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Comparison of cleaning methods on debris, surface roughness and static friction of retrieved stainless steel archwires

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ABSTRACT

OBJECTIVE: To evaluate the amount of debris, surface roughness and static friction in retrieved stainless steel (SS) archwires after four weeks of intraoral exposure and afterwards compare the effects of different cleaning methods.

METHODS: The sample gathered seventeen as-received and eighty-five retrieved SS archwire segments, which were allocated in cleaning method groups (N=17): retrieved (RT); sodium-bicarbonate jet (SB-jet); ultrasonic cleaner (U-sonic); alcohol soaked gauze (A-gauze); and steel wool sponge (S-wool). Debris (SEM images), surface roughness (rugosimeter) and static friction (universal testing machine) were compared between as-received and retrieved SS wires and between cleaning method groups.

RESULTS: Debris and surface roughness were statistically higher in RT wires than in as-received ($p<0.001$), whereas static friction showed no statistical difference ($p>0.05$). Debris were significantly lower in groups A-gauze and S-wool than in groups RT, SB-jet and U-sonic ($p<0.001$). Surface roughness was statistically lower in group S-wool compared to other groups ($p<0.001$). Static friction showed no statistical difference between cleaning methods ($p>0.05$).

CONCLUSION: Retrieved SS archwires showed higher debris and surface roughness than as-received, after four-weeks intraorally. A-gauze and S-wool were effective cleaning methods to control debris, but only S-wool has reduced surface roughness.

Keywords: Dental materials; orthodontic wires; biofilms; orthodontic friction.

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Comparação de métodos de limpeza nos níveis de detritos, na rugosidade superficial e no atrito estático de arcos de aço inoxidável recuperados

RESUMO

OBJETIVO: Avaliar a quantidade de detritos, a rugosidade superficial e o atrito estático em arcos de aço inoxidável recuperados após quatro semanas no ambiente intraoral, e comparar os efeitos de diferentes métodos de limpeza.

METODOLOGIA: A amostra incluiu 17 fios de aço novos e 85 segmentos de arcos recuperados, os quais foram alocados em grupos de métodos de limpeza (N=17): recuperados (R); jato de bicarbonato (Jato-B); cuba ultrassônica (U-som); gaze embebida em álcool (Gaze-A); e lã de aço (L-Aço). A quantidade de detritos (MEV), a rugosidade superficial (rugosímetro) e o atrito estático (máquina universal) foram comparados entre fios de aço novos e recuperados, e entre métodos de limpeza.

RESULTADOS: A quantidade de detritos e a rugosidade superficial foram maiores em fios de aço R do que novos ($p<0{,}001$), mas o atrito estático não apresentou diferença estatística ($p>0{,}05$). A quantidade de detritos (MEV), a rugosidade superficial (rugosímetro) e o atrito estático (máquina universal) foram comparados entre os fios de aço como recebidos e recuperados, e entre os submetidos aos métodos de limpeza.

CONCLUSÃO: Após quatro semanas no ambiente intraoral, os arcos de aço recuperados apresentaram mais detritos e maior rugosidade superficial do que novos. Os métodos de limpeza Gaze-A e L-Aço foram efetivos no controle de detritos, mas somente L-Aço reduziu a rugosidade superficial.

Palavras-chave: materiais dentários; fios ortodônticos; biofilme; atrito estático.

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INTRODUCTION

Stainless steel (SS) archwires are the first choice for space closure with sliding mechanics because they have high stiffness and smooth surface [1-2]. However, the archwires undergo degradation in the intraoral environment due to masticatory loads, pH and temperature variations [3-4]. Long intraoral exposure allows the formation of a mature biofilm that becomes calcified on archwire surface [5]. SS archwires retrieved after two months have showed large amount of debris, when observed in images from scanning electron microscopy [6-8]. Debris can increase surface roughness and friction levels [8,9]. Debris can also break the SS protective surface layer and trigger the onset of a corrosion process [9,10]. Such degradation cycle favors accumulation of debris on archwires and compromises biomechanics, the biocompatibility and esthetics [3-9].

Routine cleaning is crucial to avoid debris accumulation and to preserve intrinsic features of SS archwires. Cleaning with a steel wool sponge for 1 minute or ultrasonic cleaning for 15 minutes were considered as effective methods to control debris, surface roughness and frictional levels, in retrieved SS archwires exposed intraorally for eight weeks [7]. No studies investigated other methods of archwire cleaning. For instance, cleaning with an alcohol soaked gauze might be appropriate to biosafety. The use of sodium bicarbonate jet could be a faster method than ultrasonic cleaning. Furthermore, no studies considered intraoral degradation of SS archwires in ordinary time interval between orthodontic consultations.

Therefore, the goal of this study was to assess the amount of debris, surface roughness and static friction in SS archwires after four-weeks in the intraoral environment, and afterwards compare the effects of different cleaning methods using the same variables. The null hypothesis was that SS archwires have no differences related to intraoral exposure or to the cleaning method.

METHODS

The Research and Ethics Committee, Pontifical Catholic University of Rio Grande do Sul (PUCRS), approved this study (IRB 15453213.9.0000.5336).

Sample collection

Retrieved SS archwires were collected from patients under orthodontic treatment at the Faculty of Dentistry of PUCRS. The inclusion criteria were: 1) upper or lower SS archwires 0.019×0.025-in (3M Unitek, Saint Paul, MN, USA) with extension from left first molar to right first molar and no second order bends in the canines and premolars region; 2) used in fixed appliances standard edgewise 0.022×0.030-in (American Orthodontics, Sheboygan, WI, USA); 3) tied with 0.12-in elastomeric ligatures (Morelli, São Paulo, SP, Brazil); and 4) exposed to the intraoral environment for four weeks.

Forty-three retrieved archwires that met the criteria were cut at midline and originated eighty-five samples. Seventeen SS wires were evaluated as received from manufacturer. Soon after removal from the intraoral environment, SS archwires were fixed in utility wax and stored in a sealed box for ethylene oxide sterilization [4]. After a time frame of two days [7], the retrieved samples were allocated randomly in cleaning method groups using the software Research Randomizer (Version 4.0, Lancaster, PA, USA) (**Table 1**, **Figure 1**).

Table 1. Groups in the study (N=102)

Group	N	Cleaning Method
As-received archwires	17	–
Retrieved archwires (RT)	17	No cleaning
Sodium bicarbonate jet (SB-jet)*	17	Sodium bicarbonate jet at distance of 5 cm for 30 seconds
Ultrasonic cleaner (U-sonic)**	17	Immersion in ultrasonic enzymatic solution for 6 minutes
Alcohol soaked gauze (A-gauze)	17	Rubbing with an alcohol 77° soaked gauze for 20 seconds
Steel wool sponge (S-wool)***	17	Rubbing wires with a steel wool sponge for 30 seconds

* Dabi Atlante, São Paulo, SP, Brazil. ** Schuster, Santa Maria, RS, Brazil. *** Bombril, São Bernardo do Campo, SP, Brazil.

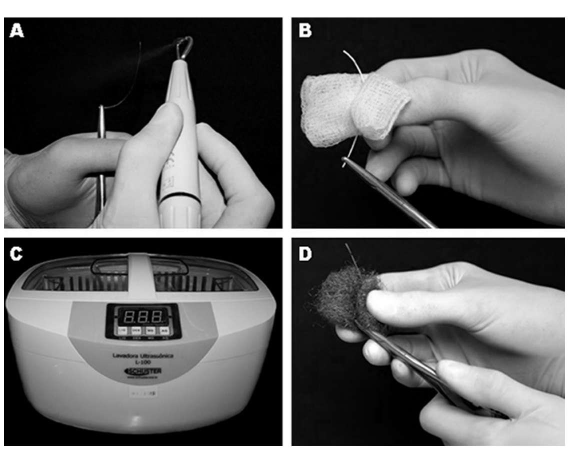

Figure 1. Cleaning methods:
A - sodium bicarbonate jet (SB-jet);
B - alcohol soaked gauze (A-gauze);
C - ultrasonic cleaner (U-sonic); and
D - steel wool sponge (S-Wool).

Assessments of debris and surface roughness

Wire segments with 8-mm length were cut distal to canine curvature and fixed with double-sided adhesive tape on a glass slab (22 mm × 22mm × 5 mm). A threshold with 1 mm length was demarcated at the center of each sample to standardize the assessments of amount of debris and of surface roughness. Debris were evaluated in scanning electron microscopy images (JSM-6060, JEOL, Akishima, Japan) with 200-x magnification. Data were obtained through comparison of the images from SS wires to an endodontic index modified according the orthodontic needs (**Figure 2**) [11-12]. Surface roughness assessments were carried out with a rugosimeter (Mitutoyo SJ-201P, Mitutoyo, Tokyo, Japan) and mean roughness of the SS wires was calculated as the average length between the peaks and valleys [6].

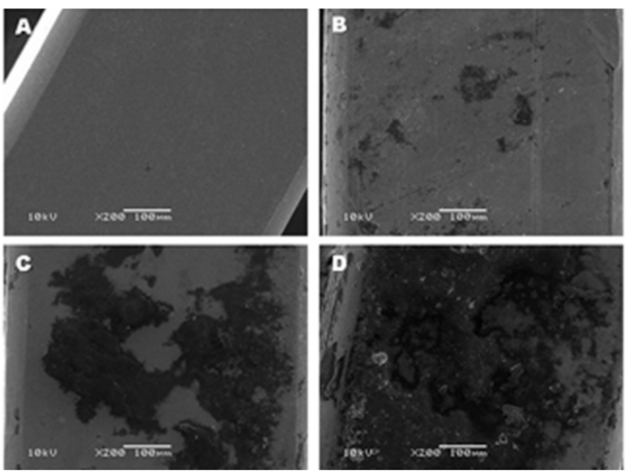

Figure 2. Debris scores: **A** - total absence of debris (index 0); **B** - presence of debris in less than 1/4 of the image (index 1); **C** - presence of debris between 1/4 and 3/4 of the image (index 2); and **D** - presence of debris in more than 3/4 of the image (index 3).

Static Friction

Prior to the frictional test, two acrylic plates (40 mm × 55 mm × 5 mm) received a metallic bracket (edgewise standard, 0.022 × 0.030-in, American Orthodontics) bonded with acrylic resin (Jet Clássico, São Paulo, SP, Brazil) at 2 mm from the edge. A SS 0.021 × 0.025-in straight wire segment was adapted to the brackets to assure their alignment. Then, the acrylic plates were assembled perpendicular to the ground in the universal testing machine (EMIC DL 2000, São José dos Pinhais, PR, Brazil). The samples were adapted in the brackets and tied with 0.12-in elastomeric ligatures placed with a Mathieu plier. The frictional test was carried out by pulling the upper acrylic plate for 5 mm, with a crosshead speed of 5 mm/min (**Figure 3**) [13-14]. Maximum static friction was obtained just before movement beginning and was indicated by the peak recorded in the software (EMIC) [15]. The acrylic plates and brackets were cleaned with alcohol soaked gauze, after each test and replaced every ten tests.

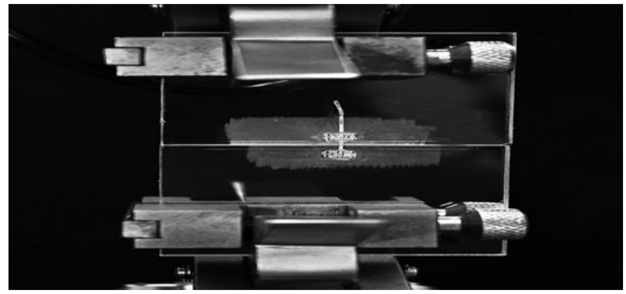

Figure 3 Universal testing machine: static friction.

A blinded investigator performed assessments of debris, surface roughness and static friction, in a random sequence. Surface roughness was calculated as the arithmetic mean between three readings per assessment. Assessments of the amount of debris were repeated in all samples, after a seven-day interval. Reproducibility of debris scores were calculated with Intraclass Correlation Coefficient (ICC=0.79–1).

Statistical analysis

The sample size was calculated to a power of 80% and two-sided significant level of 5% to detect a static friction difference of 0.8 N between groups (8.6±1.3 N) [6]. The Shapiro-Wilk test indicated normal data distribution for surface roughness and static friction. Comparison of debris between as-received and retrieved SS archwires was performed with Mann-Whitney analysis and between cleaning method groups (RT *vs* SB-JET *vs* A-GAUZE *vs* U-SONIC *vs* S-WOOL) with Kruskal-Wallis test. Following the same rationale, comparisons of surface roughness and static friction were carried out using Student's *t* test for independent samples, Analysis of Variance and Dunnet´s multiple comparisons. Data were analyzed with SPSS statistical software (version 20.0, IBM, Armonk, N.Y., USA). Significance level was set at 5%.

RESULTS

Table 2 shows that the amount of debris and surface roughness were significantly higher in retrieved SS archwires than in as-received samples ($p<0.001$), whereas static friction showed no statistical difference between groups ($p>0.05$).

Table 2. Descriptive statistics of as-received and retrieved SS archwires

	As-received Mean±SD	Retrieved Mean±SD	p
Debris (Mode)	0	2	< 0.001*
Surface Roughness (μm)	0.18±0.09	0.41±0.16	< 0.001*
Static Friction (N)	6.90±2.14	7.89±3.77	>0.05

Mann-Whitney (debris) and Student's *t* test for independent samples ($p<0.05$).
* Means statistical significance; SD, standard deviation; μm, micrometers; and N, Newton.

Table 3. Descriptive statistics and interaction between groups

	RT (N=17) Mean±SD	SB-jet (N=17) Mean±SD	U-sonic (N=17) Mean±SD	A-gauze (N=17) Mean±SD	S-wool (N=17) Mean±SD
Debris (Mode)	2A	1A	2A	1B	1B
Surface Roughness (μm)	0.41 ± 0.2A	0.35 ± 0.2A	0.35 ± 0.1A	0.32 ± 0.1A	0.25 ± 0.2B
Static Friction (N)	7.9 ± 3.8	5.7 ± 3.9	8.6 ± 2.1	9.6 ± 2.7	9.1 ± 3.9

Kruskal-Wallis (debris), Analysis of Variance and Dunnet's test (p<0.05). Different letters indicate statistical difference by line.
SD means standard deviation; RT, retrieved; SB-jet, sodium bicarbonate jet; U-sonic, ultrasonic cleaning; A-gauze, alcohol soaked gauze; S-wool, steel wool sponge; μm, micrometer; N, Newton.

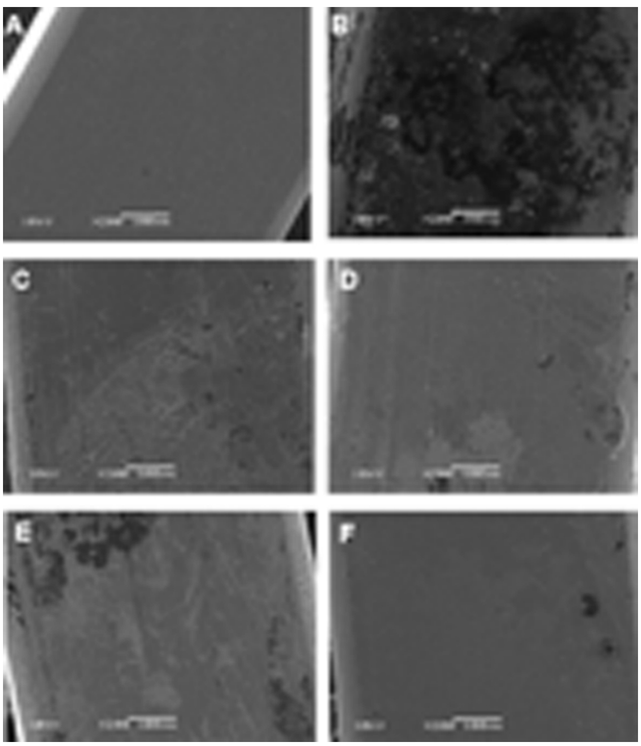

Figure 4. Scanning electron microscopy images (200-x): **A** - as-received wires; **B** - retrieved archwires (RT); **C** - sodium-bicarbonate jet (SB-jet); **D** - alcohol soaked gauze (A-gauze); **E** - ultrasonic cleaner (U-sonic); and F) steel wool sponge (S-wool).

Table 3 depicts the effects of the cleaning methods. The amount of debris was statistically lower in groups based on rub cleaning (A-gauze, S-wool) than in groups using other methods (SB-jet, U-sonic) or no cleaning (RT) (p<0.001). Debris in samples from groups SB-jet and U-sonic showed no statistical difference when compared to uncleaned SS wires (RT) (p>0.05) (**Figure 4**). A lower surface roughness in samples from group S-wool was the only significant difference between groups in this feature (p<0.001). Static friction showed no significant differences between groups (p>0.05) (**Table 3**).

DISCUSSION

The null hypothesis was partially rejected because retrieved and as-received SS archwires showed differences with statistical significance for debris and surface roughness, but not in static friction. Likewise, there were statistically significant differences between cleaning methods with regard debris and surface roughness.

The substantial amount of debris in retrieved SS archwires after four weeks, as well as the increase in surface roughness, means that the conditions to corrosion onset were established in the ordinary interval between orthodontic consultations. Other studies reported increased debris and surface roughness in SS archwires retrieved after six or eight weeks [6, 8]. We identified the same signs of intraoral degradation in a shorter period. On the other hand, the significant increases in friction observed in the same studies were not detected within four weeks [6, 8]. The study outcomes suggest cleaning SS archwires at every consultation to control intraoral degradation, especially during space closure with sliding mechanics.

Cleaning with A-gauze and S-wool were considered as adequate methods to debris control in retrieved SS archwires. S-wool also reduced surface roughness significantly, accordingly with other findings [7]. SB-jet and U-sonic for one minute failed in controlling debris and surface roughness. Successful U-sonic cleaning can take up to 15 minutes [7]. SB-JET can harm SS surface and enhance resistance to sliding [16]. One could say particles of sodium bicarbonate suspended in the air work against biosafety. Archwire cleaning was much easier using A-gauze and S-wool than using SB-jet. A-gauze rubbing seems more appropriate to biosafety, due to alcohol bactericidal effect.

Static friction of retrieved SS archwires was not altered by the cleaning methods tested. Another study carried out in eight-week retrieved SS archwires reported reduction in frictional levels after rubbing a steel wool sponge for one minute and after ultrasonic cleaning for 15 minutes [7].

Frictional test simulated sliding mechanics with brackets well-aligned, elastomeric ligation and 5 mm/min crosshead speed [13-20]. However, the influence of the adhesion of saliva to SS surface could not be reproduced [21]. In a clinical context, the sum of classic friction, binding (deflection) and notching (deformation) results in archwire resistance to sliding. Enhanced resistance to sliding can waste 60 per cent of the orthodontic forces [22, 23].

Choice of SS archwires (0.019 × 0.025-in) based on stiffness (resistance against binding and notching), low friction coefficient, and smooth surface. The latter was assured by low surface roughness values of as received wires [24-27]. Clinicians should take in account the intraoral conditions and time of exposure to avoid debris accumulation [10]. In some cases, placement of new archwires is wiser [8].

Variability in oral environment conditions was a limitation of the study. Nevertheless, in-situ studies can provide important information with regard the intraoral performance of dental materials [23]. Future studies could address other degradable features evaluated in multiple intervals and the use of new cleaning methods in archwires of different alloys.

CONCLUSIONS

• Debris and surface roughness were higher in four-week retrieved SS archwires than in as received wires, whereas the static friction did not.

• A-gauze and S-wool were effective methods to debris control.

• Only S-wool was effective to surface roughness control.

• None of the cleaning methods altered the static friction.

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