Tikrit Journal for Dental Sciences 12(1) (2024) 196-207
https://doi.org/10.25130/tjds.12.1.22

Tikrit Journal
for
Dental Sciences
https://tjds.tu.edu.iq
ISSN:2073-1213

The Effects of Air Abrasive Polishing on the Release of Iron Ions from Various Orthodontic Arch Wires (Stainless Steel and Nickel Titanium)

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Keywords:

Article Info.:

Article History:
Received: 17/8/2023
Received in revised form: 3/9/2023.
Accepted: 24/9/2023
Final Proofreading: 24/9/2023
Available Online: 1/6/2024

Citation: **Mohammed MA, Saleem AI. The Effects of Air Abrasive Polishing on the Release of Iron Ions from Various Orthodontic Arch Wires (Stainless Steel and Nickel Titanium). Tikrit Journal for Dental Sciences 2024; 12(1): 196-207**
https://doi.org/10.25130/tjds.12.1.22

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Abstract

Orthodontic treatment with has been increasingly demanded. However, when using fixed appliances for orthodontic treatment, oral hygiene is compromised, and there is a higher chance of developing dental stains, plaque-related diseases, and corrosion-related problems. Air abrasive polishing had a superior effect over the conventional method in removing dental deposits, however, its effect on corrosion process was not investigated thoroughly in details. This study designed to assess the effects of air polishing onion release and surface micromorphology of stainless steel and Nickel titanium arch wires. A total of 288 (stainless-steel , coated stainless steel , Nickel titanium and coated Nickel titanium rectangular arch wires) of one brand (The Ultimate Wire) ™ From IOS (International Orthodontic Services, Stafford, USA), (0.016 * 0.022) were subjected to varying air abrasion polishing periods (5, 10, and 20 seconds), after which they were immersed in artificial saliva with a pH of 6.75 and incubated at 37°C for 28 days. Ion release was measured using an atomic absorption spectrophotometer at 7 days, 14 days, and 28 days. The cumulative effect was then calculated. After polishing the chosen sample, corrosion and surface changes were evaluated using a scanning electron microscope (SEM). The significant difference between the analysed groups was found using an analysis of variance (ANOVA) and the LSD test, with a significance level of p 0.05. The results revealed that all types of arch wire showed a significant amount of release in the tested ions and the amounts of nickel and iron ions released was higher than chromium ion. Additionally, the longer the polishing time the higher the number of ions release that's yields the level of significance, air abrasion polishing increased surface roughness and surface pits and crevices.It may be concluded that the air polishing method enhanced the amount of ion release to a subtoxic level and could be employed in adult patients with a lengthy time between visits.This study was performed to:1. Evaluate the effect of calcium carbonate airborne particles abrasion with different polishing times 5, 10 and 20 seconds on (Fe) ions release from orthodontic arch wires. 2. Assess the surface micromorphology of orthodontic arch wires after air polishing procedure.

Introduction:

Fixed orthodontic appliances are now more frequently requested. However, there are a number of disadvantages that might arise during orthodontic treatment, including allergies and disorders linked to plaque. The unfavourable oral environment could serve as a favourable medium for the electrochemical corrosion of embedded metallic objects and the release of metal ions. This is particularly accurate for the metallic brackets, arch wires, and accessories (1) .Additionally, metal orthodontic components may experience increased metallic corrosion when exposed to harmful physical and chemical contaminants (2) Investigations into the potential carcinogenic, mutagenic, and allergic effects of the released ions from the corrosion process of the metallic alloys used to make orthodontic wires have focused heavily on corrosion and the production of corrosion by products (ions). According to several studies(1, 3-6), nickel (Ni), iron (Fe), chromium (Cr), manganese, and nickel from nickel-titanium alloys are the main corrosion products for stainless steel and titanium alloys. Fixed braces with wires, on the other hand, are thought to hinder thorough cleaning techniques and promote plaque build-up and tooth discoloration (7) .The effectiveness of air-polishing systems, which employ different types of airborne abrasive particles like sodium bicarbonate, calcium sodium phosphor silicate, or calcium carbonate and release controlled jets of air, water, and them, has been shown to be more effective than conventional Professional dental prophylaxis (PDP) for removing the dental plaque; additionally, it promotes less working time and operator effort. Additionally, this technique has been extensively utilized to treat adult patients who have discolored teeth during orthodontic treatment, improving patient compliance and treatment satisfaction (8, 9). According to earlier research, air polishing is the most successful and efficient way to remove plaque from the area around orthodontic brackets and arch wires (10). It is commonly known that air polishing outperforms traditional scaling and rubber cup polishing at removing stains and plaque deposits. Stain removal takes less time with air polishing, and the dental professional is less worn out. It has been demonstrated that utilizing air polishers on enamel surfaces is safe and does not result in the subsequent loss of enamel. Gingival bleeding and abrasion could result from air polishing. These effects don't matter clinically, though; they are fleeting (11). Orthodontic attachments are subjected to a variety of physical and chemical factors in the oral environment that could be harmful. When orthodontic appliances are used in the aggressive electrolytic environment of the human mouth, corrosion—the progressive breakdown of materials by electrochemical attack—becomes a serious issue (12) .The wet environment in the mouth cavity contributes to electrolytic or electrochemical corrosion. A surface oxide layer is created when the surface of some metals reacts with oxygen, preventing an attacking chemical from accessing the metal surface. The characteristics of the protective coating affect how easily a metal will corrode when it is shielded from the elements. As long as the surface oxide layer is there, metallic materials are resistant to corrosion. However, when an alloy's breakdown potential is reached, the oxide layer dissolves, which triggers the commencement of surface corrosion and pitting (13).Due to their imperfect smoothness, orthodontic wires and brackets are the most susceptible to pitting corrosion. They can have a lot of pits when viewed in microscopic detail. This characteristic is regarded as increasing susceptibility to corrosion because of their capacity to harbor bacteria that create plaque. These microbes produce a localized pH decrease and oxygen deprivation, both of which have an impact on the passivation procedure (14, 15). Corrosion is an electrochemical process that can be clinically described as the loss of metal or its transformation into an oxide. Since it is oxidation, it takes place at the system's anode. An associated cathode reaction is required to maintain electro neutrality, and the corrosion process halts if either the anode reaction or the cathode reaction is hindered. Serious clinical repercussions of orthodontic appliance corrosion might include everything from dimension loss that results in less force being delivered to the teeth to stress corrosion failure of the appliance (16). The clinical significance of corrosion includes (17): (1) Due to an increase in surface roughness, rust increases the orthodontic friction force at the arch wire/bracket interface. (2) Local pain or swelling near orthodontic appliances has been linked to corrosion products in the absence of an infection, which can result in a secondary infection; (3) Cytotoxic and biological reactions.

Material and Method:

One brand of orthodontic arch wires (The Ultimate Wire TM) From IOS (International Orthodontic Services, Stafford, USA) (stainless steel, coated stainless steel, nickel titanium, coated nickel titanium) were used. Teflon, Epoxy, polymer, and rhodium compounds, among others, are frequently used by manufacturers to coat stainless steel or nickel-titanium wires. The mechanical and frictional characteristics of arch wires are likely to be affected by the presence of a coating layer. As a result, the producers always strive to coat the wires with a substance that exhibits ideal visual and frictional properties (18). The wires, according to varied polishing times (5 seconds, 10 seconds, and 20 seconds, and a control group without polishing), of each type were divided into 4 groups of 6 wires, each with a length of 20 mm cut from the end of the wires. NSK Co., Japan's Prophy-Mate Neo polishing equipment and Prophy-Mate Neo flash pearl calcium carbonate airborne particles were employed for air polishing. The wires were joined to the purpose-built holding mechanism for air polishing in such a way that the C.N.C. block used a bracket at each end of the wire (Fig.1). Using a standardized measurement device, the airflow hand piece was then mounted with its tip perpendicular to the arch wire at a distance of 5 mm (19) .After air abrasion, wires were carefully removed from C.N.C. blocks using Wingert pliers (Dentaraum, Ispringen, Germany) and immersed in an ultrasonic machine (Codyson, CD-4820, China) for 5 seconds with ethanol to remove the calcium carbonate particles (20).The wire was then inserted such that it was completely submerged in a vacuum-glass tube holding 10 ml of synthetic saliva with a pH of 6.75. Each container was sealed before being placed inside the Fisher Scientific incubator (Pittsburg, PA, USA) at 37°C for 28 days (21).After the first seven days, the wires were moved to another tube containing 10 ml of artificial saliva. After the second seven days, they were moved to another tube containing 10 ml of artificial saliva for the remainder of the study (ISO/IEC 17025:2005).

Composition of artificial saliva:

Artificial saliva was employed in this study to replicate a clinical setting. It includes 1000 ml of deionized water, 0.13 g of urea, 0.33 g of KSCN, 1.5 g of NaHCO3, 0.13 g of NaHCO4, 0.26 g of Na2HPO4, 0.22 g of K2HPO4, and 0.7 g of NaCl make up this solution, the mixture was then filtered using 0.5-m pore filter paper (ZELPA, Belgium) to remove impurities and maintained at 37°C using an incubator (Fisher Scientific, USA). After that, lactic acid and 10 M of sodium hydroxide. A pH meter was used to adjust the artificial saliva's pH to 6.75 +/- 0.15. (Jenway, model 3320, Cyprus). A standard solution with a pH of 7.5 at 37°C was used to calibrate the pH meter before each measurement.

Surface micromorphology test by SEM and surface roughness test by AFM:

Wires were examined using a scanning electron microscope. (Vega-Tescan) and Atomic Force Microscope (Easyscan 2) to determine the surface roughness before and after the air polishing procedure and, at the end of the emersion period, to evaluate the changes in the surface roughness after the application of calcium carbonate abrasive particles and if a corrosion process occurred after the incubation in the challenging media. The examination of the wire under SEM was done by fixing the wire on the table of SEM using carbon tape (3MTM, Germany), then the sample was painted

(ionic paint) with a gold layer (20 nm thickness of painting). The sample was examined using HV (10.0 Kv).
The room's temperature fluctuated from 26 to 28 degrees as the AFM inspection took place in tapping mode. We utilized silicon cantilevers with an aluminum reflex coating that was 30 nm thick from NanoSensors TM (Neuchatel, Switzerland). The datasheet provided by the manufacturer states that the cantilever spring constant was between 1.5 and 15 N/m, the resonance frequency was between 15 and 500 kHz, and the radius of the tip was 10 nm. The scanning size was set to 1010m, with a 0.7 Hz scan rate. Using the common JPEG format, the images were taken in two dimensions. To process each image, AFM software was employed (Nanosurf Report Expert). To recreate three-dimensional images, Nanosurf Report Expert 5.0 (Nanosurf®, Liestal, Switzerland) was used. (Digital Surf, Nano Surf®, Liestal, Switzerland).

Results and Discussion

The results showed that there was a highly significant increase in the amount of Fe ion release in all types of arch wire concomitant with an increase in the polishing time throughout the study period. Coated Nickel titanium and coated showed the least amount of release compared to other wires (Tables 1,2, and 3 Fig.2). The surface micromorphology of the arch wires was evaluated before and after application of calcium carbonate air abrasive polishing, visualized at 2000X magnification using SEM. The surface of the fourth arch wires (stainless steel, nickel titanium, coated nickel titanium, and coated stainless steel) showed noticeable changes when compared between the control (no abrasion) and the abrasion times (5, 10, and 20 seconds) when calcium carbonate air abrasive agent was applied to the surface of the arch wires. The irregular surface is caused by the removal of the polished glazed layer, which increases the surface roughness, The most typical type of corrosion found in arch wires were pitting and uniform corrosion.

The passive oxide layer of the alloy disintegrates because of the increase in the incubation time at the medium, which enhances the local corrosion process. Moreover, pitting corrosion enhanced by the electrochemical corrosion sequences in artificial saliva. All of the wires exhibited corrosion after air abrasive polishing, according to stereomicroscopy and SEM examinations, teflon-coated and uncoated wires both experienced corrosion, but the types of corrosion were different. Uncoated SS and Niti wire corroded uniformly, but coated SS and Niti wire corroded with pitting. Adult patients needing orthodontic care are becoming more prevalent today. The eating habits of this group of patients were different from those of adolescents in that they consumed more colored liquids, such as coffee and tea, which discolour the enamel, leave a deposit, and necessitate a cleaning process (22). Over the years, the typical method for polishing teeth during professional dental prophylaxis (PDP) has consisted of the application of an abrasive paste with a rubber cup or brush. Plaque and stains that are supragingival can be removed using this treatment. However, cleaning supragingival deposits and stains from the area around bonded orthodontic appliances frequently with a rubber cup and abrasive paste is challenging, time-consuming, and ineffective (10) .Therefore, it was indicated that because air flow polishing encourages reduced working time and operator effort, it has a benefit over traditional PDP's ineffectiveness in eliminating dental plaque and discoloration. Additionally, this approach has been widely employed to address adult patients' compromised orthodontic treatment compliance and treatment satisfaction by removing tooth discoloration (8, 9). Even though, despite the presence of a protective oxide covering on the metal surface, dental alloys can nonetheless transfer metal ions into the mouth cavity due to corrosion processes (23) , Prior research had not been done on the Fe ion release from arch wires after air polishing. This study used three distinct air polishing sessions using calcium carbonate powder to show and underline the impact of air polishing on the Fe ion

release in synthetic saliva (23-25) .Ion release research from the past revealed that the metal ion release and corrosion processes lasted for four weeks. The 28th day was chosen as the incubation period for the arch wires in the artificial saliva used in this study (26, 27) .The rise in surface roughness of the arch wires, which led to an increase in the surface area of the wire, may be the cause of the increase in Fe ion release that occurs concurrently with an increase in polishing time. It was hypothesized that increased surface area and increased texture roughness would result from longer polishing times (20). In addition, when the surface roughness increased, the surface area that came into contact with the saliva increased, increasing the quantity of Fe ion release (28) .According to According to Pakshir et al. (2011) and Roberge (2012), when manufacturers create pits, the passive layer is locally dissolved and the pit's depth in the underlying metal increases quickly (30, 31). As a result, these surface irregularities accelerate the corrosion process. More ions were produced and detected as a result of the development of an electrochemical cell in which the cathode is a sizable region of passive metal and a very small area of active metal is the anode (29, 30) .Additionally, it was stated that a passive layer that is rich in chromium and is typically 3 to 5 nm deep, or around 15 layers of atoms, is what gives the material its corrosion-resistant feature (31) .An oxidation-reduction reaction, in which the passivating substance is reduced and the chromium and nickel are oxidized, produces the passive layer. Rapid general and/or galvanic corrosion may result if this layer is not permitted to form or if it is damaged (31) .The creation of a passive surface oxide film is how stainless steel and titanium alloys used in orthodontic appliances avoid corrosion. The barrier is vulnerable to mechanical and chemical damage; hence, it is not impenetrable. When SS and Niti arch wires were exposed to electrochemical corrosion in synthetic saliva by air prophy, pitting corrosion was found on the surface of the wires (17). In fact, the polishing process' abrasive particles had a negative impact on the chromium oxide layer, a protective passive layer that was likely destroyed, exposing a fresh metal to corrosion and speeding up surface degradation (32, 33).
All subgroups of the four main groups had less iron overall than their combined daily consumption. All discharged ions were present in quantities following the use of the air polishing professional cleaning method that were below daily maximums and hazardous values (34) , Due to corrosion in the oral cavity, metallic orthodontic appliances can release metal ions; air flow polishing may have an effect on ion release from orthodontic wires (35).

Conclusion

Considering the suggested polishing period, which is 5 seconds, with longer polishing breaks for those who are adults, calcium carbonate air polishing could be employed throughout orthodontic therapy. Although all varieties of arch wire showed a subtoxic level of the examined ions, this is the first investigation into the impact on surface roughness and topography of air-powder polishing in vitro. Orthodontic arch wires' surface roughness and surface topography may change as a result of the air-powder polishing system's use of calcium bicarbonate powder, according to in vitro testing. After air-powder polishing, the orthodontist might think about employing a new arch wire to reduce friction, particularly when undergoing treatment procedures that include sliding tooth movements.

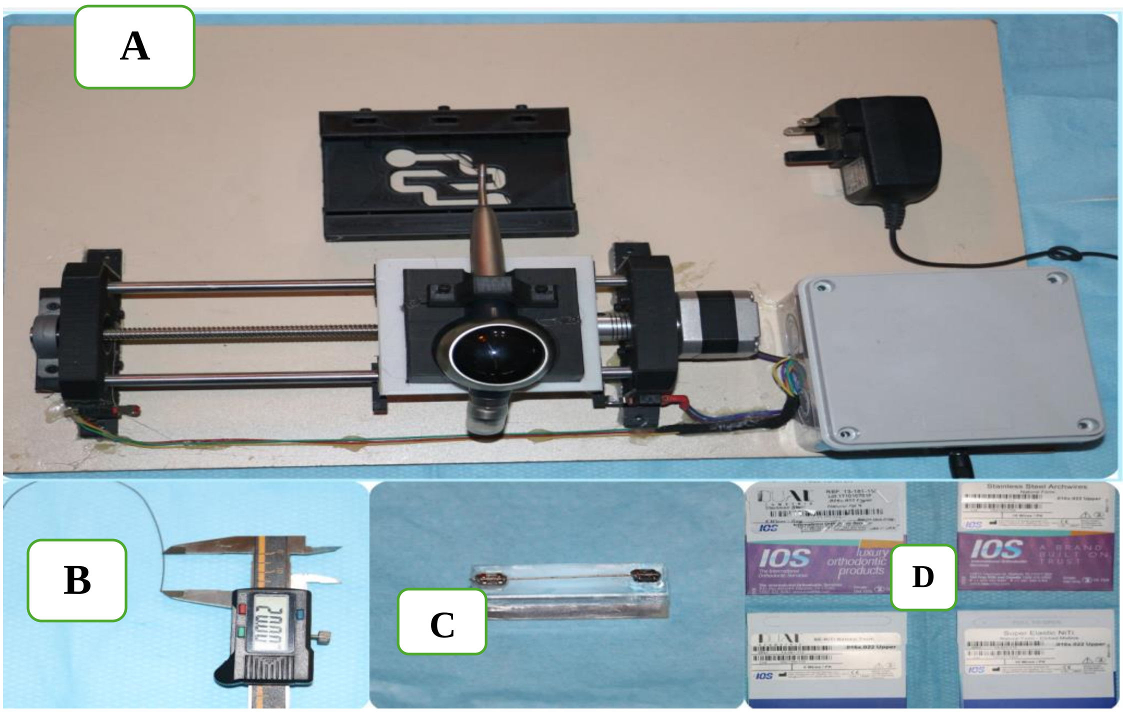

Figure 1: A: customize holding device for air polishing, B: length of wire that used, C : CNC block with wire attached to it , D : Arch wires that used.

Figure 2: A -B- C: Histogram represents the effect of polishing time on the accumulative Ni ion release of different arch wire types in normal pH 6.75 media, Figure A: 7 Days , Figure B : 14 Days , Figure C : 28 Days incubation.

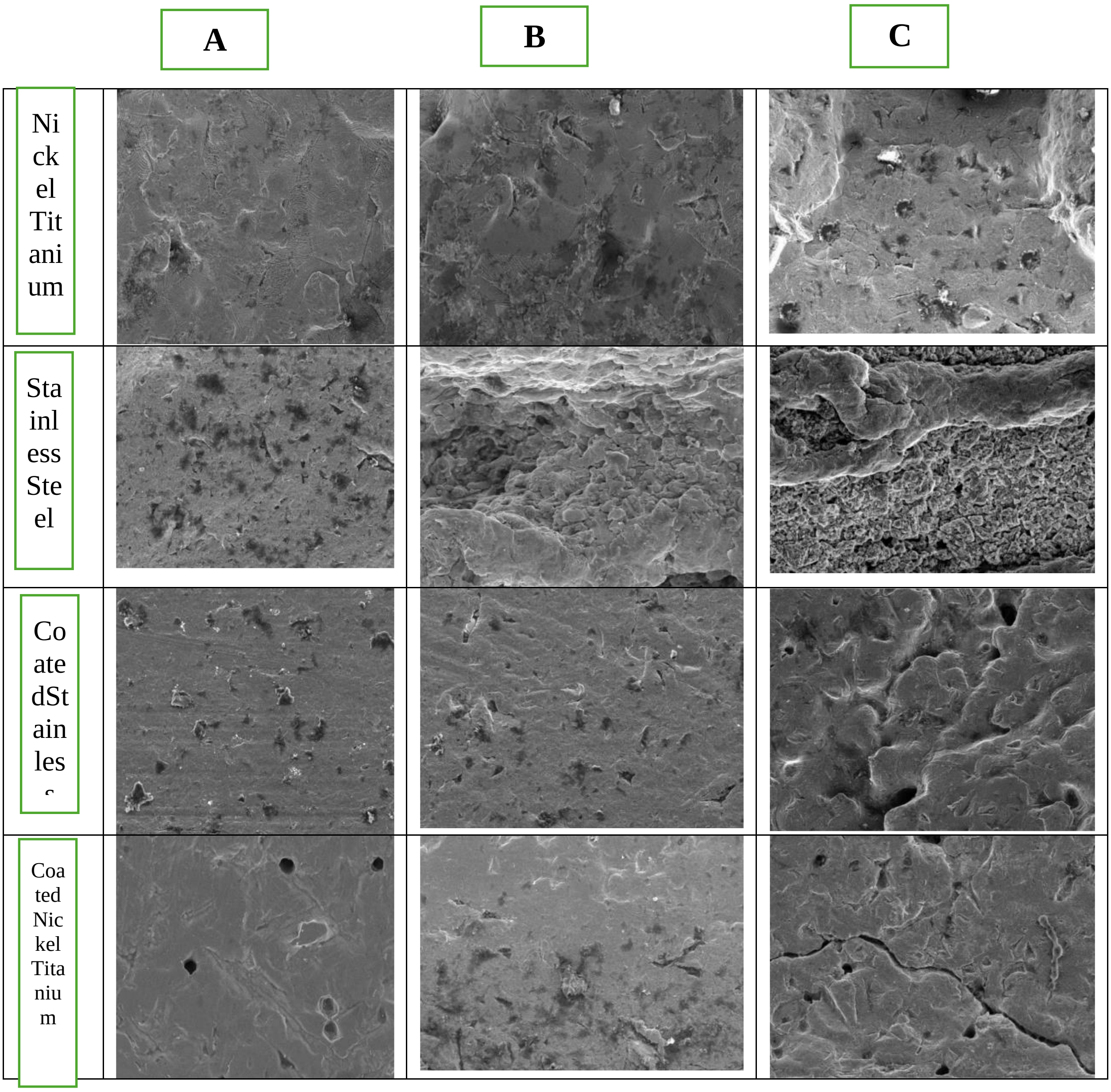

Figure 3: Surface micromorphology of each type of arc wire at 2000X magnification using SEM. A: represent the surface of control arch wires to air polishing; B: represent the surface of the arch wires after 5 sec of air polishing; C: represent the surface of the arch wires after 20 sec of air polishing.

Table 1: Accumulative Fe ion release from different arch wire types at different polishing times (incubation period 7 Days)

time of polishing	Types of wire	Mean (µg/dl)	S.D.	Min.	Max	F-test	p-value
Control	Nickel Titanium	78.14233	0.021778	78.110	78.171	117.292	0.000
	Coated Nickel titanium	78.58917	1.587916	77.122	80.053		
	Coated Stainless steel	79.68900	1.587711	78.225	81.150		
	Stainless steel (SS)	89.36750	0.865334	88.560	90.170		
5 sec	Nickel Titanium	81.46500	1.614042	79.971	82.952	50.974	0.000
	Coated Nickel titanium	78.63517	0.663449	78.013	79.256		
	Coated Stainless steel	81.87450	2.622707	79.467	84.281		
	Stainless steel (SS)	90.29900	1.411725	88.995	91.601		
10 sec	Nickel Titanium	82.70217	4.215525	78.770	86.562	36.437	0.000
	Coated Nickel titanium	77.43100	1.533331	76.012	78.845		
	Coated Stainless steel	81.64783	0.416294	81.252	82.040		
	Stainless steel (SS)	91.44317	1.582456	89.982	92.901		
20 sec	Nickel Titanium	88.35483	3.643657	85.011	91.691	36.098	0.000
	Coated Nickel titanium	82.31183	0.569983	81.776	82.848		
	Coated Stainless steel	85.29300	2.481222	83.011	87.572		
	Stainless steel (SS)	95.65983	1.435266	94.335	96.982		

Table 2: Accumulative Fe ion release from different arch wire types at different polishing times (incubation period 14 Days)

time of polishing	Types of wire	Mean (µg/dl)	S.D.	Min.	Max	F-test	p-value
Control	Nickel Titanium	86.06700	0.005550	86.061	86.073	5000877.062	0.000
	Coated Nickel titanium	80.12000	0.005550	80.114	80.126		
	Coated Stainless steel	81.91900	0.005550	81.913	81.925		
	Stainless steel (SS)	91.52700	0.005550	91.521	91.533		
5 sec	Nickel Titanium	89.88800	0.005550	89.882	89.894	9801951.364	0.000
	Coated Nickel titanium	83.06800	0.005550	83.062	83.074		
	Coated Stainless steel	82.52000	0.005550	82.514	82.526		
	Stainless steel (SS)	97.66200	0.005550	97.656	97.668		
10 sec	Nickel Titanium	91.51800	0.005550	91.512	91.524	10098249.935	0.000
	Coated Nickel titanium	85.03900	0.005550	85.033	85.045		
	Coated Stainless steel	83.63400	0.005550	83.628	83.640		
	Stainless steel (SS)	99.38700	0.005550	99.381	99.393		
20 sec	Nickel Titanium	91.68800	0.005550	91.682	91.694	11258491.068	0.000
	Coated Nickel titanium	86.56200	0.005550	86.556	86.568		
	Coated Stainless steel	86.22900	0.005550	86.223	86.235		
	Stainless steel (SS)	102.27737	0.005208	102.272	102.284		

Table 3: Accumulative Fe ion release from different arch wire types at different polishing times (incubation period 28 Days)

time of polishing	**Types of wire**	**Mean (µg/dl)**	**S.D.**	**Min.**	**Max**	**F-test**	**p-value**
Control	Nickel Titanium	91.91867	0.004633	91.913	91.925	4042848.755	0.000
	Coated Nickel Titanium	89.92317	0.012156	89.913	89.946		
	Coated Stainless steel	109.51633	0.015410	109.498	109.536		
	Stainless steel	110.72833	0.018118	110.698	110.752		
5 sec	Nickel Titanium	92.52267	0.008641	92.514	92.536	2232897.154	0.000
	Coated Nickel Titanium	90.52383	0.010381	90.514	90.541		
	Coated Stainless steel	112.16567	0.004926	112.158	112.172		
	Stainless steel	113.24117	0.037547	113.168	113.268		
10 sec	Nickel Titanium	93.63533	0.007581	93.628	93.648	2852135.543	0.000
	Coated Nickel Titanium	91.63567	0.008981	91.628	91.652		
	Coated Stainless steel	115.75583	0.014770	115.736	115.772		
	Stainless steel (SS)	116.81900	0.034928	116.756	116.852		
20 sec	Nickel Titanium	96.23933	0.016207	96.223	96.263	3678896.557	0.000
	Coated Nickel Titanium	93.22867	0.010405	93.218	93.248		
	Coated Stainless steel	120.95967	0.018662	120.931	120.976		
	Stainless steel (SS)	121.97983	0.029089	121.921	121.996		

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