Assessment of Surface Roughness of Nickel Free Orthodontic Brackets and Archwires (An In Vitro Comparative Study)

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Abstract

Objectives: Orthodontic appliances may cause many side effects, one of these is inducing nickel hypersensitivity as a result of nickel content of these appliances**,** therefore, it is essential to choose a bracket and archwire that are nickel free and have a better surface characteristic to be more efficient for the orthodontic treatment. Hence, the aim of this study is to assess the surface roughness of nickel free metal brackets and archwires.

Materials and Method: Two types of nickel free brackets were used (Ni free SS brackets and Co-Cr brackets), a 0.022-inch slot, and three types of nickel free archwires of 0.018 x 0.025 inch were used (Ni free SS, TMA, and rhodium coated SS archwires). These brackets and wires were examined for their surface roughness by the atomic force microscope (AFM) using the roughness average parameter (Ra). For the statistical analysis Mann-Whitney U test was used for the comparison between the brackets, while, Kruskal-Wallis test was used for the comparison among the archwires (non-parametric tests) at level of significant 0.05, by using SPSS software version 23.

Results: Regarding the brackets, there was no statistically significant difference between the surface roughness of the two brackets types, while, regarding the archwires, there was a statistically significant difference between the as received archwires; as the nickel free stainless steel wires had the lowest value of roughness average, while, the TMA wires had the highest value of roughness average.

Conclusions: Ni free SS wires considered the best choice as a working wire for patients with nickel allergy.

Keywords: *Nickel hypersensitivity, Nickel allergy, Nickel free brackets, Nickel free archwires, Surface roughness.*

Introduction

The orthodontic patients are at risk of exposure to a high amount of nickel, cobalt, chromium, and other metals that derived from the alloys of the orthodontic appliances. These alloys exposed to a various conditions in the oral cavity because of the microbiologic and aqueous oral environment, in addition to that, they affected by the pH of saliva, the intake of foods, drinks and mouthwashes, which may lead to the corrosion of these alloys and hence leaching of ions into the oral cavity. The consequence of that leaching is the trigger of a hypersensitivity reaction. [1-3]Nickel is the most common metal induce an allergic reaction. [4]The prevalence of nickel allergy is 1-3% in males and 10%-30% in females,[5] the higher prevalence in female was related to the to the environmental exposure like the ear piercing[6] or wearing of jewelries .[7]The concerns about the biocompatibility from using these nickel alloys in the oral cavity for a prolonged period of time have encouraged studying an alternative materials. Therefore, nonmetallic, polycarbonate, nickel free, or stainless steel with a reduced amount of nickel had been used for the

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orthodontic treatment.[8,9]These materials considered as a hypoallergenic materials made with a low nickel concentration and have the ability to liberate minimum quantities of nickel ions, hence, they are typical for patients with nickel hypersensitivity.[10]

Surface roughness of orthodontic appliances considered an essential feature that has association with several clinical factors such as: aggregation of plaque, corrosion, metal ion release, biocompatibility and esthetics. Additionally, it has an impact on frictional force, bracket locking, anchorage, and tooth movement speed. Therefore, it influences treatment quality**.** [11-14]Many methods had been used for the assessment of surface roughness such as: Profilometer, scanning electron microscope (SEM), and atomic force microscope (AFM).

The aim of the present study is to assess the surface roughness of nickel free orthodontic brackets and archwires and hence, choosing the better one for the patients with nickel hypersensitivity.

Materials and Method

Materials

24 metal nickel free brackets were used for this study: **12** Cobalt chromium brackets (Topic, Dentarum company, Germany) and **12** Nickel free stainless steel brackets (Mini-Sprint, Forestadent company, Germany), all the brackets were for the upper right 1st premolars (slot dimensions 0.022 x 0.030 inch) with Roth prescription. While, for the archwires: **27** pieces from three types of archwires were used: **9** pieces of Nickel free stainless steel archwires (Noninium®, Dentarum Company, Germany), **9** pieces of Titanium molybdenum archwires (Rematitan® Special, Dentarum Company, Germany), and **9** pieces of Rhodium coated stainless steel archwires (Fantasia Archwire, IOS Company, USA), all the wires had the gauge of 0.018 x 0.025 inch.

Method

Grouping of sample

Three samples from each brackets and archwires as received from the manufacturer were examined, and after the sliding of the three archwires with the two brackets; three samples from each type of brackets and archwires were taken, in order to examine the changes that occur to the slots of these brackets and to the surface of the wires as a result of that sliding.

Preparation of the brackets

In order to examine the slot base, the wings of the brackets had been cut by using a metal disk bur. The reason behind removing the wings was to enable the probe of the microscope from touching the surface of the slot base without hindrance from the wings. The center of the mesial side of the brackets slots was chosen to be examined.

The brackets fixed on a metal slide to be examined under the microscope.

Preparation of the archwires

Before examining the wires that had been underwent previous sliding, the length of the wire that slided along the bracket slot was marked which was 5mm (because only the center of this 5 mm was chosen to be examined under the microscope). While the as received wires did not need any marking and any area can be examined. The length of the wire piece that fixed on the metal slide of the microscope was 20mm.

The scanning process

The atomic force microscope (AFM) was used for surface roughness assessment, it was of model: **NTEGRA prima NT-MDT**, with a silicon probe mounted on cantilever. It was operating in a tapping mode with a duration of 540 seconds per scan (9 minutes).The examination was in an air condition at room temperature with a scanning speed of 0.8 line/s. For the brackets; the resolution 512×512 pixels, the scanned area 10 × 10 μm². While, for the wires, the resolution 256×256 pixels, the scanned area 30×30 μm². Subsequently, the *3*D view of the surface of the brackets slots and the wires were displayed on the monitor of the computer that connected to the AFM.

Results

For this study, only the roughness average (Ra) parameter of the surface roughness was analyzed. The levels of significance for the statistical evaluation were: Non-significant difference NS $P > 0.05$, significant difference S $0.05 \geq P > 0.01$, highly significant difference HS $P \leq 0.01$. Statistical analysis for the data was done by using SPSS23 (Statistical Package of Social Science, version 23). The statistics used were:

Descriptive statistics

Median, minimum, and maximum values of the roughness average (Ra) as shown in table (1). All values were expressed in nanometer (nm).

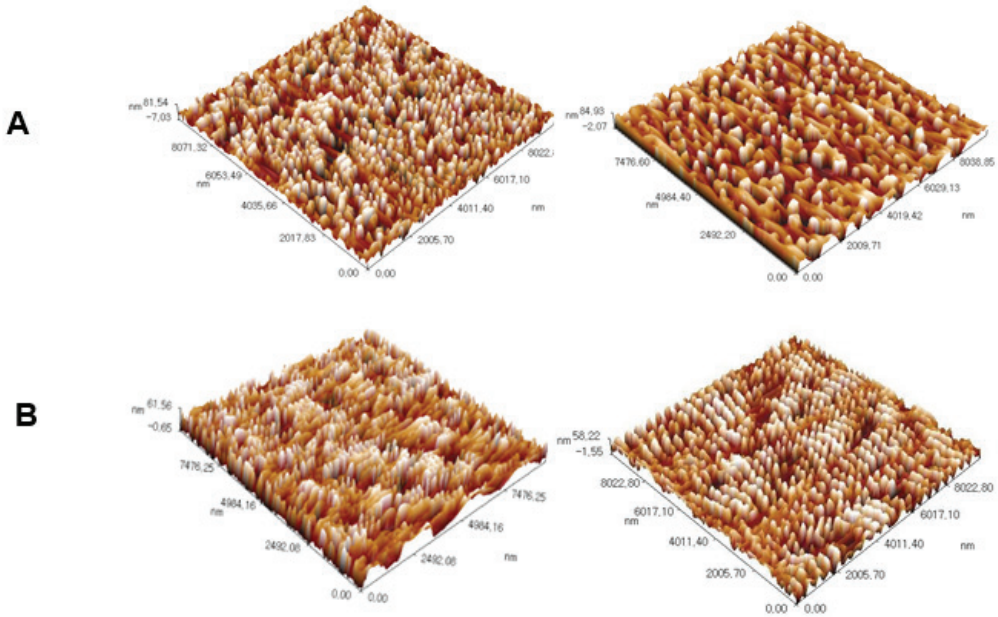
Inferential statistics

Comparison between Ra of the brackets (table 2)

For the comparison between the surface roughness (by using the Ra) of cobalt chromium and nickel free stainless steel brackets in four conditions (as received, after sliding with Ni free SS wires, after sliding with TMA wires, and after sliding with rhodium wires); **Mann-Whitney U test** was used, it showed that there was no statistically significant difference between the two brackets.

Comparison among Ra of the archwires (table 3 and 4)

For comparing the surface roughness (by using the Ra) among the wires in three conditions (as received, after sliding with cobalt chromium brackets, and after sliding with Ni free SS brackets); **Kruskal-Wallis test** was used. It showed a statistically significant difference among the wires when they were in as received condition, as the P value was **0.039.** In order to know where exactly was the difference, **Pairwise comparison** test was performed, and it showed that the statistically significant difference was between the as received nickel free stainless steel wires and the as received TMA wires (P value was **0.034)** as illustrated in **table 4,** as the nickel free stainless steel wires had the least value of roughness average among the tested wires **(21.20),** while, the TMA wires had the highest value **(109.00).**



Cont... **Figure 1**

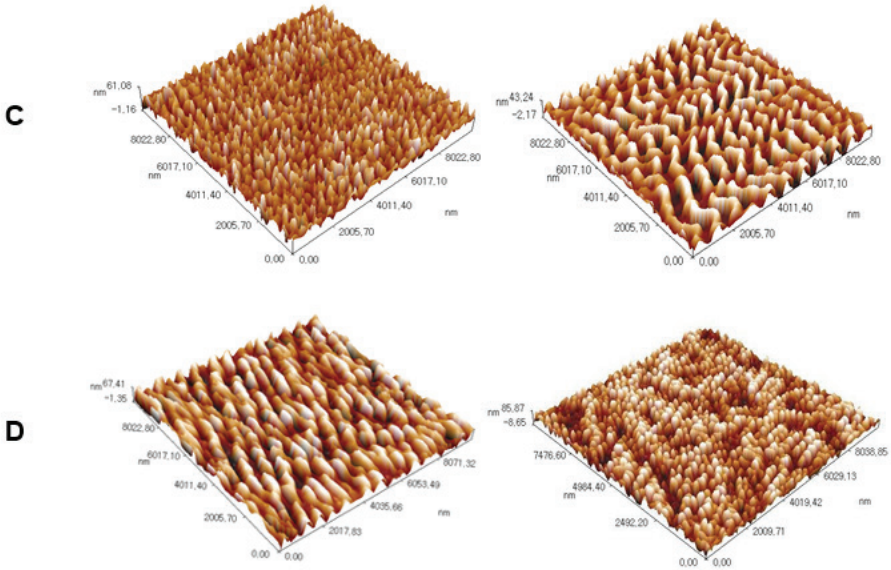


Figure 1. 3D images (10*10 µm²) of surface topography of the cobalt chromium brackets (the left figures) and Ni free SS brackets (the right figures) when they were A- As received B- After sliding with Ni free SS wires C- After sliding with TMA wires D- After sliding with rhodium wires.

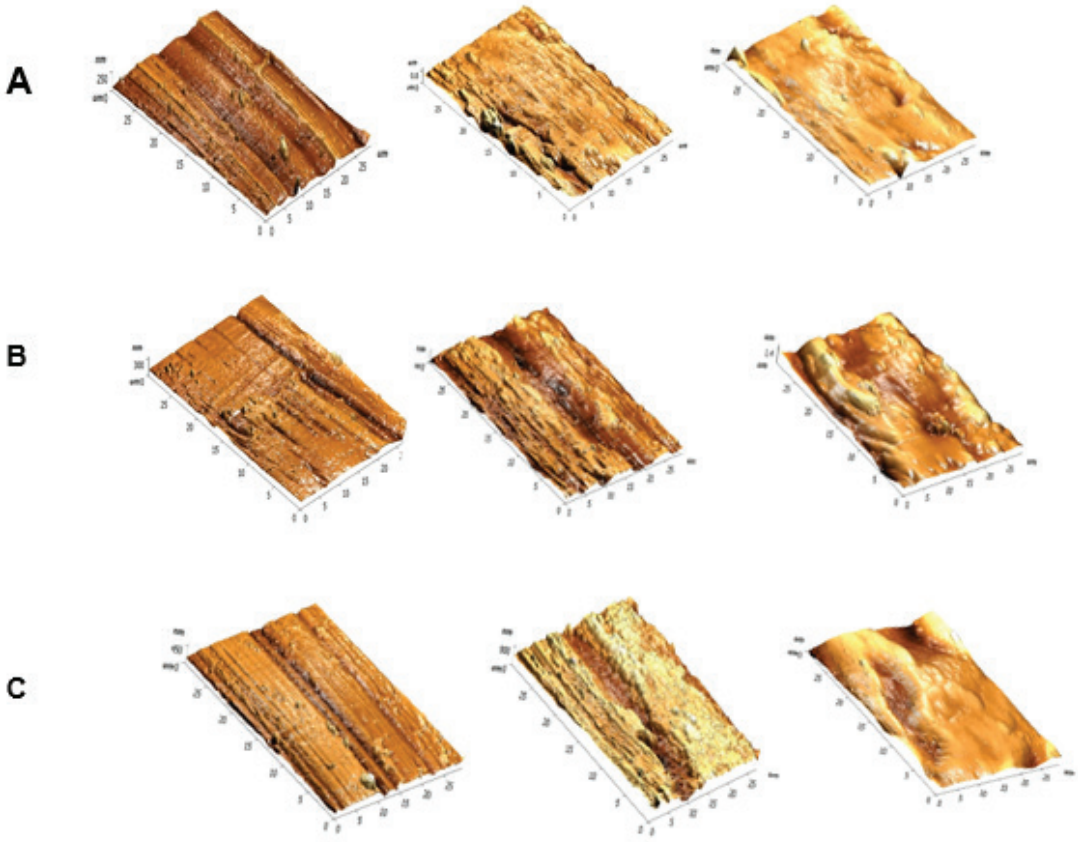


Figure 2. 3D images (30*30 µm²) of surface topography of the archwires; Ni free SS (left), TMA (middle), and Rhodium (right), in following conditions: A- As received B- After sliding along cobalt chromium brackets slots C- After sliding along nickel free SS brackets slots

Table 1. Descriptive statistics of the Ra (nm) of the brackets and the archwires

Brackets				
Condition	**Type**	**Median**	**Minimum**	**Maximum**
As received	Co-Cr	22.10	10.50	27.90
	Ni free SS	17.30	15.60	26.10
Ni free SS wires	Co-Cr	14.60	13.20	15.10
	Ni free SS	14.90	8.19	17.90
TMA wires	Co-Cr	9.53	8.36	11.10
	Ni free SS	11.40	8.56	13.60
Rhodium wires	Co-Cr	15.00	13.00	17.20
	Ni free SS	21.40	7.31	21.90
Wires				
Condition	**Type**	**Median**	**Minimum**	**Maximum**
As received	Ni free SS	21.20	15.07	21.94
	TMA	109.00	96.10	121.97
	Rhodium	43.01	26.34	96.70
Co-Cr brackets	Ni free SS	27.09	25.99	35.88
	TMA	108.82	88.70	142.25
	Rhodium	99.80	81.70	102.00
Ni free SS brackets	Ni free SS	31.90	26.02	46.33
	TMA	135.46	51.27	137.00
	Rhodium	80.00	27.21	131.00

Table 2. Mann-Whitney U test for comparison between the two brackets

Condition	Test Statistic	Exact Sig. (2-sided test)
As received	4.000	1.000 (NS)
Ni free SS wires	5.000	1.000 (NS)
TMA wires	7.000	.400 (NS)
Rhodium wires	6.000	.700 (NS)

Table 3. Kruskal-Wallis test for comparison among the archwires

Condition	Test Statistic	Sig. (2-sided test)
As received	6.489	.039 (S)
Co-Cr brackets	5.956	.51 (NS)
Ni free SS brackets	4.356	.113 (NS)

Table 4. Pairwise comparison test

Sample 1- Sample2	Sig.
Ni free SS wires-Rhodium wires	.408 (NS)
Ni free SS wires-TMA wires	.034 (S)
Rhodium-TMA wires	.890 (NS)

Discussion

Surface roughness is a characteristic of the materials and it is highly affected by the process of manufacturing and/or surface polishing process.[15] It has an effect on the performance of the appliance, and consequently, it affect quality of the treatment, as it has impact on friction, bracket locking, anchorage, and tooth movement speed. Besides, it has an effect on corrosion behavior, metal ion release, and biocompatibility. [11-14]

In this study, **Ra** parameter was used for the assessment of surface roughness, it is an indication of the absolute magnitude of the heights of the surface. Atomic force microscope (AFM) was used for the surface roughness assessment of both brackets and archwires. Choosing of this device was for many reasons, as it considered superior device for measuring the roughness of the surfaces because it give a quantitative measurement of the roughness with a 3D configuration, it scan the specimen without changing the area**,**[15,16] Other methods like SEM and the Profilometer may change the morphology and the roughness of the surfaces**.**[17] As according to **Choi et al. (2012)** the profilometry considered an invasive technique, as the surface might be damaged during scanning[18]. While, **Winchester (1991)** reported that SEM considered unreliable method of measuring the surface roughness as it depend on a subjective interpretation. [19]

The results of surface roughness assessment of this study showed that there was no statistically significant difference regarding the median values of roughness average of both cobalt chromium brackets and the nickel free stainless steel brackets. While, for the archwires, there was a statistically significant difference among the as received archwires in the regard of their median values of their roughness average, as the TMA wires showed the higher value of roughness average, while, the nickel free stainless steel wires showed the lower values. It is important to notice that in the all conditions (when they: as received, coupled with cobalt chromium brackets, and coupled with nickel free stainless steel brackets) the TMA wires showed this high values of their roughness average with an obvious difference from the other two wires (except in the case when it coupled with cobalt chromium brackets, the difference from the rhodium wires was not very high). This may be attributed to the manufacturing process as according to **Brantly (2001)** the rough surface of the TMA wire was attributed to the cold welding or the adherence of the titanium ions to the rollers or the dies during the manufacturing process. [20]

The finding of this study agreed with other studies that also find the TMA wires had the highest surface roughness. [21-23]

While, nickel free stainless steel wires showed a very low values of their roughness average in the all conditions inspite of the statistical difference was only in

the as received condition. This give the wire a superiority as working wire in the sliding mechanic of the second stage of the orthodontic treatment, as its smooth surface will enhance the performance of the appliance, and hence, the quality of the orthodontic treatment.

Ethical Clearance: The Research Ethical Committee at scientific research by ethical approval of both MOH and MOHSER in Iraq

Conflict of Interest: Non

Funding: Self-funding

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