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AUTOCLAVE STERILIZATION OF UNCOATED AND COATED NITI WIRES AND POSSIBLE EFFECTS ON THE MECHANICAL PROPERTIES AND SURFACE ROUGHNESS

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ABSTRACT

Introduction: The frequency of patients' exposure to infection and cross contaminated dental materials raises concern about sterilization of orthodontic arch wires.

Objective: To explore if autoclave sterilization may modify the mechanical properties and surface roughness of NiTi arch wires or not.

Methods: In the present study a total number of ninety maxillary superelastic NiTi wires with a diameter of 0.016" were used. They were equally divided into three groups. Group 1: uncoated NiTi wires (OrthoOrganizers), group 2: teflon coated NiTi wires (OrthoOrganizers), group 3: aesthetic NiTi wire (Jiscop). The three groups were examined using three point bending tests and profilometry before and after autoclave sterilization at 134°C for 18 minutes.

Results: The three point bending test revealed statistically significant higher loading forces after sterilization at deflections of 1mm and 2 mm in uncoated NiTi wire and at 1mm in aesthetic NiTi wire. Significant lower loading forces were recorded at deflections of 2mm &3mm in Aesthetic wire. On the other hand, statistically significant lower loading forces after sterilization were detected in teflon coated NiTi wire. As regards the unloading forces, they were significantly lower after sterilization when deflected for 0.5mm, 1.5mm and 2.5 mm in Teflon coated Niti wire. A significant decrease in the elastic modulus was detected in all groups after autoclave sterilization and the profilometry revealed a significant decrease in the surface roughness of uncoated Niti group.

Conclusion: Autoclaving causes significant changes in the mechanical properties and surface roughness of NiTi archwires.

KEY WORDS: Orthodontic wires, sterilization, properties, surface.

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INTRODUCTION

All the instruments contacting the oral mucosa should be sterilized according to CBC recommendations[1]. Orthodontic wires are often sold in sealed packages. The instructions on these packages mostly recommend sterilization of wires to prevent cross contamination. However, the sterilization process may have adverse effects on the characteristics of orthodontic wires[2]. Conflicting results have been detected by most authors in the literature testing the effect of sterilization on the surface parameters and mechanical properties of NiTi archwire[2,3]. To assess the mechanical properties of the orthodontic arch wires, the three point bending test is used as it estimates the load deflection properties, which are the most powerful parameters in determining the biological nature of tooth movement[4]. Surface roughness is a fundamental factor in detecting the efficiency of arch wire planned tooth movement[5]. Several methods can be used to determine the surface roughness of orthodontic arch wires, as laser spectroscopy[6], atomic force microscopy[5] and contact surface profilometry[5]. The orthodontic profession was continuously looking forward to enhance and optimize the aesthetics of orthodontic wires since the apperance of aesthetic brackets. Aesthetic wires are usually either composite wires of reinforced polymers or coated NiTi wires[7]. Previous studies have concentrated on rectangular nickel nitanium wires and their properties after sterilization[2, 8]. No sufficient investigations have been done on round coated or uncoated nickel titanium wires. The hypothesis assumed that sterilization would modify the mechanical properties and the surface roughness of NiTi arch wires. So, the present prospective study was conducted to determine the effect of autoclaving which is the most effective method of sterilization in the orthodontic office on the mechanical properties and surface roughness of uncoated NiTi and two types of coated wires (Teflon coated and aesthetic NiTi wires).

MATERIAL AND METHODS

A total number of ninety maxillary superelastic NiTi wires were used in this study & equally divided into three groups, group 1: uncoated NiTi wires (OrthoOrganizers), group 2: teflon coated NiTi wires (OrthoOrganizers), group 3: aesthetic NiTi wire (Jiscop). All types have the same diameter with a cross section of 0.016”. All wires were autoclaved for 18 minutes at 134°C according to the French Ministry of Health (recommendation no. DGS/5C/DHOS/E2/2001/138 of the French Ministry of Health, 14 March 2001)[2]. The autoclave used was Poleax Series SA-232X- STURDY, Taiwan. The three groups were examined before and after sterilization using three point bending tests and profilometry. Samples measuring 30mm in length were cut from the straight sections of the arch wires of one side using wire cutters before sterilization. They were taken from the other side of the arch wire after sterilization. The samples were marked with a permanent marker at 15mm and subjected to the different tests.

The three-point bending test

A jig was made with two parallel brass rods and a diameter of 5 mm. On the top of these rods, two self-ligating Damon® central incisor brackets (Ormco) were bonded with a slot size of 0.022 × 0.028” and a distance of 14 mm between the brackets. The jig was placed at the base of the testing machine (Instron model 3345, England) (figure 1). The force was directed vertically toward the center of the interbracket distance using a third brass rod joined to the moving part of the Instron machine, at 1 mm crosshead speed per minute for both loading and unloading. Since the arch wires were not heat-activated NiTi, testing was done at room temperature. Force values were measured at loading deflections of 1, 2, 3 mm and unloading deflections of 0.5, 1.5 and 2.5mm. Both loading and unloading forces were recorded at the rate of 10mm/min by the load cell. The data were registered using computer software Bluehill version 3.3.

The Surface profilometry

It was performed using a contact stylus profilometer (Talysurf- version i60; Metek, UK with software ultra) to analyze the surface roughness of the arch wires (figure 2). The profilometer was equipped with a metal probe having a diamond tip as a ball of radius 2 microns, which has a vertical resolution of 16 nm along 1 mm vertical range, and a traverse surface scanning on eight 0.25-mm-long sections (cut-off wavelength) of each specimen at medium speed (0.25 mm/sec). The irregular vertical movements of the tips were plotted against the profile of the surface explored. The examined distance at each scan was (0.25 x 8 sections) = 2 mm (in case of 2 mm length). At least three profilometric scans were performed at different parts of each wire specimen for standard repeatability. The equipment can determine the profilometric mean roughness from the surface profile by using the above-mentioned software.

Data entry and statistical analyses were processed using SPSS (statistical package of social sciences) version 16.0 (SPSS Inc., Chicago, IL, USA). Mean ± standard deviation was used to express parametric data. Non parametric data were expressed in median, minimum and maximum. **Paired t test** was applied to compare parametric variables before and after sterilization. **Wilcoxon signed rank** test was used for comparison before and after sterilization of non-parametric variables. P value is considered statistically significant <0.05.

RESULTS

Three point bending test

Table 1 show the results of the three point bending tests for the uncoated NiTi arch wire at the different loading and unloading stages. There was higher loading forces after sterilization compared to before at loading deflections of 1mm and 2 mm in uncoated NiTi wire with statistically significant difference ($p<0.05$). However, it showed lower loading forces when deflected for 3mm after sterilization with no statistically significant difference ($p>0.05$). Uncoated nickel titanium wire

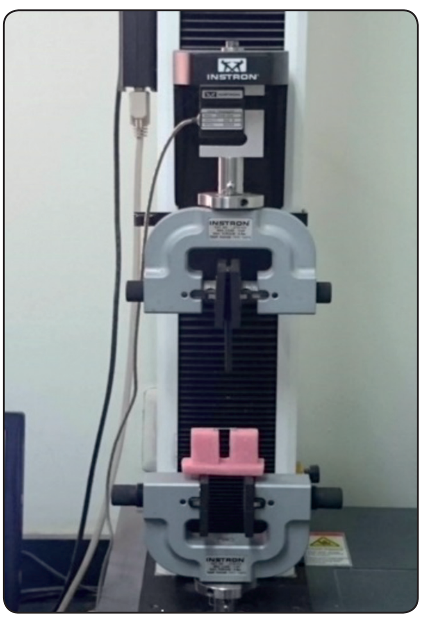

Fig. (1): The three point bending test

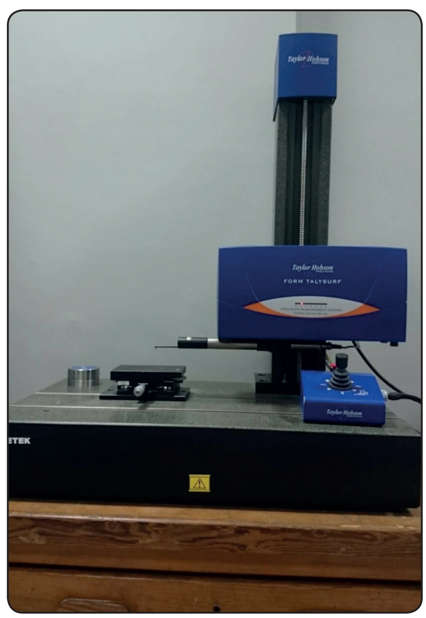

Fig. (2): The surface profilometry

showed a statistically significant higher force value at unloading deflection of 0.5 mm only.

Teflon coated NiTi arch wire exhibited statistically significant lower mean force values after sterilization compared to before at loading deflections of 1mm, 2mm and 3mm. Also, the mean unloading forces were less after sterilization when deflected for 0.5mm,1.5mm and 2.5 mm with a statistically significant difference (p<0.05) (Table 2).

Aesthetic wire showed statistically significant higher force values after sterilization compared to before at 1 mm loading and 2.5 mm unloading (p<0.05). However it revealed lower loading forces after sterilization when deflected for 2mm &3mm with statistically significant difference (p<0.05) (Table 3).

The three point bending test enabled the determination of the elastic modulus for each of the wires tested. Mean Modulus of Elasticity was slightly less after sterilization compared to before with a statistically significant difference (p<0.05) for all groups as shown in table (4) & figure (3).

Profilometry

Table (5) & figure (4) showed that the median of profilometer measurements had decreased in uncoated NiTi and Aesthetic wire groups with statistically significant difference for the uncoated NiTi group only (p<0.05). However it increased slightly after sterilization in teflon coated group but with no significant difference (p>0.05).

TABLE (1): Uncoated NiTi wire before and after sterilization

Variable	Deflection(mm)	NITI Before n=30		NITI After n=30		Significance test	
		Mean	SD	Mean	SD	t	P -value
Loading	1.0	0.61	0.03	0.73	0.17	3.04	0.005*
	2.0	3.01	0.08	3.5	1.09	2.4	0.02*
	3.0	4.97	0.12	4.8	0.32	2.01	0.053
unloading	2.5	1.92	0.12	1.90	0.11	1.4	0.17
	1.5	0.93	0.04	0.96	0.14	1.04	0.3
	0.5	0.02	0.008	0.06	0.04	3.1	0.001*

Paired t test ****p value is considered statistically significant <0.05***

TABLE (2): Teflon Coated arch wire before and after sterilization

Variable	Deflection (mm)	Teflon Coated Before n=30		Teflon Coated After n=30		Significance test	
		Mean	SD	Mean	SD	t	P-value
Loading	1.0	1.009	0.05	0.77	0.02	32.3	≤0.001*
	2.0	2.4	0.09	2.08	0.03	17.7	≤0.001*
	3.0	2.9	0.07	2.82	0.11	3.17	0.004*
unloading	2.5	1.03	0.03	0.96	0.06	4.5	≤0.001*
	1.5	0.69	0.03	0.50	0.02	18.5	≤0.001*
	0.5	0.36	0.01	0.12	0.01	113.11	≤0.001*

Paired t test ****p value is considered statistically significant <0.05***

TABLE (3): Aesthetic arch wire before and after sterilization

	Deflection (mm)	Aesthetic NITI Before n=30		Aesthetic NITI After n=30		Significance test	
		Mean	SD	Mean	SD	t	P-value
Loading	1.0	1.48	0.57	1.72	0.01	2.2	0.03*
	2.0	4.9	0.1	4.8	0.03	3.1	0.004*
	3.0	6.5	0.19	6.19	0.03	11.8.	≤0.001*
unloading	2.5	2.08	0.08	2.17	0.07	6.5	≤0.001*
	1.5	1.13	0.04	1.16	0.09	1.3	0.19
	0.5	0.18	0.03	0.18	0.03	0.13	0.8

Paired t test ****p value is considered statistically significant <0.05***

TABLE (4): Modulus of Elasticity of the studied wire groups

Study groups	Before n=30	After n=30	Significance test	
	Mean (SD)	Mean (SD)	t	P value
Gp 1 (Uncoated NiTi)	4.3 (0.21)	4.09 (0.25)	3.4	0.002*
Gp 2(Teflon coated)	2.9 (0.09)	2.03 (0.17)	34.7	<0.001*
Gp 3(Aesthetic wire)	4.4 (0.11)	4.3 (0.09)	4.4	0.001*

TABLE (5): Profilometer before & after sterilization

Study groups	Profilometer Before n=30	Profilometer After n=30	Significance test	
	Median (IQ range)	Median (IQ range)		P-value
Gp 1 (Uncoated NiTi)	0.07 (0.12)	0.03 (0.04)	3.06	0.002*
Gp 2 (Teflon coated)	0.48 (0.21)	0.6 (0.7)	0.12	0.9
Gp 3 (Aesthetic wire)	0.07 (0.06)	0.06 (0.04)	0.7	0.4

Wilcoxon- signed ranks, ***IQ range: Interquartile range*** ****p value is considered statistically significant <0.05***

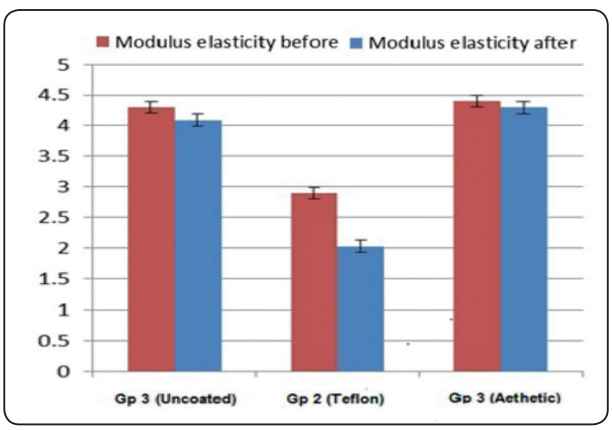

Fig. (3): Error bar chart for Modulus of Elasticity of the studied wire groups

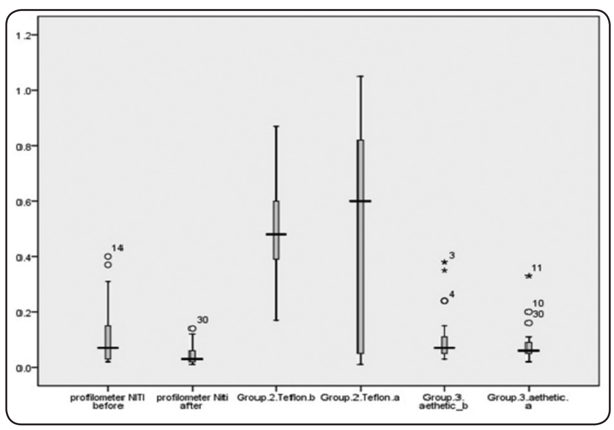

Fig. (4): Box plot for profilometer before and after in each group

DISCUSSION

In the present work, three types of 0.016" Niti archwires were used. Uncoated Niti wire and two of the new generation coated nickel titanium wires, Teflon coated and Aesthetic NiTi arch wires were chosen to study the effect of autoclaving on both mechanical properties and surface roughness.

Niti wires were chosen because of their superelasticity. This diameter was selected because it has the highest application rate in the clinic for alignment and leveling. Autoclaving was utilized as it is the sterilization method commonly used in orthodontic clinics and most manufacturers recommend it.

In the present study, the three point bending test revealed significant changes in the uncoated and coated Niti arch wires (Teflon coated and Aesthetic) after autoclave sterilization compared to before at the different loading and unloading forces utilized. The autoclave sterilized Teflon coated NiTi wire generated a significantly lower loading forces ($p<0.001$) compared with the as received one at 0.5, 1.5 and 2.5 mm deflections and this is not the case neither with sterilized Aesthetic nor with the uncoated NiTi arch wire.

Contradictory results have been detected by most authors in the literature regarding the influence of sterilization on the mechanical properties of nickel titanium archwires. Pernier et al.[2] found no adverse effects on the mechanical and surface properties of six different orthodontic wires after autoclave sterilization. Nikolai and Heurter[9] investigated the combined effects of sterilization and clinical application on the properties of NiTi wires. They confirmed that evident changes occurred in the mechanical properties of these wires. Alavi et al.[3] studied the effects of dry-heat and steam sterilization on superelastic NiTi wire; they reported that both methods of sterilization cause changes in their mechanical and bending properties. However, the dry-heat process caused greater changes in the mechanical properties of wires compared with the steam sterilization process due to longer time and higher temperature.

Another finding of the present research is a significant decrease in the elastic modulus for each of the wires tested after autoclave sterilization compared to before. This is unlike the findings obtained by Pernier et al.[2] who used the same protocol for autoclave sterilization and reported that this did not modify the elastic modulus for the six alloys tested (1 Stainless steel, 2 nickel titanium, 3 titanium molybdenum alloys). However, they utilized a small number of wires (six wires of each alloy) and they mentioned that their findings should be interpreted with caution as no satisfactory statistical analysis of the results could be carried out.

The aesthetic outcome, biocompatibility and resistance to corrosion are influenced by the surface structure of orthodontic arch wires[2]. In the present study, profilometry values showed no difference in the average roughness of the two types of coated NiTi arch wires indicating that sterilization by this protocol did not affect their surface features. On the contrary, there was a statistically significant decreased roughness of the uncoated NiTi wire after autoclaving with an average roughness decrease of approximately 0.04µm after sterilization. But in general, this decrease was extremely small and it is most unlikely that it would have any clinical effect. There is conflicting data in the literature concerning the effect of autoclaving on the surface properties of orthodontic arch wire. Pernier et al.[2] reported no significant change in the surface features of six orthodontic wires. Thierry et al.[10] found that both dry heat and autoclave sterilization increased the surface roughness of nickel titanium disks. The same was also reported by Alavi et al.[3] on three types of superelastic NiTi wires. Isac et al.[8] reported that autoclave sterilization did not affect considerably the surface characteristics of any of the three types of archwire used (SS, nitinol and β-Ti). This variation in different studies may be due to the difference in archwire manufacturer and measurement methods that might have influenced the outcome in those studies. Our results agree with that of Bavikati et al.[11]who evaluated the physical and mechanical properties of recycled and clinically used Superelastic NiTi Wires by autoclaving of four different commercially available Niti archwires. They observed a significant decrease in surface roughness between the control and experimental arch wires within each group.

CONCLUSION

The results of the current study showed that autoclaving non-used arch wires results in some changes in the mechanical properties and surface roughness of NiTi wires which may differ according to the archwire manufacturer, this may discourage the use of recycled NiTi arch wire.

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