectant cycles [1]. Lee and Chang found that, recycling of nickel titanium wires does not show significant differences in maximum tensile strength, tensile strength, elongation rate, modulus of elasticity and bending fatigue [11].

Our study results are in accordance with Pernier et al; findings. Kapila et al; reported that, changes in load deflection characteristics of Nickel Titanium alloy wires after dry heat sterilization were relatively small and their clinical significance is therefore questionable. On the other hand, clinical recycling increased the loading and unloading forces of both NiTi and Nitinol wires. According to Staggers and Margeson, dry heat sterilization significantly increased the tensile strength of TMA wire after one cycle, whereas autoclave sterilization did not significantly alter the tensile strength of TMA wires. Dry heat and autoclave sterilization significantly increased the tensile strength of Sent alloy wires, but no significant changes noted in stainless steel wires.

## Conclusion

Scanning electron and Atomic force microscopy did not provide a clear evidence of any statistically significant change in the surface features of the wires tested, after sterilization. The three-point bending test also showed no statistically significant change in the load deflection behavior of wires, after sterilization. These findings supported the dental practitioners who wanted to guarantee maximum safety for their patients, as sterilization of orthodontic wires before placement does not alter the properties of the alloys. Further research is however, required to evaluate other sterilization methods on the surface topography and mechanical properties of above mentioned and recently introduced wires.

***Conflict of Interest:*** *None declared*
***Source of Support:*** *Nil*
***Ethical Permission:*** *Obtained*

## References

1. James E. Buckthal and Robert P. Kusy. Effects of cold disinfectants on the mechanical properties and the surface topography of nickel titanium arch wires. American Journal of Orthodontics and Dent facial Orthopaedics 1988; 94: 117-122.
2. Sunil Kaplia, Gary W. Reichhold, R. Scott Anderson and Larry G. Watanabe. Effects of clinical recycling on mechanical properties of nickel titanium alloy wires. American Journal of Orthodontics and Dent facial Orthopaedics 1991; 100: 428 - 435.
3. Crotty OP, Davies EH and Jones SP. The effects of cross infection control procedures on the tensile and flexural properties of super elastic nickel titanium wires. British Journal of Orthodontics 1996;23(1):37-41.
4. Julie Ann Staggers and Dailas Margeson. The effects of sterilization on the tensile strength of orthodontic wires. The Angle Orthodontist 1993; 63 (2): 141-144.
5. Sunil Kapila and Rohit Sachdeva: Mechanical properties and clinical applications of orthodontic wires. American Journal of Orthodontics and Dent facial Orthopaedics 1989; 96: 100-109.
6. Sunil Kaplia, John W. Haugen and Larry G. Watanabe. Load deflection characteristics of nickel titanium m alloy wires after clinical recycling and dry heat sterilization. American Journal of Orthodontics and Dent facial Orthopaedics 1992; 102: 120-126.
7. Pernier C, B. Grosgogeat, L. Ponsonnet, G. Benay and M. Lissac. Influence of autoclave sterilization on the surface parameters and mechanical properties of six orthodontic wires. European Journal of Orthodontics 2005; 27: 72-81.
8. Peter D. Wilkinson, Peter S.Dysart, James A. Hood and G. Peter Herbison. Load deflection characteristics of super elastic nickel titanium orthodontic wires. American Journal of Orthodontics and Dent facial Orthopaedics 2002; 121: 483-495
9. Glen A. Smith, J.A. Von Fraunhofer and Glenn R. Casey. The effect of clinical use and sterilization on selected orthodontic arch wires. American Journal of Orthodontics and Dent facial Orthopaedics 1992; 102: 153-159.
10. Christoph Bourauel, Thomas Fries, Dieter Drescher and Reinhard Plietsch. Surface roughness of orthodontic wires via atomic force microscopy: laser specular reflectance and profilometry. European Journal of Orthodontics 1998; 20: 79-92.
11. Sung Ho Lee and Young II Chang. Effects of recycling on the mechanical properties and the surface topography of nickel titanium alloy wires. American Journal of Orthodontics and Dent facial Orthopaedics 2001; 120: 54-63.
12. Robert P. Kusy, John Q. Whitley, Michael J. Mayhew and James E. Buckthal. Surface roughness of orthodontic arch wires via Laser spectroscopy. The Angle Orthodontist 1988; 1: 33-45.
13. Grosgogeat, Jablonska, Vernet, Jaffrezic, Lissac and Ponsonnet. Tribiological response of sterilized and un-sterilized orthodontic wires. Materials science and engineering 2006; 26: 267-272.
14. Michael J. Mayhew and Robert P. Kusy. Effects of sterilization on the mechanical properties and the surface topography of nickel titanium arch wires. American Journal of Orthodontics and Dent facial Orthopaedics 1988; 93: 232-236.
15. Robert R. Prososki, Michael D. Bagby and Lesile C. Erickson. Static frictional force and surface roughness of nickel titanium arch wires. American Journal of Orthodontics and Dent facial Orthopaedics 1991; 100: 341-380.
16. Vinod Krishnan and K. Jyothindra Kumar. Mechanical properties and surface characteristics of three arch wire alloys. The Angle Orthodontist 2004; 74: 823-29.
17. William A, Brantley and Theodore Eliades. Orthodontic materials, scientific and clinical aspects Stuttgart, New York 2001; Orthodontic wires, page no: 78-100.