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Research Article

The Effect of Intraoral Ageing and Debris Accumulation on the Frictional Resistance of Orthodontic Archwires: An *In-Vivo* Study

Palaskar Nikhil[1], Hegde Ashwith[2], Nene Salil[2], Kalia Ajit[3] and Khan Aman[4]*

[1]Department of Orthodontics and Dentofacial Orthopaedics, M.A. Rangoonwala College of Dental Sciences and Research Centre, Pune, Maharashtra, India

[2]Professor, Department of Orthodontics and Dentofacial Orthopaedics, M.A. Rangoonwala College of Dental Sciences and Research Centre, Pune, Maharashtra, India

[3]Professor and HOD, Department of Orthodontics and Dentofacial Orthopaedics, M.A. Rangoonwala College of Dental Sciences and Research Centre, Pune, Maharashtra, India

[4]Resident, Department of Orthodontics and Dentofacial Orthopaedics, M.A. Rangoonwala College of Dental Sciences and Research Centre, Pune, Maharashtra, India

***Corresponding Author:** Khan Aman, Resident, Department of Orthodontics and Dentofacial Orthopaedics, M.A. Rangoonwala College of Dental Sciences and Research Centre, Pune, Maharashtra, India.

Received: June 29, 2020; **Published:** July 29, 2020

Abstract

Aim: To evaluate, the degree of debris accumulation on stainless steel (SS) archwires after prolonged intraoral use and to evaluate, the effect of these debris on the frictional resistance of stainless (SS) archwires. To compare, the effectiveness of two commonly used archwire cleaning methods to remove these accumulated debris.

Objectives: To evaluate, whether the accumulation of debris on the surface of the stainless steel (SS) orthodontic archwires has any effect on its frictional resistance and to evaluate, whether the two commonly used archwire cleaning methods are helpful in removing these accumulated debris.

Materials and Methods: The samples were classified into 4 major groups: T_0, $T1_{SWS}$, $T2_{US}$, $Tc_{control}$ respectively. Group T_0, T1 consist of 10 hemi-sectioned archwire segments which were tested for frictional resistance and debris accumulation without cleaning and post- cleaning for 1 minute and that of T2 with Ultrasound cleaning for 15 minutes. Tc consist of involved 20 non-cleansed control hemi-sectioned archwire segments obtained from patients from above mentioned T1 and T2.

Results: Median average debris of T1 and T2 did not differ significantly compared to average debris at T_0 but Average debris of Tc differed significantly compared to average debris at T0. Also, Average debris T1 differed significantly compared with average debris of T2, debris of T1 and t2 differed significantly with debris of T_0.

Conclusion: Increased levels of frictional resistance between archwire and bracket surfaces during sliding mechanics phase of orthodontic treatment were effectively reverted back after cleaning the orthodontic archwire by rubbing with steel wool sponge for 1 minute or through immersion in an ultrasound cleaning machine for 15 minutes.

Keywords: *Intraoral Ageing; Debris; Frictional Resistance; Orthodontic Arch Wire*

Introduction

Orthodontic treatment involves correction of malocclusion with the use of fixed orthodontic brackets and archwires. Orthodontic brackets have undergone extensive development through multiple milestones. Edward Angle, the "Father of Modern Orthodontics", had a powerful influence on the development of modern orthodontic appliances. The Edgewise appliance was probably one of the most important orthodontic appliances that Angle developed. In this appliance, Angle oriented the slot to horizontal and inserted a rectangular wire with its maximum cross-sectional dimension oriented horizontally. This appliance allowed for excellent torque control and proper root positioning [1].

As the fixed Orthodontic appliances evolved, the use of precious metals proved ineffectual for the optimal performance of some stabilizing procedures. The precious metals were excessively flexible and also lacked the essential stiffness to move teeth into their proper position.

Sliding mechanics is one of the most preferred methods for retraction of teeth. The major drawback of these sliding mechanics is the frictional resistance caused at the bracket-archwire interface, which may reduce the efficiency of orthodontic appliances and ultimately result in slower tooth movement [2-5]. Due to the application and great acceptance of this type of mechanics, the role of friction in Orthodontics has been of much interest for both clinicians and scientists. The friction encountered during orthodontic sliding mechanics represents a clinical challenge to the orthodontists because high levels of friction may reduce the effectiveness of the mechanics, decrease tooth movement efficiency and further complicate anchorage control [3]. One of the major concerns, in the search for ideal conditions for orthodontic tooth movement (OTM), is the reduction of frictional resistance at the bracket-wire-ligature interface4 and thereby achieving lower orthodontic forces which would still be sufficient to promote orthodontic tooth movement (OTM) [5].

One of the major goals of the companies, which are manufacturing orthodontic materials, is the search for newer products that would cause lesser amount of friction during the sliding mechanics. Major efforts have been made to come up with the so called low-friction brackets, wires and ligatures during past 20 years [6-18].

Rectangular stainless steel (SS) archwires employed during sliding mechanics might need to be present intra-orally for several months. Marques., *et al*. [19] found that stainless steel (SS) rectangular wires, when exposed to the intraoral environment for 8 weeks, revealed a significant increase in the degree of debris and frictional resistance. The authors observed a significant correlation between the amount of debris accumulation and frictional resistance. They suggested that research is needed to further evaluate the efficiency of methods employed to clean orthodontic archwires. So, in order to decrease the amount of debris accumulated onto archwire surface, two commonly used cleaning methods were selected by Normando., *et al*. They suggested the use of Steel wool sponge (SWS) and Ultrasound (US) to clean orthodontic archwires.

Actual mechanical debridement, with fine mesh made with strands of steel in order to detach the debris with actual surface-to-surface contact, is the basic mechanism of action for steel wool sponge (SWS) cleaning method. It is widely used as an abrasive in finishing and repair work for polishing wood or metal objects, cleaning household cookware, cleaning windows, and sanding surfaces too. Steel wool is made from low-carbon steel in a process similar to broaching, where a heavy steel wire is pulled through a toothed die that removes thin, sharp, wire shavings.

Ultrasound (US) cleaning uses the cavitation bubbles induced by high frequency pressure (sound) waves to agitate a liquid. The agitation produces high forces on contaminants adhering to substances like metals, glass, plastic, rubber and ceramics etc. resulting in loosening of the contaminants.

This study evaluated how the changes produced in the archwire after sixteen weeks of intra-oral usage and how accumulation of debris over the archwire affected frictional resistance between orthodontic archwire and the bracket slot of fixed orthodontic appliance.

Materials and Methods

The study was conducted on twenty patients already undergoing orthodontic treatment in the Dept. of Orthodontics. Consents were sought by asking the subjects to sign a form that explained the nature and purpose of the investigation. All the subjects were explained with the study procedure and were also made familiar with routine oral hygiene maintenance methods.

Inclusion criteria

1. Orthodontic patients within the age group of 18 to 30 years with comparable degree of oral hygiene maintenance.
2. Orthodontic patients being treated with non-extraction treatment modality.
3. Orthodontic patients undergoing treatment with Pre-adjusted Edgewise brackets with 0.022" x 0.028" slot and were in the finishing stages of treatment.

Exclusion criteria:

1. Patients with missing teeth.
2. Patients with poor oral hygiene status and habits.

Methodology

- This study assessed the effects of debris and intraoral ageing on Orthodontic archwires after 16 weeks of intraoral use and further evaluated the effectiveness of two commonly used archwire cleaning methods (Steel Wool Sponge and Ultrasound) to remove these debris. Further, we assessed the effect of these debris on the frictional resistance of the archwires at the bracket-archwire interface.
- The samples were classified into four major groups:
    1. Group T_0 contained 10 hemi-sectioned as received archwire segments which were tested for frictional resistance and debris accumulation (without any form of cleaning).
    2. Group $T1_{SWS}$ consisted of 10 hemi-sectioned archwire segments which were tested for debris accumulation and frictional resistance (post-cleaning) (SWS) for 1 minute at the time of routine appointments with 4 weeks interval obtained from 10 patients.
    3. Group $T2_{US}$ comprised of 10 hemi-sectioned archwire segments which were tested for debris accumulation and frictional resistance (post-cleaning) using ultrasound (US) cleaning for 15 minutes at the time of routine appointments with 4 weeks interval obtained from 10 patients other than those of Group T1.
    4. Group Tc-$_{Control}$ involved 20 non-cleansed control hemi-sectioned archwire segments obtained from patients from above mentioned T1 and T2 groups using other half portion of archwire than the cleaning sides. These archwire segments were tested for debris accumulation and frictional resistance (without any form of cleaning) after clinical use for 16 weeks.
- Degree of debris accumulation and levels of frictional resistance were evaluated for two groups of orthodontic archwire segments, based on two different archwire cleaning methods, containing 10 subjects each with half portions of the archwires as control (T1-$_{SWS}$, T2-$_{US}$, Tc-$_{Control}$, n = 40).
- Degree of debris accumulation and levels of frictional resistance were evaluated for as received orthodontic archwires containing 10 archwire segments after splitting (T_0, n = 10).
- Thus, the experimental material comprised of 50 hemi-sectioned archwire segmental in total (T_0, T1-$_{SWS}$, T2-$_{US}$, Tc-$_{Control}$, n = 50).
- Degree of oral hygiene maintenance was assessed while selecting the patients for this study and also at the time of the clinical appointments using Simplified Oral Hygiene Index (OHI-S) proposed by Greene J. C. and Vermillion J. R. in 1964.
- All the twenty patients who fulfilled the inclusion and exclusion criteria were ready to receive a rectangular 0.019" x 0.025" stainless steel (SS) archwire after initial levelling and alignment.

- A V-bend was placed on the rectangular 0.019” × 0.025” stainless steel (S.S.) maxillary archwire to differentiate the wires into right and left halves. The right halves of the archwires in the patients were subjected to intermittent cleaning and the left halves were used as control.
- Also, the V-bend helped in handling the wires with a plier without disturbing the surface area to be tested during intermittent cleaning.
- In group 1, the right half portions of Maxillary archwires of 10 patients were cleaned using steel wool sponge (SWS) cleaning method for the duration of 1 minute, at the time of routine clinical appointments after 4 weeks and the other half portion was kept as control.
- In group 2, right half portion of each of the Maxillary orthodontic archwires of 10 patients was cleaned using ultrasound (US) cleaning method for the duration of 15 minutes, at the time of routine clinical appointments after four weeks; and the other half portion was kept as control.
- Patients were instructed for proper oral hygiene maintenance and were called back for routine appointments after 4 weeks interval. The same procedure of cleaning was repeated with ultrasound after every 4 weeks till 16 weeks of intraoral use.
- After the intraoral use for 16 weeks, the wires were carefully removed from the patients mouths and cleaned with the already set cleaning pattern for the final time.
- The wires were then transported in special fibro-plastic sealed and well-labelled containers containing artificial saliva, in order to preserve their mechanical status, from the hospital to the laboratories for the purpose of testing.
- The wires were tested for friction and debris accumulation using “Universal Testing Machine (UTM)” and “Scanning Electron Microscope (SEM)” respectively.
- For the microscopic debris analysis, the central area (0.025 inch) of the wires was observed by scanning electron microscopy (SEM) using the JSM6360A model scanning electron microscope by JEOL®, Japan, available at Pune, India, with 10 - 20 kV, and images were obtained from secondary electrons, with magnification of ×200.
- During the test procedure, special care was taken to avoid loss of any accumulated debris. Assessment of the amount of debris on the surface of the wires was performed by a single examiner with unchanged computer setup such as image magnification, monitor resolution and brightness.
- The following scores were assigned, according to previously published methods used in Endodontics and later modified for Orthodontics by Marques., *et al.* (2010): 0 = Complete absence of debris; 1 = Some amount of debris, involving less than quarter of the image analysed; 2 = Moderate presence of debris, involving one to three-quarters of the image analysed; 3 = Presence of a large amount of debris involving more than threequarters of the image under observation.
- Frictional resistance was evaluated on a computerised Universal Testing Machine (UTM) by Star testing system, India with model no. STS 248. A Universal Testing Machine (UTM) is generally used to test the tensile, shear and compressive properties of materials.
- Friction testing was performed using the Bracket/Wire assembly fixed onto two rectangular acrylic plates 0.5 cm in thickness and with surface area of 4 × 5.5 cm.
- Firstly, a standard Frictional resistance test was performed in an Universal Testing Machine of the material to be assessed for an application, for quality control and to predict the material behaviour under the particular type of forces.
- Now, the test samples were tested enabling the machine and the upper grip slid at a speed of 0.5 mm/minute for a distance of 5 mm. The test model was the same for all friction tests, so only the wire segments and elastic ligatures were changed. After each friction test, the brackets bonded to the 60 plate were cleaned with gauze soaked in alcohol (96 per cent) to eliminate possible debris from the previous wire. Kinetic frictional force was measured in Newton (N), using the mean force exerted from the beginning of the movement until the end of the test.

- The degree of debris accumulated and frictional resistance were evaluated with initial as-received (T_0) archwires, control portions ($Tc\text{-}_{Control}$) after 16 weeks of intraoral exposure and after cleaning with a steel wool sponge (SWS) for 1 minute ($T1\text{-}_{SWS}$) or ultrasound (US) cleaning for 15 minutes ($T2\text{-}_{US}$).

Statistical analysis

After the evaluation and data collection, data entry was done in Microsoft Excel 2010. Data analysis was done using Statistical Package for Social Sciences (SPSS ver. 16.0, Inc. Chicago) software for MS Windows. Quantitative data was presented with the help of Mean and Standard Deviation. P value less than 0.05 was taken as significant level difference. The results obtained were statistically analysed using Mann-Whitney U test with the post-Hoc Bonferoni's correction for multiple group comparisons. The data on continuous variables were presented as Median (Min - Max). The statistical significance of inter-group difference of average (Median) of continuous variables was tested using Mann-Whitney U test with the post-Hoc Bonferoni's correction for multiple group comparisons. The power and sample size calculation was based on the previously published data and was done beforehand. If the true difference in the median response of initial and post cleaning samples was approximately 2N (friction) using minimum sample size 10 we were able to reject the null hypothesis that this response difference was zero with probability (power) 0.80. The Type I error probability associated with this test of this null hypothesis was 0.05. Also, the power of the study ranged between 0.80 to 0.90 for the sample sizes between 10 to 25.

Results

Debris (SEM)	Initial (T_0) (n = 10)	$T1\text{-}_{sws}$ Test (n = 10)	$T2\text{-}_{us}$ Test (n = 10)	$TC\text{-}_{Control}$ (n = 20)
Median	0	0	1	3
Min	0	0	1	2
Max	0	1	1	3

Table 1: *Distribution of average (median) scores of debris for as received archwires (T_0) and after cleaning with steel wool sponge ($T1\text{-}_{SWS}$) or ultrasound ($T2\text{-}_{US}$) and Controls ($Tc\text{-}_{Control}$). Values are median, min-max.*

	Statistical Comparisons		
Debris (SEM)	**T_0 vs $T1\text{-}_{sws}$**	**T_0 vs $T2\text{-}_{us}$**	**To vs $Tc\text{-}_{control}$**
P-value	0.157^{NS}	0.214^{NS}	0.001***
	$T1\text{-}_{sws}$ vs $T2\text{-}_{us}$	$T1\text{-}_{sws}$ VS $TC\text{-}_{Control}$	$T2\text{-}_{us}$ VS $TC\text{-}_{Control}$
P-value	0.002**	0.001***	0.001***

Table 2: *Statistical comparison of the average (median) scores of debris at T_0 (as received), $T1\text{-}_{SWS}$ (SWS cleaning), $T2\text{-}_{US}$ (US cleaning) and $Tc\text{-}_{Control}$ (Control) [As received, SWS, US and Control Samples]. P-values by using Mann-Whitney U test [independent group comparisons]. P-value < 0.05 is considered to be statistically significant. *P-value < 0.05. **P-value < 0.01. ***P-value < 0.001. NS: Statistically Non-Significant.*

Inter-group comparison of debris between T_0, $T1\text{-}_{SWS}$, $T2\text{-}_{US}$ and $Tc\text{-}_{Control}$ samples:

1. The average debris of $T1\text{-}_{SWS}$ and $T2\text{-}_{US}$ did not differ significantly compared to average debris at T_0 (P-value > 0.05 for all).
2. The average debris of $Tc\text{-}_{Control}$ differed significantly compared to the average debris at T_0 (P-value < 0.001).

3. The average debris of T1-$_{SWS}$ differed significantly compared the average debris of T2-$_{US}$ samples (P-value < 0.01).
4. The average debris of T1-$_{SWS}$ and T2-$_{US}$ differed significantly compared the average debris of T_0 samples (P-value < 0.01 for both).

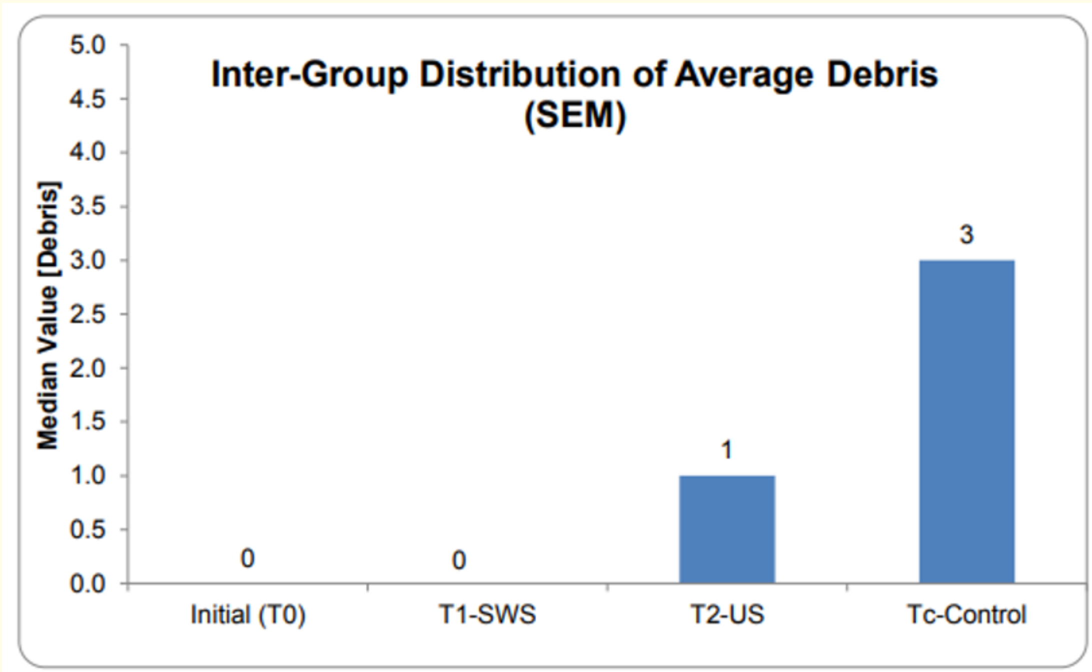

Figure 1: *Debris for as-received archwires (T_0) and after cleaning with steel wool sponge (T1-$_{SWS}$) or ultrasound (T2-$_{US}$) and Control (Tc-$_{Control}$) sample.*

Frictional Resistance (N)	Initial (T_0) (n = 10)	T1-$_{sws}$ Test (n = 10)	T2-$_{us}$ Test (n = 10)	Tc-control (n = 20)
Mean	5.60	6.10	7.57	13.10
SD	0.16	0.33	0.64	0.38
Median	5.64	6.21	7.85	13.07
Min	5.36	5.21	6.59	12.60
Max	5.76	6.34	8.22	13.72

Table 3a: *Descriptive statistics [mean, standard deviation (SD), median, min - max] for the frictional resistance at T_0 (as received), T1-S_{WS} (SWS cleaning), T2-$_{US}$ (US cleaning) and Tc-$_{Control}$ (Control) [As received, SWS, US and Control samples]. Values are Mean, SD and Median, Min - Max.*

Inter-group comparison of frictional resistance between T_0, T1-$_{SWS}$, T2-$_{US}$ and Tc-$_{Control}$ samples:

1. The distribution of median frictional resistance of T1-$_{SWS}$ group did not differ significantly compared to median friction of T_0 group of samples (P-value > 0.05).

	Statistical Comparisons		
Frictional Resistance (N)	**T_0 v T1-$_{SWS}$**	**T_0 v T2-$_{US}$**	**T_0 v Tc**
P-value	0.225NS	0.043*	0.001***
	T1 SWS v T2 - US	T1 SWS v Tc	T2 US v Tc
P-value	0.001***	0.001***	0.001***

Table 3b: *Statistical comparison of the average frictional resistance at T_0 (As received), T1-$_{SWS}$ (SWS cleaning), T2-$_{US}$ (US cleaning) and Tc-$_{Control}$ (Control) [As received, SWS, US and Control Samples]. P-values by using Mann-Whitney U test [independent group comparisons]. P-value < 0.05 is considered to be statistically significant. *P-value<0.05, **P-value<0.01. ***P-value < 0.001. NS: Statistically Non-Significant.*

2. The distribution of median frictional resistance of T2-$_{US}$ differed significantly compared to median frictional resistance of T_0 group of samples (P-value < 0.05).
3. The distribution of median frictional resistance of Tc-$_{Controls}$ differed significantly compared to median frictional resistance of T_0 group of samples (P-value < 0.001).
4. The distribution of median frictional resistance of T1-$_{SWS}$ differed significantly compared to median friction of T2-$_{US}$ and Tc-$_{Control}$ group of samples (P-value < 0.001 for both).
5. The distribution of median frictional resistance of T2-$_{US}$ differed significantly compared to median friction of Tc-$_{Control}$ group of samples (P-value < 0.001).

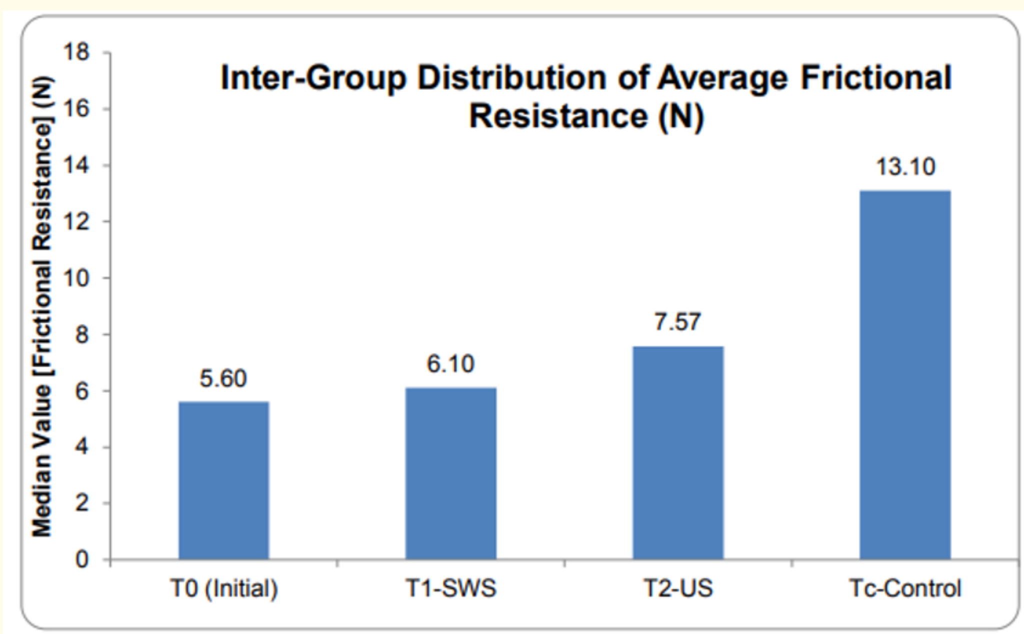

Figure 2: *Frictional resistance for as-received archwires (T_0), after cleaning with steel wool sponge (T1-$_{SWS}$) or ultrasound (T2-$_{US}$) and Control (Tc-$_{Control}$) Samples.*

Discussion

Orthodontic wire experiences friction at the bracket and wire interface since the initial stages of alignment and levelling to the finishing stages. A lower friction at the bracket and wire interface is directly associated to a significant decrease in treatment duration [18]. Thus, the frictional resistance affecting sliding of the bracket along the orthodontic wire and vice-versa is important in clinical practice.

There are only a few studies discussing ageing of orthodontic archwires in oral environment and effects of the same on mechanical properties of the orthodontic archwires [17]. Rectangular stainless steel (SS) archwires are the most commonly used wires for sliding mechanics due to lower coefficient of friction [20,21,23] and lower surface roughness [22]. Also, during mechanical en-masse retraction of anterior teeth, a rectangular stainless steel (SS) archwire often needs to be kept intra-orally for several months.

The present study evaluated the degree of debris accumulation and frictional resistance of orthodontic archwires, before and after intra-oral exposure. In addition, two commonly used methods to clean orthodontic archwires were also assessed for their cleaning efficiency. Marques., *et al*. [19] demonstrated that stainless steel (SS) rectangular archwires, when exposed to the intraoral environment for 8 weeks, showed a significant increase in the degree of debris, causing an increase in frictional resistance during orthodontic tooth movement.

The results obtained in the present study revealed that the as-received stainless steel (SS) archwire segments (T_0) showed complete absence of debris as observed using SEM, with a median score of 0 without any standard 82 deviation (Table 1). Also, the frictional resistance of the as received archwire segments at T_0 was found to be minimum with mean value of 5.60 ± 0.16N (Table 2). Similar findings had previously been reported by Marques., *et al*. [19] and Normando., *et al*. for rectangular stainless steel (SS) wires. Since the debris of as-received wires were almost nil, they were considered as a standard against which other groups (Tc-$_{Control}$, T1-$_{SWS}$, T2-$_{US}$) of archwires were compared.

The study found that the amount of debris at Tc-$_{Control}$ increased significantly (p = 0.001) with median score of 3 (Table 1) with average frictional resistance increasing by 57.25 per cent attaining the mean value of 13.10 ± 0.38N. Table 2 compared to the archwires at T_0. Because of increase in the degree of debris accumulation, the frictional resistance has correspondingly increased in Tc-$_{Control}$. Similar results where elevation in the amount of debris leading to increased frictional resistance had been reported earlier by Marques., *et al*. [19] for stainless steel (SS) wires.

The comparison of T_0 to T1-$_{SWS}$ showed median score of 0 (Table 1) in degree of accumulated debris. The levels of frictional resistance at T1-$_{SWS}$ had an average value of 6.10 ± 0.33N (Table 2). The reduced amount of debris resulted in decreased levels of frictional resistance at T1-$_{SWS}$ compared to levels at Tc. An earlier study by Normando., *et al*. [19] too showed similar results after cleaning with steel wool sponge (SWS).

Values of T2-$_{US}$ revealed level of debris (p = 0.214) with a median score of 1 (Table 1) and frictional resistance with a mean value of 7.57 ± 0.64N (p = 0.043) (Table 2). Compared to Tc, decrease in amount of debris accumulated, resulted in decreased levels of frictional 83 resistance at T2-$_{US}$. Marques., *et al*. [19] also got similar results wherein there was a moderate decrease in the amount of debris achieved using ultrasound (US) cleaning method.

When compared with Tc-$_{Control}$, the degree of debris accumulation at T1-$_{SWS}$ was significantly (p = 0.001) lesser with an average decrease of 100 per cent in the scores of debris (Table 1). Correspondingly, the average magnitude of frictional resistance at T1-$_{SWS}$ was significantly (p = 0.001) reduced with mean decrease of 7.0N (53.43 per cent) (Table 2) compared to Tc. Frictional resistance values decreased as the degree of debris accumulation reduced at T1-$_{SWS}$. These findings were consistent with results obtained by Normando., *et al*. suggesting a major reduction in the values of both variables while steel wool sponge (SWS) cleaning was employed.

In comparison with Tc-$_{Control}$, values of debris accumulation at T2-$_{US}$ were significantly (p = 0.001) lesser with an average decrease of 66.66 per cent (Table 1). The frictional resistance at T2-$_{US}$ too was found to be significantly (p = 0.001) reduced by 42.21 per cent (Table 1) compared to Tc.

In the present study we found that after cleaning with steel wool sponge (T1-$_{SWS}$) the degree of debris accumulation was found to be reduced to a greater extent than with ultrasound cleaning method (T2-$_{US}$) with a significant (p = 0.002) difference of 33.33 per cent (Table 1). When compared with T2-$_{US}$ samples, values of frictional resistance at T1-$_{SWS}$ were found to be further reduced (p = 0.001) by 1.47N (11.22 per cent) (Table 2). This suggests that steel wool sponge (SWS) method was found to be 84 more efficient in cleaning the debris and thereby reduce the frictional resistance than ultrasound (US) method. The results in a similar study by Normando., *et al*. however, found that both methods of cleaning were almost equally efficient.

This difference in the results of the two studies could be due to shorter duration of intra-oral presence and absence of intermittent cleaning in the previous study. No previous study had evaluated the effectiveness of cleaning methods after orthodontic archwires have undergone clinical usage with intermittent cleaning pattern at routine appointments with intervals of 4 weeks using SWS and US cleaning methods.

Normando., *et al*. [19] had studied stainless steel (SS) rectangular wires, and had cleansed the wires finally, after 8 weeks of exposure to the oral environment, with the two commonly used cleaning methods without any intermittent cleaning. They concluded that increase in the degree of debris and surface roughness caused higher friction levels between the wire and bracket during sliding mechanics. They found both the cleaning methods significantly efficient to effectively eliminate the changes occurred in the archwire due to intraoral ageing process although authors felt that steel wool sponge (SWS) cleaning method was more useful, in routine, than the ultrasound (US) method.

Even though amount of debris accumulation and frictional resistance increased significantly after clinical use for 16 weeks (Table 1 and 2), the wires showed a significant reduction of these variables when any of the two cleaning methods was used. The evaluated variables returned to values similar to those of as-received archwire segments after cleaning the wire (Table 2). Moreover, the use of SWS cleaning method was found to be more 85 efficient for the removal of debris accumulated on the orthodontic wire surface with debris levels significantly lesser than US method. SWS cleaning method has the advantage of being less time-consuming (1 minute) in an orthodontic clinical setup with busy routine.

Significant positive correlations were found between the degree of debris accumulated on the archwire surface and frictional resistance. However, changes in the structural characteristics of the archwire surface were not studied. It might be possible that other factors, other than the accumulation of debris on the surface of the archwire, may have contributed to the higher level of friction. Cleaning the archwire using a steel wool sponge (SWS) could elevate frictional resistance via an increase in surface roughness or could decrease friction by reducing the size of the wire due to surface abrasion, if any.

In an earlier study by Normando., *et al*. [19] when comparing the values of friction at T_0 with those observed for wires without clinical use and rubbed with steel wool sponge (SWS), no significant differences in the levels of frictional force were observed. This indicated that the steel wool sponge (SWS) cleaning method did not affect the structural composition of archwire surface significantly.

This study evaluated the degree of debris accumulation and frictional resistance of orthodontic archwires, before and after intra-oral exposure, and also assessed the cleaning efficiency of two commonly used methods to clean orthodontic archwires. The results revealed that there is increase in the amount of debris accumulation on archwires after prolonged intraoral use which directly contributed to the increase in the level of frictional resistance 86 during sliding mechanics. Although, both the cleaning methods could significantly/

effectively reduce the degree of debris accumulated, steel wool sponge (SWS) cleaning method was found to be more efficient than the ultrasound (US) cleaning method.

Conclusion

Thus, from the present study, we could conclude that:

1. After exposure to intra-oral environment for 16 weeks, Stainless steel (SS) rectangular archwires exhibited a significant rise in the amount of debris accumulation causing increased levels of frictional resistance between the archwire and bracket surfaces during sliding mechanics phase of the orthodontic treatment.
2. These changes were effectively reverted back after cleaning the orthodontic archwire by rubbing with steel wool sponge (SWS) for 1 minute or through immersion in an ultrasound cleaning machine (US) for 15 minutes, although steel wool sponge (SWS) cleaning method seemed to be clinically more efficient and more practical for routine orthodontic setup.

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