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Randomized clinical trial evaluating mechanical and surface properties of esthetic archwires compared to conventional superelastic nickel titanium archwires after alignment phase.

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Abstract

Aim: *to assess surface roughness and coating retention of epoxy coated wires after clinical use and to compare them to conventional nickel titanium archwires.*

Materials and methods: *Wires were retrieved from 26 patients attending the Outpatient Clinic of Orthodontic Department Faculty of Dentistry, Ain Shams University. Patients enrolled in group A (n=13) received conventional superelastic nickel titanium archwires with wire sequence 0.014 niti, 0.016 niti, 0.016 X 0.022 niti, while patients enrolled in group B (n=13) received coated nickel titanium archwires (Ortho Technology) with the same wire sequence. Wires were divided into 4 main groups; two groups containing wires as received from the manufacturer and the other two groups were wires retrieved from patients after alignment. Each group was further divided into 3 subgroups according to wire size. Surface roughness of retrieved and as received coated and conventional nickel titanium wires was assessed using AFM. SEM was used to assess the micro morphological characteristics of coated archwires before and after use in the oral cavity.*

Results: *In as received: surface roughness in group A was significantly higher than in group B regarding 0.014 NiTi, 0.016 NiTi, and 0.016X0.022 NiTi. In retrieved: surface roughness in group A was significantly lower than in group B regarding 0.014 NiTi, 0.016 NiTi, and 0.016X0.022 NiTi.*

Conclusions: *Surface roughness of coated nickel titanium archwires is initially less that of conventional archwires, with clinical use surface roughness increased in both groups with significant higher increase regarding coated archwires. Coated retrieved archwires showed areas of coating loss.*

Introduction

Adult orthodontic treatment has increased drastically over the last years for so many reasons for example; adult patients who had orthodontic treatment when they were younger and then experienced relapse due to inadequate retention, or adult patients who simply want to improve their smile. Orthodontic treatment can also be used as an adjunctive approach with other branches of dentistry such as with implants or prosthodontics; orthodontic treatment can be carried out as a first step for correction of space problems, or intruding opposing teeth. Although adult patients cooperate better than adolescents, they present a different set of challenges for the orthodontist namely; possible long treatment time and also esthetics during this period of treatment is of prime concern for these patients[1]. As a result, the need for esthetic orthodontic appliances has

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also increased drastically. Tremendous efforts have been made to improve appearance of labial fixed appliances mainly by eliminating their metallic appearance such as esthetic tooth-colored brackets, wires and ligatures[2]. Tooth colored brackets included plastic, composite and ceramic brackets. Wires were also modified to improve esthetics, many prototypes were introduced such as fiber reinforced wires and Optiflex wires but still they are not widely spread in the market[3–8]. The more commonly used esthetic wires are the coated nickel titanium or stainless-steel wires. Finally it is important to evaluate the properties and performance of these coated wires and to weigh their pros and cons in order to decide whether they can be used as an alternative to conventional non-coated archwires.[9]

The aim of our study is to assess the surface roughness and coating retention of epoxy coated wires after clinical use and to compare them to conventional superelastic nickel titanium archwires.

Materials and Methods

Study sample:

Sample size was calculated depending on a previous study by Rongo etal as reference[10]. According to this study, the minimally accepted sample size was 10 wires per group, with mean and standard deviation of group 1 176.2 ± 94.5 while mean and standard deviation of group 2 was 74 ± 30.1, with 1.32 effect size when the power was 80 % & type I error probability was 0.05. The independent t test was performed by using G.power3.1.9.7. Total sample size was increased to 13 wires per group to compensate for 15 % drop out. Wires were retrieved from a total of 26 patients attending the Outpatient Clinic of Orthodontic Department Faculty of Dentistry, Ain Shams University. Retrieved wires were then compared to as received wires.

Sampling Criteria:

Patients with age ranging between 18 to 30 years were included in the study. To exclude any variables that might affect tooth movement, patients with fixed prosthetic restorations in the anterior region, enamel defects, medical condition affecting tooth movement such as osteoporosis or undergoing bisphosphonate therapy were excluded. Patients with severe crowding were also excluded from the trial as well as vulnerable patients and those with bad oral hygiene.

Withdrawal criteria

Participants could withdraw from the study at any time without compromising the treatment.

Randomization

Patients who met the inclusion criteria and agreed on participation in the study were randomly assigned into 2 equal groups; control group (group A) and study group (group B) using simple randomization. A fellow colleague who was not involved in the study generated sequences using “Microsoft Excel” computer program. Even numbers were assigned for the study group while odd numbers were assigned for the control group. Every patient enrolled in the clinical trial was given a number according to the order in which the showed up for diagnosis then this number was matched with

the generated sequence and allocated to the control group if the number was odd, and to the study group if the number was even. In this clinical trial blinding was ensured as the investigator was not involved in patient allocation and this was insured by having a colleague make and keep the generated sequence.

Patient consent

An informed consent was signed by patients in both groups before their enrollment in the study in which the aim of the study, study methodology and possible complications were clearly described.

Research ethics approval

This research was reviewed and approved by the research ethics committee, Faculty of Dentistry, Ain Shams University. FDASU-RecIM121806

Declaration of interests

There were no financial competing interests, this study was a part of a master's degree in orthodontics, Faculty of Dentistry, Ain-Shams University.

Also, no financial conflict of interest was declared, any extra fees concerning the brackets and wires used in the study were self-funded by the primary investigator.

Intervention

- **For both group A and group B: single tubes were fitted on the first molars, monocrystalline ceramic brackets slot 0.018inch Roth prescription were placed on teeth in upper arch.**

Patients enrolled in group A (n=13) received conventional non-coated superelastic nickel titanium archwires with wire sequence 0.014 niti, 0.016 niti, 0.016 X 0.022 niti, while patients enrolled in group B (n=13) received tooth tone coated nickel titanium archwires (Ortho Technology) with the same wire sequence. (figure 1)

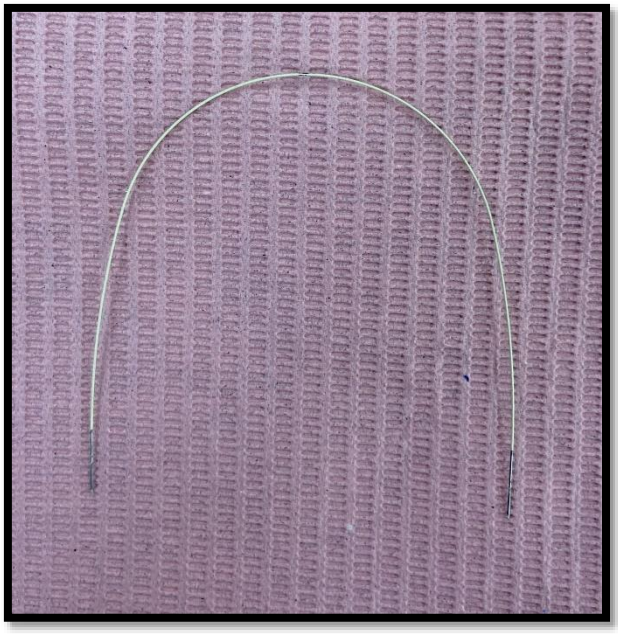

Fig. (1): Epoxy coated nickel titanium archwire

Wire retrieval

Each group yielded a total of 39 retrieved wires, 13 wires of each of the wire sizes used in the study. After wires were retrieved, they were washed under running water to get rid of any loose bound precipitations, wiped with gauze soaked in alcohol, and placed in a labelled plastic envelope.

Wires used in the study were divided into 4 main groups; two wire groups containing wires as received from the manufacturer and the other two groups were wires retrieved from patients after alignment. Each group was further divided into 3 subgroups according to wire size. The following diagram represents the wire grouping ready for testing. (Figure 2)

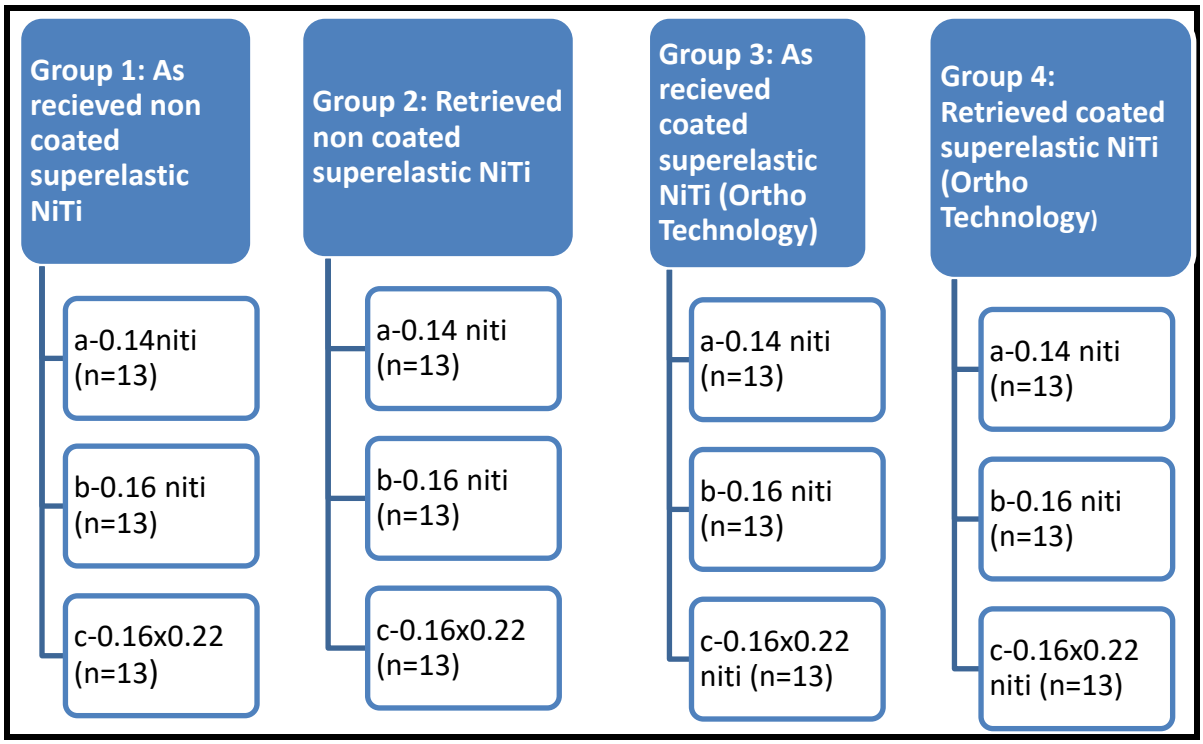

Fig. (2): Wire groups used in the study

Wire segments with length 20mm were cut from the main archwire, prepared and then placed inside labelled plastic containers as seen in (figure 3).

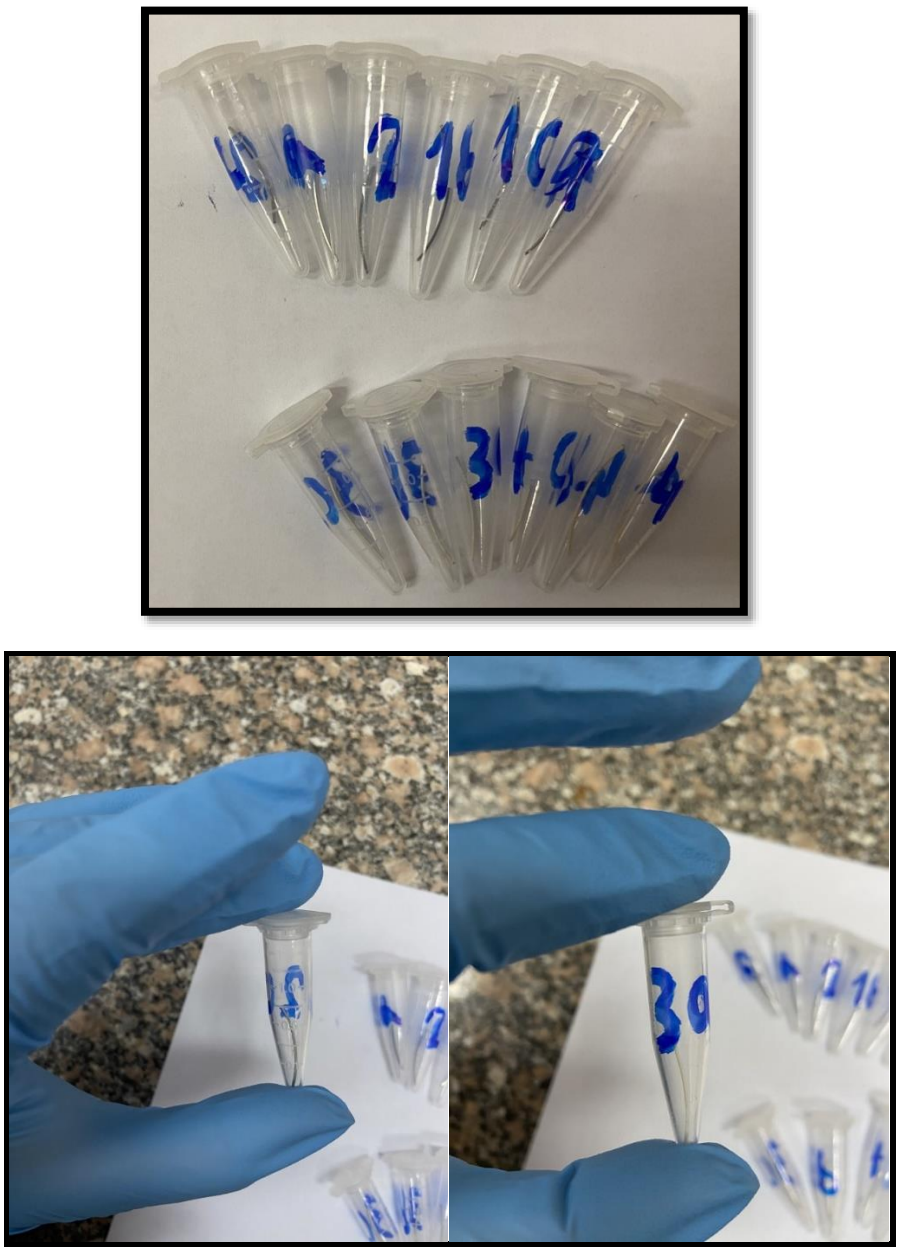

Fig. (3): Labelled plastic containers with wire segments cut from the retrieved and from the as received wires.

Methods of assessment

Surface roughness

Surface roughness of retrieved esthetic and conventional nickel titanium wires when compared with as received state was assessed using Atomic Force Microscope (AFM). *5600Ls, Agilent technology, USA*

AFM produces high resolution 2d and 3d images of the specimen with a detailed surface topography.[10,11]

Coating stability

Scanning Electron Microscope (SEM) was used to assess the micro morphological characteristics of the coated archwires before and after use in the oral cavity such as coating stability**.** SEM images were taken using a Zeiss LEO Supra 55VP Field Emission and SEM Zeiss 1530. Wire sections were placed on a carbon holder which is a type of specimen holder used in SEMs to hold samples for imaging. Carbon holders are used for the analysis of non-conductive samples like biological specimens, ceramics, and polymers. Specimens were viewed with magnification 70X to show areas of wire deterioration, debonding of wire coating and metal exposure.

Results

Surface roughness

Mean and standard deviation of surface roughness of as received and retrieved wires in group A & B were presented in table (1) and figure (4) 2d and 3d images are shown in figure5.

Comparison between both groups was performed by using Independent t test which revealed significant difference between them as $P<0.05$, as:

- **In as received:** Group A was significantly higher than group B as $P<0.0001$, 0.006, and 0.004 regarding 0.014 NiTi, 0.016 NiTi, and 0.016X0.022 NiTi respectively.
- **In retrieved:** Group A was significantly lower than group B as $P<0.0001$, <0.0001 and 0.001 regarding 0.014 NiTi, 0.016 NiTi, and 0.016X0.022 NiTi respectively.
- **In difference between received and retrieved:** Group A was significantly lower than group B as $P<0.0001$, <0.0001, and 0.0006 regarding 0.014 NiTi, 0.016 NiTi, and 0.016X0.022 NiTi respectively.

Table 1: *Surface roughness of as received and retrieved conventional and coated archwires and comparison between group A and group B in terms of mean and standard deviation using Independent t test*

		Group A		Group B		Comparison between as received and retrieved wires in both groups				
						MD	SEM	95% CI		P value
		M	SD	M	SD			L	U	
AsReceived	0.0 14 NiTi	55.77	8.02	31.92	0.62	-23.85	2.23	-28.45	-19.25	<0.0001**
	0.0 16 NiTi	34.87	6.07	29.8	1.18	5.07	1.71	-8.61	-1.53	0.006**
	0.016X0.022 NiTi	66.38	32.38	36.64	9.34	29.74	9.34	-49.03	-10.46	0.004**
Retrieved	0.0 14 NiTi	172.22	18.77	300.54	31.22	128.3	10.1	107.5	149.2	<0.0001**
	0.0 16 NiTi	169.87	10.75	398.11	19.51	228.2	6.17	215.5	241	<0.0001**
	0.0 16X0.022 NiTi	174.29	80.47	327.89	125.07	153.6	41.25	68.47	237.8	0.001**
Difference	0.0 14 NiTi	116.45	16.31	268.62	31.85	152.2	9.92	131.7	172.7	<0.0001**
	0.0 16 NiTi	135	16.71	368.31	19.12	233.3	7.04	218.8	247.8	<0.0001**
	0.0 16X0.022 NiTi	107.91	112.24	291.25	124.67	183.3	46.35	87.32	279.45	0.0006**

M: mean SD: standard deviation **highly significant difference as P<0.001.
MD: mean difference SEM: standard error mean
CI: confidence interval L; lower arm U: upper arm

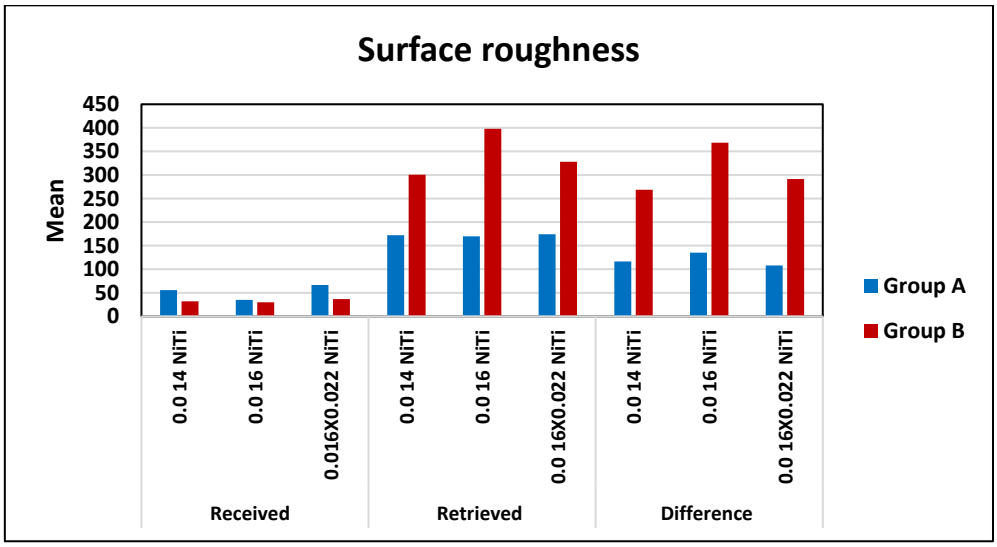

Fig. (4): Bar chart showing comparison between group A and group B surface roughness of as received and retrieved conventional and coated archwires.

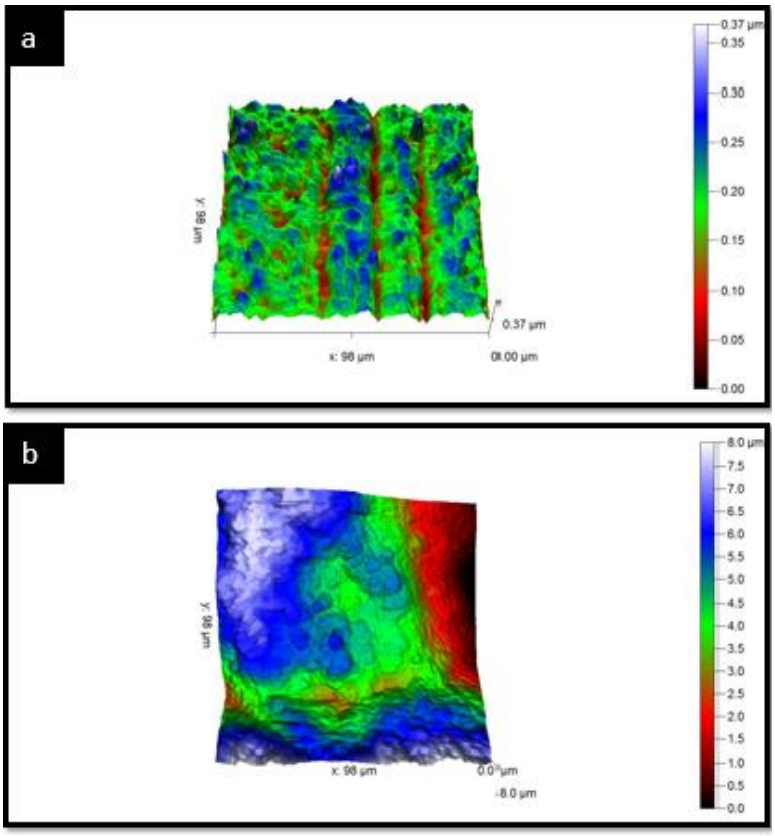

Fig (5): (a) 3d image of wire specimen, (b) 2d image of wire specimen

Coating Stability

When analyzing the as received coated wires, Scanning Electron Microscope images showed a relatively homogenous surface. On the other hand, the labial surface topography of retrieved coated archwires showed considerable coating loss and delamination as shown in figure 6. SEM images showed varied and uneven surface with the presence of craters and bumps on the surface of retrieved coated archwires, no defects were found on the exposed metal core under the peeled polymer layer. In several specimens a relationship was observed between bracket imprints and areas of delamination.

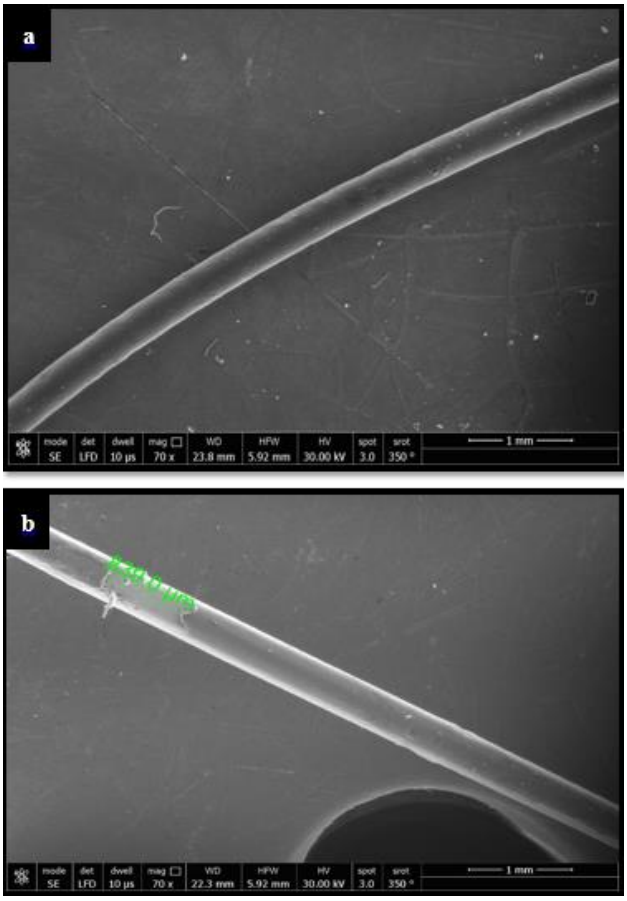

Fig (6): (a) As received wire specimen under microscope, (b) Retrieved wire specimen under microscope.

Discussion

There is a growing necessity to closely examine the surface and mechanical properties of coated wires such as surface roughness, friction and surface topography and to evaluate the effect these properties have on clinical efficiency of coated wires.

Following each visit, retrieved wires were subjected to a disinfection process that preserved the inherent characteristics of wires. This process involved washing retrieved wires under running water for removing any loose debris or food particles, air dried and then were gently wiped with gauze soaked in alcohol for disinfection. Finally they were carefully stored in a plastic labelled envelope for identification. This disinfection process was described before by **Bradley T et al** [7].

In this study AFM and SEM were utilized for evaluating the topographic changes in coated and non-coated wires. AFM provided quantitative information regarding surface roughness regardless of its limitations such as small scan size, while SEM provided a qualitative assessment of the surface at on a larger micrometer scale. As received coated wires had a relatively homogenous surface while retrieved coated archwires showed

considerable coating loss and delamination which is consistent with previous research findings [12,13]The specimens showed varied and uneven surface with the presence of craters and bumps. This deterioration can compromise the esthetic qualities of coated archwires potentially affecting patient satisfaction, no defects were found on the exposed metal core under the peeled polymer layer. It is of great importance to emphasize that the presence of these irregular surfaces can lead to plaque accumulation and also the presence of bracket edges within these irregularities may impact tooth movement. In some areas the coat remained intact while exhibiting a rougher, discolored and deteriorated surface when compared to coated wires in the as received state. Higher incidence of delamination and exposed underlying metal cores was observed on the posterior sections of the wire, particularly in the region of the premolars. All the previous findings align with the observed increase in surface roughness parameters for the retrieved coated wires in our study.

In this study Atomic Force microscope was used to investigate surface roughness of coated nickel titanium wires versus non-coated nickel titanium wires and to evaluate surface roughness of the same wires after use in the oral environment. AFM was the method of choice in this test despite its higher cost as it is a non-destructive optical technique giving accurate 3d images with high resolution and a more detailed surface topography. It offers many advantages over contact profilometry such as reduced tip to specimen forces which decreases the chances of damage to the sample or wear to the probe tip, moreover, when compared to a conventional profilometer AFM provides better resolution and a higher level of precision due to its lower loading force and more precise tip.[14]

When comparing the mean surface roughness (Sa) in both groups, there was a statistically significant difference in mean surface roughness between the wires in their original (as received) state and the retrieved wires in each wire size group in groups A and B. For instance, in group B, the coated 0.016 X 0.022 niti wires exhibited an increase in mean surface roughness from (36.64± 9.34 nm) in the as received state to (327.89± 125.07 nm) in the retrieved state, with a mean difference of 291.25 nm. In group A, the uncoated conventional superelastic 0.016 X 0.022 niti wires supplied by the same manufacturer showed an increase in mean surface roughness from (66.38± 32.38 nm) to (174.29± 80.47 nm) with a mean difference 107.91. When comparing group A with group B, it is evident that **regarding as received wires** Group A had significantly higher surface roughness than group B as ($P<0.0001$, 0.006, and 0.004 regarding 0.014 niti, 0.016 niti, and 0.016X0.022 niti respectively). **Regarding retrieved wires,** Group B had significantly higher surface roughness than group A as ($P<0.0001$, <0.0001, and 0.001 regarding 0.014 niti, 0.016 niti, and 0.016X0.022 niti respectively). **In difference between received and retrieved:** Group A was significantly lower than group B as ($P<0.0001$, <0.0001, and 0.0006 regarding 0.014 niti, 0.016 niti, and 0.016X0.022 niti respectively). This indicates that coated nickel titanium wires in their original state had a smoother surface with less

surface roughness than uncoated nickel titanium wires. However, following clinical use and retrieval, coated wires exhibited a mean surface roughness higher than that of the non-coated counterpart.

This data aligns with the findings of the study conducted by **Rongo R. et al.** [15], where five types of wires were examined: Sentalloy, Sentalloy High Aesthetic, Superelastic Titanium Memory wire, esthetic Superelastic Titanium Memory wire and Everwhite. For each wire type four samples were analyzed in the original state and after 1 month of clinical use. It was found that surface roughness increased after clinical use. Also it aligns with the results of **Shamohamadi et al.**'s in the in vitro study, which examined the as received state of 25 coated and non-coated niti wires supplied by different manufacturers. Their study revealed significant differences were between the coated and uncoated wires in terms of (Sa) values ($P<0.01$) signifying that uncoated wires exhibited higher surface roughness.[16]

Conclusions

1. Surface roughness of epoxy coated nickel titanium archwires is initially less that of conventional non-coated archwires, with clinical use surface roughness increased in both groups with significant higher increase regarding coated archwires.

2. Coated retrieved archwires showed areas of coating loss and delamination which contributed to increased surface roughness

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