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Evaluation of Effect of Chlorhexidine and Povidone-Iodine Mouthwash on Frictional Resistance and Surface Characterization of Honeydew (ion-implanted) Titanium Molybdenum Alloy Wires in Self-Ligating Brackets -An *Invitro* Study

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Abstract

Regular mouthwash use is advised for patients receiving orthodontic treatment in order to prevent caries or periodontal infections. However, using these mouthwashes might endanger the properties of orthodontic appliances. The aim of this study is to evaluate the effect of chlorohexidine and povidone-iodine mouthwashes on frictional properties and surface characteristics of honey dew (ion implanted) titanium molybdenum alloy (TMA) archwires in metal self-ligating brackets (SLB). Evaluation of frictional resistance: 45 samples of honey dew TMA wires which are cut into 7cm long were divided into 3 groups (15 in each group) and incubated in artificial saliva at 37˚C for one month, followed by immersion in Chlorhexidine 0.2% (group 2), Povidone-iodine 0.5% (group 3) respectively for 1.5 hours (1 min per day for 3 months). The samples were then washed with distilled water and stored for two months in artificial saliva. The 7cm samples were cut into 6cm long for frictional resistance test and 1cm long for surface morphology test. The frictional resistance was evaluated using instron universal testing machine. Honey dew TMA wires of 1cm length were evaluated for surface characteristics using scanning electron microscope (SEM). Analysis of variance was used in the statistical analysis of the findings, and the Group 1 honeydew TMA wires in artificial saliva revealed mean kinetic frictional value of 1.3492 N, while Group 2 archwires in chlorohexidine showed a mean value of 2.1358 N and Group 3 archwires in povidone-iodine showed a mean value of 2.8103 N. The changes in friction are seen in the following order - control group< chlorohexidine group < povidone iodine group. The SEM photographs showed significant corrosion rate among povidone-iodine group when compared to chlorohexidine and artificial saliva. SEM images showed surface modifications on honey dew TMA wires. Among the study groups, povidone iodine group showed higher friction than chlorohexidine group, so chlorhexidine mouthwash can be considered as a better alternative to povidone iodine mouthwash for orthodontic patients. The results showed that friction between honey dew wires and self- ligating brackets is relatively less and can be used as an alternative in retraction cases.

Keywords: Honey dew TMA, Friction, Self-ligating brackets, Chlorhexidine, Povidone-iodine

Full-length article **Corresponding author's* e-mail: gneeshma@gmail.com

1. Introduction

In orthodontics, friction plays a major role in closing extraction space. Friction may be due to type of archwire, bracket, angulation of wire to bracket, surface roughness of the archwire and bracket, method of ligation [1]. The friction between the brackets and archwire causes decrease in tooth movement, reduces the force applied and can cause loss of anchorage [2].

Titanium molybdenum alloy (TMA) wires were introduced by Burstone and Goldberg in the year 1978.These wires gained popularity because of their unique properties such as high spring back, low force delivery levels, formability, weldability and low stiffness [3]. It exhibits force levels more than nickel-titanium archwires (Ni-Ti) and less than stainless steel (SS).

The high rate of friction of TMA wires makes them unfit to be used for space closure procedure in sliding mechanics [1]. Burstone and Farzin-Nia F presented the ion implantation method of coating the archwire with high energy ions. This method proved to be of immense advantage in coating TMA wires to formulate colored TMA wires with low friction and improved surface characteristics to use in sliding mechanics [4]. Honeydew coated TMA wires are recommended in situations where the frictional characteristic influences the treatment outcome and can replace the SS during retraction in space closure procedure [3].

Self-ligating brackets (SLB) (Stolzenberg, 1935) are ligature-free bracket systems that include a mechanical device integrated into the bracket to seal off the edgewise slot; they are more comfortable for patients because of no ligature, less chairside time for removal and insertion of archwire, longer intervals between appointments, better periodontal health due to elimination of elastomeric modules and reduced risk of enamel decalcification [5]. Other advantages include greater bond strength to withstand orthodontic and normal masticatory stresses, more efficient during levelling and alignment, ability to reduce the forces acting on the teeth which in turn reduces root resorption [6]. Due to the absence of wire ligatures, SLB are typically smoother, more pleasant, and simpler to clean from the patient's point of view· [7].

According to studies done by Henao and Kusy 2005; Thomas et al 1998; Berger 1990; Read-Ward et al 1997; Sims et al 1993,1994; Thorstenson and Kusy 2001; SLB showed significant decrease in friction compared with conventional brackets [8]. In a study by syed altaf khalid et al 2012, the SLB with TMA archwires showed less friction when compared with SS wire [1]. The orthodontic wires and brackets are exposed to saliva and other oral hygiene aids in oral environment. Studies show these cleansing agents effect orthodontic appliances [9,10]. Patients undergoing orthodontic treatment are generally prescribed mouthwashes like chlorhexidine and povidone-iodine, which are potent against most bacteria [11,12,13].

There is a limited data showing the effect of highly potent mouthwashes on frictional and surface properties of Honey dew TMA wires. So, the purpose of this study is to evaluate the effect of chlorhexidine and povidone-iodine mouthwashes on frictional resistance and surface characteristics of the honey dew TMA archwires.

2. Materials and Methods

This study was conducted in Department of Orthodontics and Dentofacial Orthopedics, SRM Dental College, Ramapuram, Chennai-89. Approval of the study design was obtained from the institutional review board of SRM Dental College, Ramapuram, Chennai-89 – SRMDC/ IRB/ 2020/ MDS/ No.107.

2.1. Groups

45 samples of honey dew TMA wires cut into 7cm long were used. These wires were divided into three groups with 15 in each group:

- Group 1(Control): Artificial Saliva of pH 6.5
- Group 2: 0.2% Chlorhexidine (Hexidine)
- Group 3: 0.5% Povidone- iodine (Intadine)

2.2. Materials

0.019×0.025-inch Honey dew TMA wires (Ormco) (Figure 1), 0.022 slot Lower incisor metal Self ligating brackets (Damon Q-Ormco), Artificial saliva of pH 6.5, 0.2% Chlorhexidine mouthwash (Hexidine), 0.5% Povidone-iodine mouthwash (Intadine), Perspex sheet, Containers, Instron Universal Testing Machine, Scanning Electron Microscope.

2.3. Sample size determination

The sample size was calculated using G power software version 3.1.9.7. With power 95 total sample size calculated was 45 with 15 in each group. (Table 1)

2.4. Inclusion criteria

- 0.019×0.025-inch Honey dew TMA wires
- 0.022 slot lower incisors metal Self ligating brackets (Damon Q)

2.5. Exclusion Criteria

- Wire without any gross distortions
- Bracket without any gross distortions

2.6. Methods

In this study, frictional resistance and surface characteristics of honey dew TMA wires were measured after immersion in artificial saliva and mouthwash (Chlorhexidine and Povidone-iodine).

Artificial saliva with pH of 6.5 was prepared with the following formulation: 2.2mM monosodium phosphate ($NaH2PO4$), 2.2mM calcium chloride ($CaCl2$), 100mM sodium chloride, ($NaCl$), 50mM acetic acid, 0.02% sodium azide ($NaN3$) and 1 part per million (ppm) sodium fluoride (NaF) [10]. The Honeydew TMA wires were physically checked for any gross distortions and cleansed with alcohol wipes to remove any residue or debris. The samples from all groups were incubated in artificial saliva at 37°C for a month before being immersed for 1.5 hours (1 minute per day for three months) (Figure 2) in 0.2% chlorhexidine and 0.5% povidone-iodine. The samples were then reintroduced to artificial saliva for two months after being cleaned with distilled water [14]. 7cm length wire was cut into 6cm length for frictional resistance and 1cm length for surface characteristics.

2.6.1. Frictional resistance

Evaluation of frictional resistance is done by using Instron Universal Testing Machine. For friction testing, four Damon Q lower incisor brackets were used. Brackets were cleansed with alcohol wipes to remove manufacturing grease and dirt. All the orthodontic brackets were attached onto Perspex sheet using adhesive with interbracket distance of 8mm (Figure 3). In order to negate the effects of built-in torque in the brackets, 0.021 × 0.025-inch SS wire was placed in the bracket slot to align the lower incisor brackets (Figure 4).

The dried wires of 6cm length were engaged into the brackets and were locked. This set up was mounted onto the Instron Universal Testing Machine. The perspex sheet was tightly attached to the lower jig of the Instron testing machine. The wire sample which was placed in the bracket slot is attached to the upper jig. The Instron machine's upper jig travels at a predefined speed (5 mm/min), while the lower jig is stable (Figure 5). While moving, the upper jig pulls the 0.019 × 0.025-inch TMA wire which was attached to it and the readings for the kinetic friction were noted. This procedure was repeated for all 45 samples of Group 1, Group 2 and Group 3 respectively.

2.6.2. Surface Characteristics

Evaluation of Surface Characteristics was done by Scanning Electron Microscope (SEM). Two samples of one cm straight length wire from each group were taken to evaluate the surface characteristics after immersion in the respective test groups for one and half hour followed by artificial saliva for two months. The samples were studied using SEM. The wires were placed in the vacuum chamber of the SEM and to optimize the quality of the micrograph, the angle of fit, accelerating voltage, and the aperture were adjusted. The samples were viewed at the magnification of 500x and 1000x and the images were obtained.

2.7. Statistical analysis

Statistical analysis was done by IBM SPSS (IBM Corp. Released 2011. IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp). Mean and SD was used to summarize the data. A ‘P’ value of <0.05 was considered as statistically significant difference. Inter and intragroup comparisons were done using one-way ANOVA and Tukey’s post-hoc test.

3. Results and Discussion

3.1. Results

3.1.1. Evaluation of frictional resistance

The objective of the study was to evaluate the frictional resistance between the honeydew TMA archwires (0.019×0.025-inch) and metal SLB (Damon Q) in artificial saliva, 0.2% chlorhexidine and 0.5% povidone iodine mouthwash. 45 archwires were divided into 3 groups with 15 archwires in each group. Honeydew TMA archwires in artificial saliva are referred to as group 1, honeydew TMA archwires in chlorhexidine are referred to as group 2, and honeydew TMA archwires in povidone iodine mouthwash are referred to as group 3. Instron testing machine was used to evaluate the frictional resistance. The frictional resistance data were tabulated and expressed in Newton.

Table 2 shows the calculated standard deviation and mean of frictional resistance of honeydew TMA wires in artificial saliva, chlorhexidine and povidone iodine mouthwash using one way ANOVA analysis.

The overall mean of the archwire in artificial saliva ranged from 1.2208-1.4775N, chlorhexidine from 1.9977-2.2740 N and povidone iodine ranged from 2.7191-2.9015 N with the standard deviation of 0.23174, 0.24941 and 0.16470 respectively. With a p-value of 0.05, the statistical analysis conducted revealed a significant difference in friction between all the three groups. The results showed increase in friction in the following order - control group< chlorhexidine group < povidone iodine group. Table 3 represent the intra and inter group differences in values of friction between the three groups (artificial saliva, chlorhexidine and povidone iodine mouthwash) using Tukey’s post hoc analysis.

According to the findings of the Tukey post hoc analysis, there was a significant difference in the amount of friction between each group and the other groups (Figure 6).

3.1.2. Evaluation of surface morphology

The wire samples when viewed under SEM under a magnification of 500x and 1000x showed the following results, which were shown in figure 7,8,9. The wires in control (artificial saliva) group showed fewer surface alterations followed by chlorhexidine group and povidone-iodine group. Povidone -iodine group had more pitting when compared to other groups which resulted in more frictional resistance.

3.2. Discussion

Friction is a clinical problem in orthodontics, especially when sliding mechanics is used, and it needs to be effectively controlled to achieve the best orthodontic results. In friction mechanics, during retraction, the force generated between the ligature, wire and orthodontic bracket impedes the tooth movement and the forces are transmitted to posterior teeth, which has a detrimental impact on the need for anchorage and could lead to anchorage loss [15]. Profit reported that 50% of the force applied is utilized for tooth movement while the remaining 50% is required to overcome the frictional force generated at the archwire/bracket interface [2].

In 1978, Burstone and Goldberg introduced titanium molybdenum alloy (TMA) wires which exhibits less elastic modulus, excellent formability, weldability, they possess high surface roughness, which increases in friction [1,3,16]. Because of its high friction when compared to other wires, these wires were not used during space closure in sliding mechanics [17,18,19,20]. To enhance the qualities of the traditional TMA wires, Ormco produced low-friction TMA wires in 2014. They modified the surface and improved the manufacturing process of TMA to create low friction materials. The surface topography was improved and frictional characteristics were enhanced by altering the procedure. These low-friction wires appear to be useful for reducing friction in particular clinical applications [15].

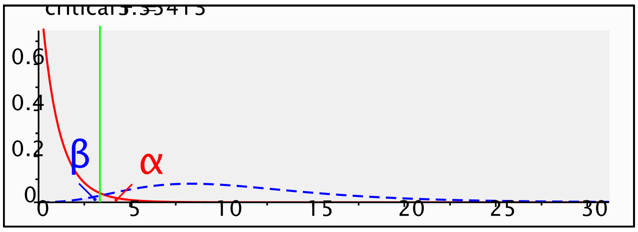
According to Schumacher et al., the type of ligation primarily determines friction. SLB were first introduced in 1935 as Russell attachment, which was intended to reduce ligation time and improve operator efficiency.

Table 1. Sample size determination

Sample size calculation

F tests - ANOVA: Fixed effects, omnibus, one-way

Analysis:	A priori: Compute required sample size		
Input:	Effect size f	=	0.61
	α err prob	=	0.05
	Power (1-β err prob)	=	0.95
	Number of groups	=	3
Output:	Total sample size	=	45 (15 in each group)
	Actual power	=	0.9515862



Sample size calculated from G*Power version 3.1.9.7

Reference: Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behavior Research Methods, 39, 175-191

Table 2. One-way ANOVA for intergroup comparison of friction between the groups

Group	Mean	Std. Deviation	95% Confidence Interval for Mean		F	P value
			Lower Bound	Upper Bound		
1	1.3492	.23174	1.2208	1.4775	168.25	0.0001
2	2.1358	.24941	1.9977	2.2740		
3	2.8103	.16470	2.7191	2.9015		

Table 3. Tukey's post-hoc test for multiple pairwise comparison

(I) Group	(J) Group	Mean Difference (I-J)	P value
1	2	-.78668*	.0001
	3	-1.46116*	.0001
2	1	.78668*	.0001
	3	-.67448*	.0001
3	1	1.46116*	.0001
	2	.67448*	.0001

Figure 1. 0.019x0.025-inch Honey dew TMA wires

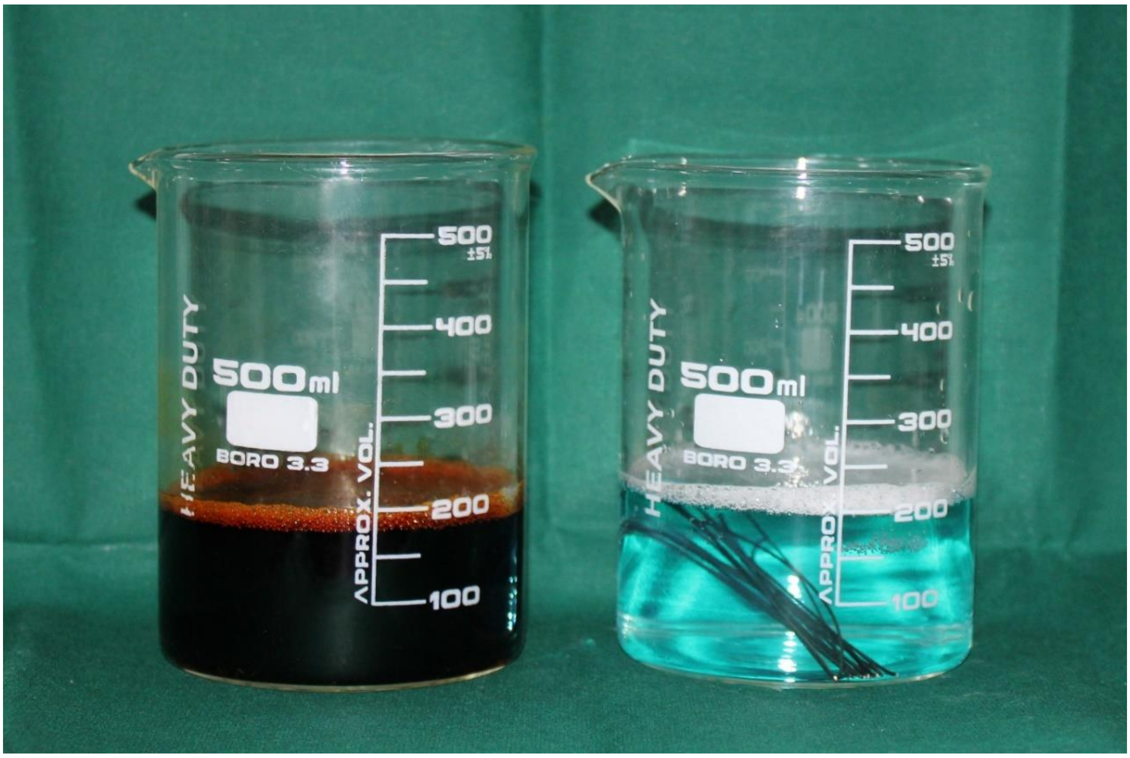


Figure 2. The test groups immersed in the mouthwashes (povidone-iodine and chlorhexidine) for one and half hour

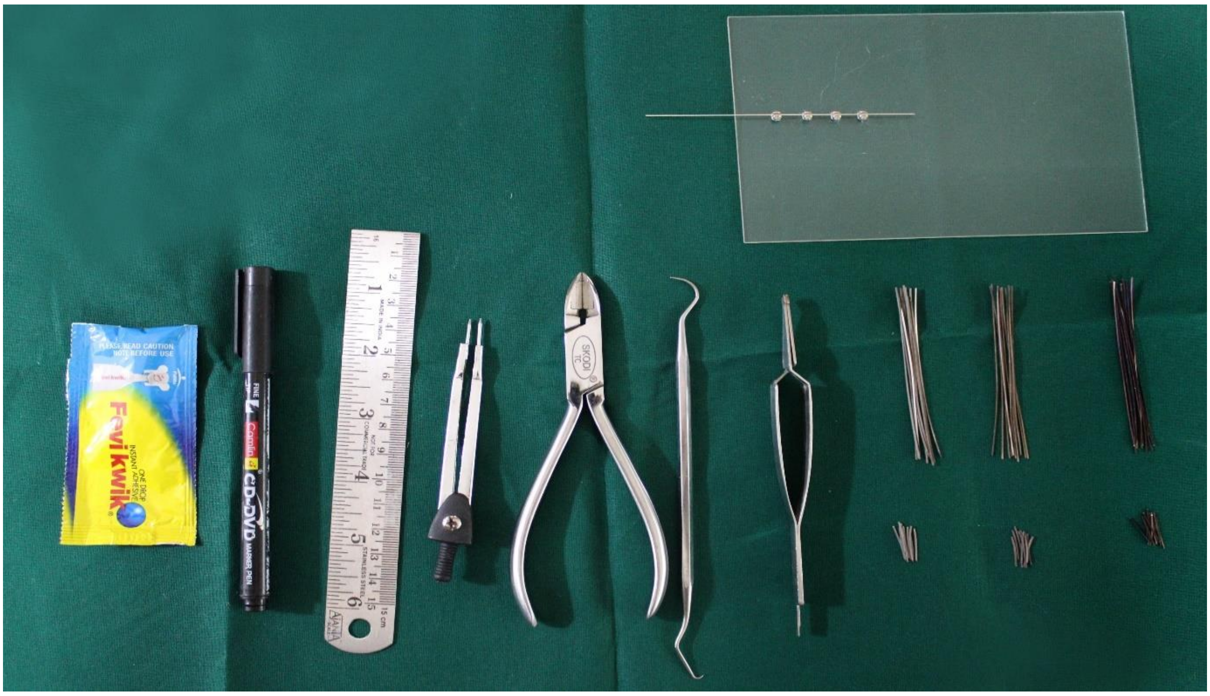


Figure 3. Armamentarium used

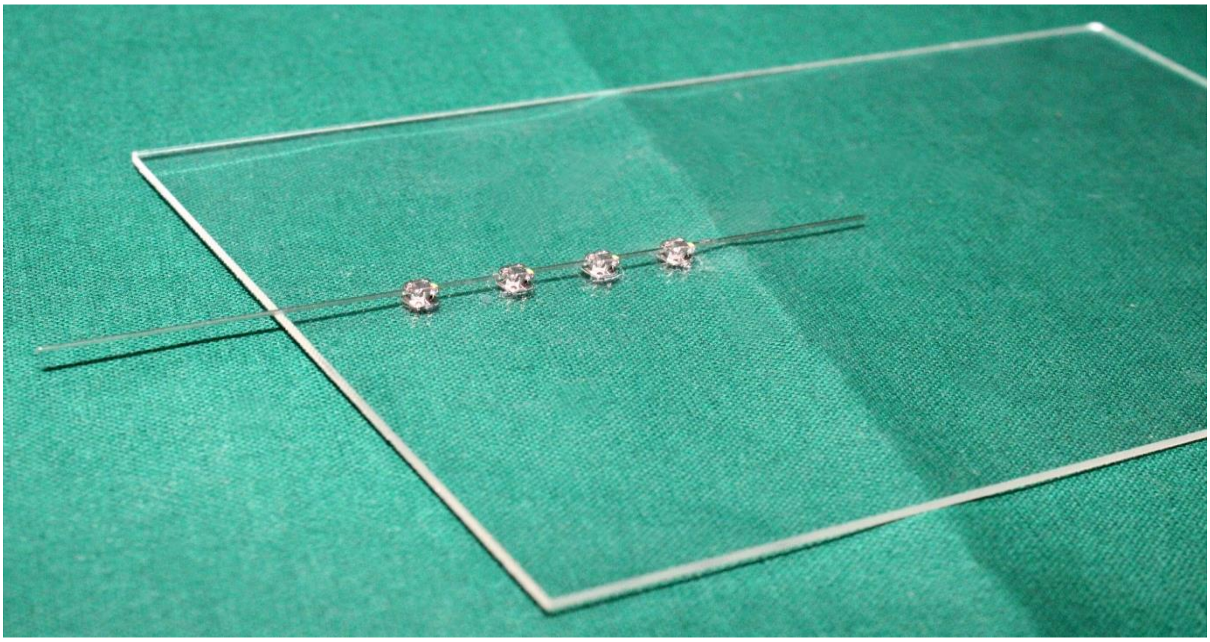


Figure 4. Brackets were fixed onto Perspex sheet

Figure 5. Instron testing machine

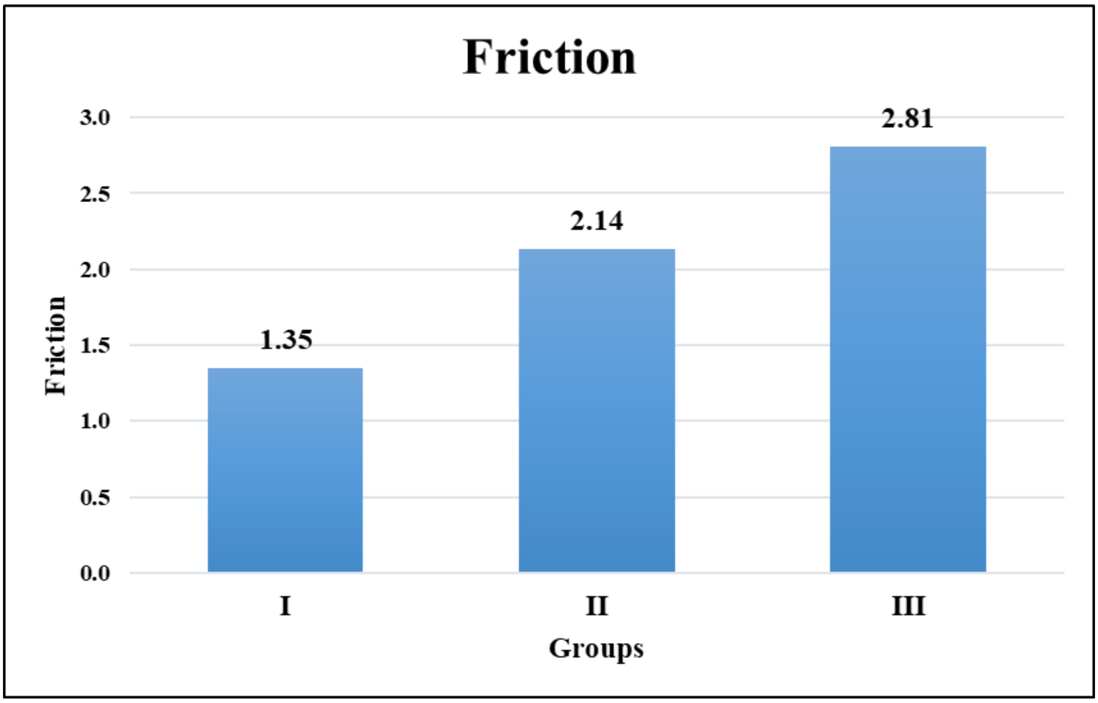


Figure 6. Bar diagram showing the mean values of friction for all the groups

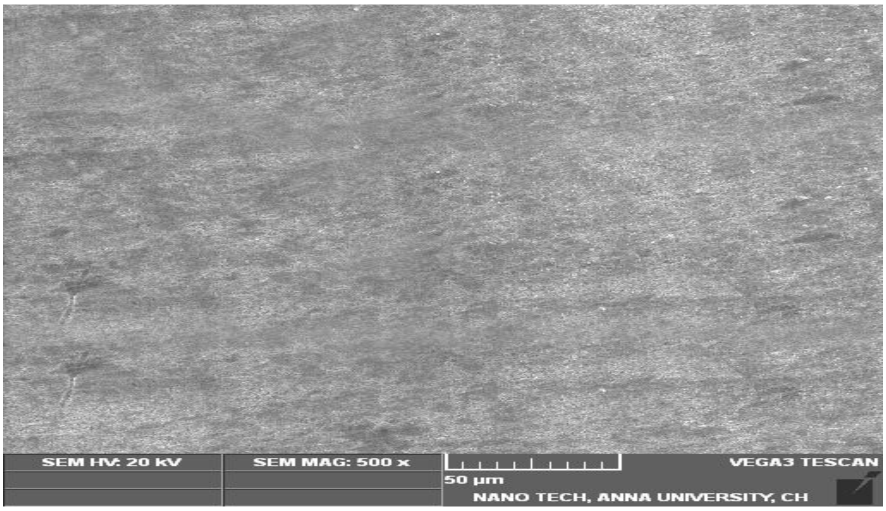


Figure 7 (a). SEM image of Group 1 (Artificial saliva)- 500x

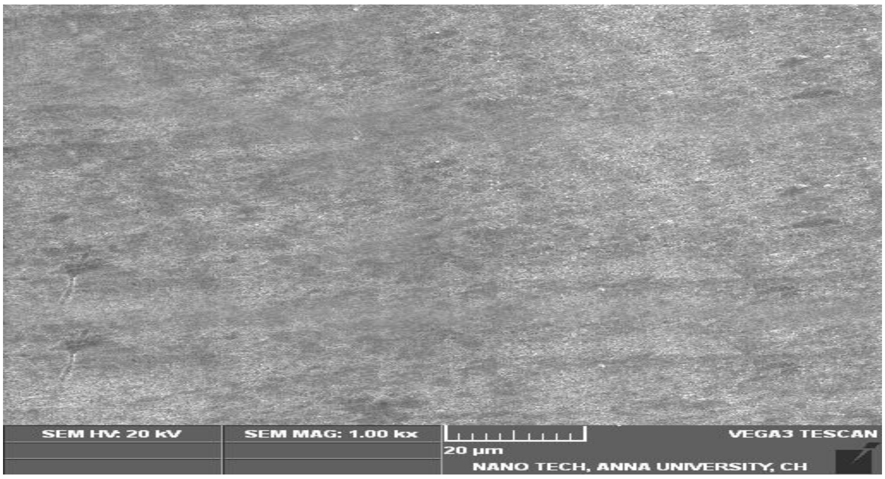


Figure 7 (b): SEM image of Group 1 (Artificial saliva)- 1000x

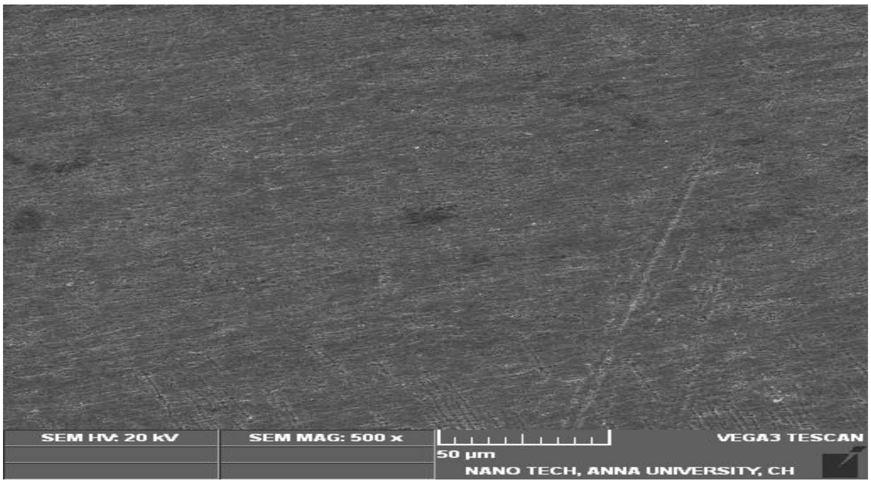


Figure 8 (a). SEM image of Group 2 (Chlorhexidine)- 500x

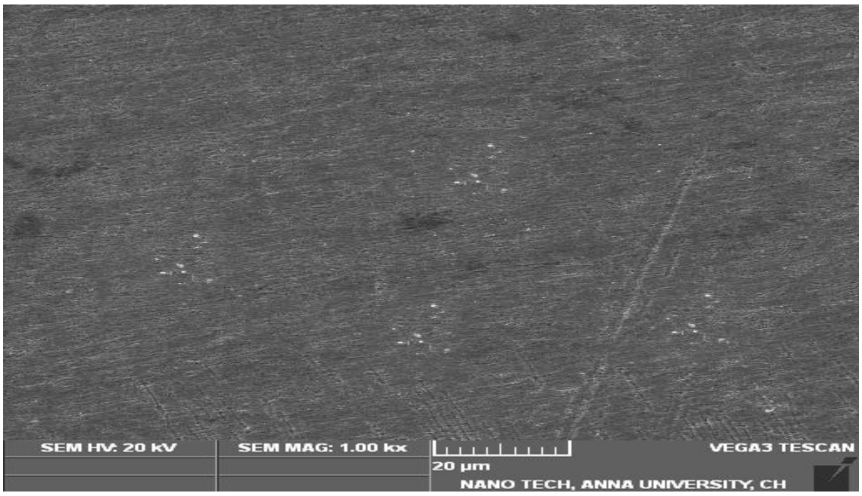


Figure 8 (b). SEM image of Group 2 (Chlorhexidine)- 1000x

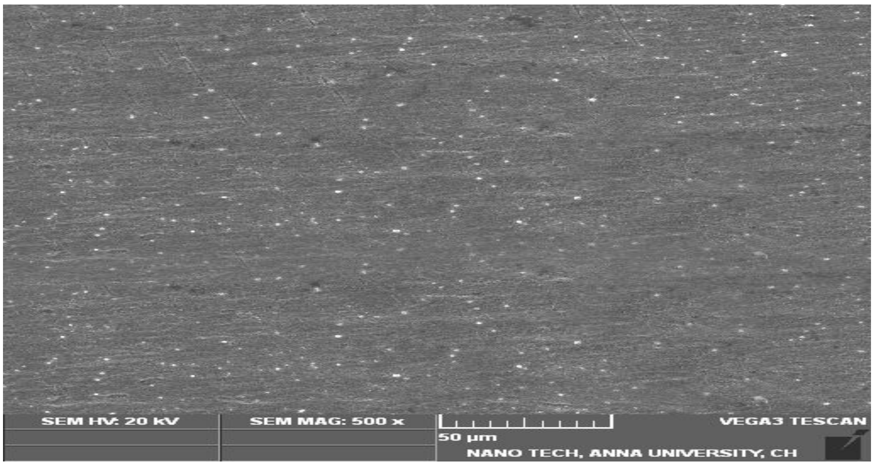


Figure 9 (a). SEM image of Group 3 (Povidone-iodine)- 500x

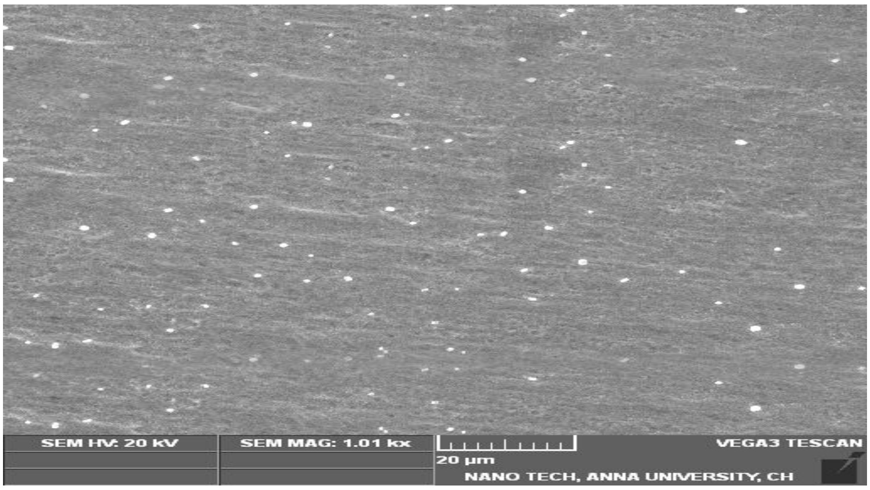


Figure 9 (b). SEM image of Group 3 (Povidone-iodine)- 1000x

These brackets exhibit significantly less friction than conventional bracket designs, according to a number of studies [20]. Additionally, it is asserted that Damon SLB streamline orthodontic treatment mechanics, enhance workplace productivity and profitability, and encourage more people to undergo orthodontic treatment. According to early observations, Damon SLB facilitated archwire placement and decreased frictional forces, which is advantageous when sliding mechanics are used [21].

In order to improve gingival health and potentially lower the incidence of caries and periodontal disease in orthodontic patients, it would be of considerable therapeutic advantage if a chemical agent could be employed throughout the active phase of orthodontic therapy to prevent bacterial plaque accumulation. When mechanical measures alone are ineffective for maintaining plaque control in orthodontic patients, these chemical agents should be employed as a supplementary treatment [12]. According to Anderson et al (1997) [22], Gehlen et al (2000) [23], Demir et al (2005) [13]; chlorhexidine and povidone-iodine mouthwash seems to be efficient to reduce plaque and gingivitis in orthodontic patients along with other preventive measures.

Thus, so far, no research had been done to evaluate frictional resistance between honey dew TMA wires and SLB used along with mouthwashes. In this study, a total of 45 honey dew TMA archwires with 7cm length were immersed in artificial saliva of pH 6.5 for one month and were divided into three groups (fifteen in each group). These wires were then immersed in 0.2% chlorohexidine and 0.5% povidone iodine mouthwash for one and half hour and were returned to artificial saliva for two months. The 7cm length wires were cut into 6cm and 1cm to evaluate frictional resistance and surface morphology respectively. Frictional resistance of honey dew TMA wires against SLB and surface characteristics was evaluated by Instron testing machine and SEM respectively.

3.2.1. Frictional resistance

Evaluation of frictional resistance was done by using Instron testing machine as suggested by Kusy et al. The four Damon Q lower incisor brackets were attached to the Perspex sheet with the help of adhesive with the interbracket distance of 8mm and were maintained in the straight line with the help of 0.021 × 0.025- inch stainless steel wire. The sheet was attached to the fixed lower jig and the wire was held in the upper jig and the crosshead speed was determined at 5mm/min. It was found that highest frictional resistance was observed in povidone-iodine group (mean-2.8103N) followed by chlorhexidine group (mean-2.1358) and artificial saliva group (mean-1.3492) (Table 2,3) (Figure 6).

When comparing the values of honey dew TMA wires of the current study to other studies done by Kusy et al (1992) [24], Michelberger et al (2000) [25], Krishnan et al (2013) [26]; it showed similar results that ion implantation reduces friction of the wires. Cash et al (2004) [2], According to Ryan et al. (1997) [27], Alsabati et al. (2020) [28], honeydew TMA wires have friction that is higher than that of SS wires but lower than that of TMA wires. On the other hand, according to Burstone and Farzin Nia, ion implantation lowers the frictional coefficient of TMA to a level that is comparable to SS [3].

But all these studies were conducted in dry environment whereas this study was conducted in wet environment to mimic the oral environment conditions. The other reason for conducting the study in wet conditions was saliva can act as an accelerating or inhibiting factor during frictional characteristics evaluation [3,7]. According to Kusy et al (1991) [29], TMA wires reduced 50% of their frictional values in the wet state as opposed to the dry state. According to studies done by Budd et al (2008) [5], Tecco et al (2007) [8], Thomas et al (1998) [30], Tecco et al (2005) [31]; Damon SLB has less friction when compared to conventional brackets. Khalid et al (2012) [1] stated that SLB with TMA wires has less friction than SLB with SS wire. Elayyan et al (2010) [32] stated that coating archwires with Damon SLB has less friction when compared with other archwire/bracket combinations.

According to Pandis et al (2006) [33], SLB are as effective as conventional brackets in space closure. According to Cash et al (2004) [2], Kula et al (1998) [34], Doshi et al (2011) [35]; they stated that Honey dew TMA wires are better substitute for SS wires for retraction in sliding mechanics. So, the combination of Honey dew TMA wires and SLB was chosen in this study. According to Nik et al. (2013) [36], Ni-Ti and SS archwires submerged in artificial saliva and chlorhexidine had same frictional resistance and surface characteristics. In contrast to that, Kao et al (2006) [9] stated that mouthwash effect the mechanical properties of archwire, which is similar to the result of the current study where the frictional resistance of chlorhexidine (mean-2.1358) and povidone iodine (mean- 2.8103) mouthwash is more when compared to artificial saliva (mean- 1.3492). There is significant difference seen between all three groups (Table 2,3) (Figure 6).

According to Schiff et al (2006) [37], mouthwashes ought to be given in accordance with the orthodontic materials utilized. This recent study demonstrated that as compared to chlorhexidine mouthwash, povidone iodine mouthwash increases frictional resistance. When compared with artificial saliva (control group), chlorhexidine and povidone-iodine (experimental group) showed increase in frictional resistance. Hence the hypothesis has been proved that mouthwashes cause effect on the mechanical properties of the archwire.

3.2.2. Surface characteristics

The changes in surface characteristics of the archwire after immersion in the mouthwashes (chlorhexidine and povidone-iodine) is evaluated by SEM in 500x and 1000x. Changes in surface can lead to increase in the corrosion rate of the archwire. Corrosion has two effects: it increases the possibility of local allergic reactions brought on by ions discharged into the environment and decreases the mechanical performance of the wire-bracket system, which would be detrimental to the effectiveness of the therapy [37].

The results of surface characteristics showed that povidone-iodine group has more pitting (surface irregularities) compared with chlorhexidine and artificial saliva. The high pitting results in increase in rate of corrosion of the archwire. (Figure 7,8,9). The high frictional resistance of povidone-iodine group in this study can be attributed to more surface irregularities as found in the study done by Khalid et al (2012) [1]. From this study chlorhexidine was found to be better mouthwash similar to study conducted by Sabah et al (2011) [38].

4. Limitations

This analysis does not precisely simulate the oral environment during orthodontic tooth movement, which is a limitation of any in-vitro study. To demonstrate the effectiveness of these wires in orthodontic biomechanics, in-vivo research must be carried out in the future to evaluate them in various clinical scenarios.

5. Summary and Conclusion

Friction is one of the main concerns in orthodontic space closure. Several researches have been conducted to reduce the friction and to come up with ideal bracket/archwire combination. So, in this study honey dew TMA wires and Damon Q SLB were used as they claim to have less friction. As many studies stated that surface roughness also effects friction, the surface changes were tested. The samples were immersed in artificial saliva to mimic the oral environment and 0.2% chlorhexidine and 0.5% povidone iodine mouthwashes were preferred in this study. The current study evaluated the frictional resistance and surface characteristics of honey dew TMA wire after immersion in artificial saliva and mouthwashes.

The following results were derived while taking into account the limitations of the study:

- The frictional resistance between povidone iodine group and SLB was more when compared with chlorhexidine and artificial saliva group because povidone iodine group has more surface irregularities when compared with other groups
- So, chlorhexidine mouthwash can be considered as a better alternative to povidone iodine mouthwash for orthodontic patients.
- The results showed that friction between honey dew wires and SLB is relatively less, hence honey dew wires can be used as an alternative to SS archwires in retraction cases.

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