Evaluation of Kinetic Friction between Regular and Colored Titanium Molybdenum Alloy Archwires

Abstract

**Aim:** The aim of this study was to evaluate the kinetic frictional properties of colored titanium molybdenum alloy (TMA) archwires (purple-coated TMA and honey dew-coated TMA) and the regular TMA archwires. **Materials and Methods:** The experiment comprised of three groups, Group I – Regular TMA archwires, Group II – Purple-coated TMA archwires, Group III – Honey dew-coated TMA wires involving 21 samples each that were evaluated for their frictional properties using Instron Universal Testing Machine. **Results:** The results were subjected to statistical analysis using analysis of variance wherein Group I Regular TMA wires revealed mean kinetic frictional value of 8.236 N and a standard deviation of 0.4038 N, while Group II (purple-coated TMA wires) showed a mean value of 5.297 N, standard deviation of 0.3128 N and Group III (honey dew-coated TMA wires) showed a mean value of 4.206 N and a standard deviation of 0.5353 N. **Conclusion:** The kinetic frictional values are higher for regular TMA wire exhibiting superior characteristic of color-coated TMA. Wires exhibiting superior characteristics are color-coated TMA wires, especially honey dew-coated TMA wires over the regular and purple-coated TMA wires. These superior properties of newly introduced wires can be considered for its application in both details friction and frictionless mechanics in retraction phase of fixed orthodontic treatment.

**Keywords:** Honey dew titanium molybdenum alloy wires, Instron Universal Testing Machine, kinetic friction, purple titanium molybdenum alloy wires, titanium molybdenum alloy wires

Introduction

Since the introduction of titanium molybdenum alloy (TMA) wires by Burstone and Goldberg[1] to orthodontics in the year 1978, these wires gained popularity because of their properties, such as unique balance of high spring back and formability with low stiffness. Because of its high friction (due to its increased surface roughness), these wires are not used during space closure in sliding mechanics.[2,3] To overcome this defect, manufacturers have introduced low friction-colored TMA wires.

In this study, we have evaluated the frictional characteristics of newer generation TMA wires such as Purple-coated and honey dew-coated TMA wires with the regular TMA wires manufactured by Ormco.

Materials and Methods

This study involves three different groups of archwires, namely, 0.019” x 0.025” regular TMA, 0.019” x 0.025” honey dew TMA, and 0.019” x 0.025” purple TMA comprising 21 samples each that are tested for frictional characteristics [Figure 1].

Stainless steel lower incisor brackets of 0.22 slot MBT were used for testing the frictional characteristics. The lower anterior brackets were mounted on a perspex sheet and 0.019” x 0.025” TMA wires were placed in the bracket slot using modules [Figure 2].[3]

The evaluation of frictional characteristics was done with Instron Universal Testing Machine number (ABS Instron 3382/66216).

Methodology

For this kinetic frictional testing, the stainless steel lower incisor brackets of 0.22 slot MBT prescription with tip values of 0° and torque values of −6° were taken.

All the brackets were attached onto the perspex sheet using adhesive with interbracket distance of 8 mm, and care is taken to maintain the slots in a straight line [Figure 2].

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The 21 samples of each group to be tested are taken, and the length of each wire is cut to 6 cm. This wire is physically checked for any gross distortions, and after ruling it out, this sample wire is carefully engaged into the bracket slot using an unstretched elastomeric module for the purpose of standardization.[4,5]

This set up is mounted onto the Instron Universal Testing Machine. The perspex sheet is tightly attached to the lower jig of the Instron machine [Figure 3]. The wire sample which is placed in the bracket slot is attached to the upper jig. The crosshead speed was determined and set at 5 mm/min. The lower jig of the Instron machine is stable whereas the upper jig moves at a specified predetermined speed (5 mm/min);[5] while moving, the upper jig pulls the 0.019” × 0.025” TMA wire which is attached to it and the readings for the kinetic friction are noted. This procedure is repeated for all the 21 samples of Group I, Group II, and Group III, respectively.[4‑8]

The mean and standard deviation were estimated from the sample for each study group, and the result was statistically analyzed using one-way analysis of variance followed by post hoc comparison test for multiple comparison within the groups to evaluate and determine the group of statistical significance. Initial data analysis was used to determine the mean and standard error of the mean.

On multiple comparison using post hoc test, Bonferroni test was employed for equal variances while Tamhane test was advocated for variances that were not equal resulting in statistically significant data. The data were tabulated and analyzed [Tables 1 and 2].

**Results**

The mean kinetic frictional values were statistically analysed and tabulated [Tables 1 and 2].

**Discussion**

Friction is one of the major obstacles encountered in prolonging the treatment time as it hinders the tooth movement. Many studies have been performed to assess the frictional characteristics and the factors influencing the friction.[2,5,9,10] With the advent of new materials into the field of orthodontics which are suggested to have superior qualities by the manufacturers, the orthodontists are zealous to use these materials. However, lack of scientific studies on these newer materials has created an uncertainty in the minds of many orthodontists.

The frictional characteristics for this study were evaluated between the 0.022 slot MBT stainless steel brackets as suggested by McLaughlin et al.,[11] and the three archwires which are 0.019” × 0.025” rectangular regular TMA wires manufactured by Ormco, 0.019” × 0.025” rectangular Purple-coated TMA, and 0.019” × 0.025” rectangular honey dew-coated TMA wires. In this study, 0.019” × 0.025” dimension wire is tested for friction because according to McLaughlin et al.,[11] 0.019” × 0.025” dimension wire is recommended with 0.022” slot brackets in sliding mechanics as it gives good overbite control and stability while allowing free sliding through the buccal segments. The process followed for evaluation of frictional characteristics by subjecting the wires to Instron Universal Testing Machine was as suggested by Kusy et al.[3]
Alexander, et al.: Frictional characteristic of TMA Arch wires

Table 1: Mean kinetic frictional values for all the 21 samples of all the three groups

| Kinetic friction | Descriptives | 95% CI for mean | Minimum | Maximum |
|------------------|--------------|-----------------|---------|---------|
|                  | n | Mean | SD | SE | Lower bound | Upper bound |
| 1                | 21 | 8.236 | 0.4038 | 0.0881 | 8.052 | 8.420 |
| 2                | 21 | 5.297 | 0.3128 | 0.0683 | 5.155 | 5.440 |
| 3                | 21 | 4.206 | 0.5353 | 0.1168 | 3.962 | 4.449 |
| Total            | 63 | 5.913 | 1.7663 | 0.2225 | 5.468 | 6.358 |

CI=Confidence interval, SE=Standard error, SD=Standard deviation

Table 2: Comparison of mean kinetic frictional values for all the 21 samples of all the three groups

| Dependent variable kinetic friction (Bonferroni) | Mean difference (I-J) | SE | Significant | 95% CI |
|-------------------------------------------------|-----------------------|----|-------------|--------|
| Group I (I) Group I (J)                         |                       |    |             |        |
| 1                                               | 2                     | 2.9386* | 0.1318 | 0.000 | 2.614 | 3.263 |
| 1                                               | 3                     | −4.0300* | 0.1318 | 0.000 | −4.355 | −3.705 |
| 2                                               | 3                     | 1.0914* | 0.1318 | 0.000 | 0.767 | 1.416 |

*0.001. CI=Confidence interval, SE=Standard error

Lower incisor brackets of 0.022” slot MBT prescription were chosen as this prescription is very popular globally. This study was performed in dry conditions since a study done by Andreasen and Quevedo[12] has shown no difference between dry and wet conditions. The other reason for conducting the study in dry conditions was to prevent contamination due to saliva, and saliva can act as an accelerating or inhibiting factor during frictional characteristics evaluation; thus, the results acquired when subjected to wet condition may not be appropriate and cannot be standardized.

Since Cash et al.[14] had stated that there is difference in thickness of ion implantation between honey dew- and purple-colored TMA wires, we chose to evaluate and compare these two colored TMA wires in two different groups with the control group of uncoated TMA wires.

The frictional properties of these three groups of samples were tested, and the readings were obtained in graphical representation interpreting the kinetic frictional values in Newtons for each of the sample that were subjected to Instron Universal Testing Machine.

The mean kinetic friction value obtained for all the 21 samples in Group I (0.019” × 0.025”Ormco Regular TMA) is 8.236 N with standard deviation of ±0.4038 and with a standard error of 0.0881. With 95% confidence Interval, Group I shows lower bound mean value of 8.052 N with a minimum value of 7.4 N. The upper bound with 95% confidence interval for mean was 8.042 N, with a maximum value of 9.0 N. These values obtained after kinetic friction evaluation suggest that the frictional values are higher when compared to the kinetic frictional values obtained for stainless steel archwires as stated by Cash et al.[4] Studies conducted by Cacciafesta et al.[17] Loftus et al.[13] and Kusy et al.[6] also generated a similar conclusion stating that regular TMA wires exhibited comparatively higher frictional forces compared to the stainless steel and other archwire bracket combinations. Hence, these wires exhibited comparatively higher frictional forces.

For all the 21 samples in Group II (0.019” × 0.025”Ormco Regular TMA), the mean kinetic value friction is 5.297 N along with a standard deviation of ±0.3128 and a standard error of 0.0683. At 95% confidence interval for mean, a lower bound mean value of 5.155 was evident with a minimum value of 4.7 N. The upper bound for mean was 5.440 N with a maximum value of 5.9 N. The results suggest that purple-coated TMA wires have a moderate frictional characteristics as concluded by Premanand and Kumar[5] and Burstone and Farzin-Nia.[14]

In Group III (0.019” × 0.025” Honey dew TMA wires), the mean kinetic friction value is 4.026 N for all the 21 samples with a standard deviation of ±0.5323 N and a standard error of 0.1168 N. At a confidence interval of 95% for mean, Group III showed a lower bound mean value of 3.962 N with a minimum value of 3.0 N and upper bound of 4.449 N with a maximum value of 5.0 N, suggesting that honey dew-colored TMA wires has the least kinetic frictional resistance; this can be due to the increased thickness of ion implantation in the honey dew-colored TMA wires [Table I]. Similar conclusion was drawn by Premanand and Kumar[5] and Burstone and Farzin-Nia.[14]

The comparison of kinetic frictional values between Group I (regular 0.019” × 0.025” rectangular TMA) and Group II (0.019” × 0.025” rectangular purple-coated TMA wires) showed a mean difference of 2.9386 N with a standard error of 0.1318. When 95% confidence interval was taken into consideration, the lower bound was 2.614 N and the upper bound was 3.263 N. The reduction in the frictional characteristics in the Group II compared to Group I could be attributed to the process of ion implantation as it tends to increase the hardness (by formation of oxide layer on the surface of the wire),
thus improving the surface finish regardless of the composition of the material.[15]

On comparing the kinetic frictional values of Group I (regular 0.019” × 0.025” rectangular TMA wires) with Group III (regular 0.019” × 0.025” rectangular honey dew TMA wires), the mean difference was found to be −4.0300 N with a standard error of 0.1318. The 95% confidence interval was taken into consideration, the lower bound was −4.355 N and the upper bound was −3.705 N.

TMA uncoated wires exhibit statistically higher frictional characteristics than ion-implanted TMA wires such as honeydew-coated TMA wires. These ion-implanted TMA archwires can be considered as an alternative choice for closing extraction spaces to the stainless steel wires. In support of our result, some studies have suggested that honey dew-coated wires may have a similar or even lesser frictional resistance than stainless steel wires. Michelberger et al.[4] study was in contrast with our study results as they suggested increased friction in ion-implanted TMA. A mean difference of 1.0914 N was evident with a standard error of 0.1318 on comparing the kinetic frictional values between Group II and Group III. At a confidence interval of 95%, the lower bound was 0.767 N and the upper bound was 1.416 N. The honey dew-colored TMA wire showed reduced friction when compared to purple TMA wire. This result was in concurrence with the results of Cash et al.[4] and Premanand and Kumar.[5] Cash et al.[4] found reduction in frictional resistance only in honey dew-colored TMA wires.

When the kinetic frictional values are combined for all the three groups (Group I, Group II, and Group III), the resultant mean value obtained for kinetic friction was 5.913 N with a standard deviation of 1.766 N and the standard error was at 0.2225 N. When the mean value is evaluated for 95% confidence interval, the lower bound mean value was 5.468 N with a minimum value of 3.05 N and the upper bound mean value was 6.358 N with a maximum value reaching 9.0 N [Table 2]. The combined mean value obtained for frictional resistance of all the three groups is 5.913 N which is very less compared with the regular TMA (8.236 N) and this value is slightly above the frictional values of purple TMA (5.297 N); but when it is compared with the Group III, the frictional values of Group III (4.026 N) are far less compared to the mean values of both the groups (Group I and II).[5,16,17]

In this study, the ion-implanted varieties of the TMA archwires exhibited significantly lower frictional resistance than the uncoated TMA archwires. Several studies on ion-implanted TMA by Burstone and Farzin-Nia,[14] Ryan et al.,[13] Husmann et al.[2] and Doshi and Bhad-Patil[9] and Krishnan and Kumar[20] showed similar results of reduction in frictional forces for ion-implanted TMA wires. Burstone and Farzin-Nia[14] had even said that ion implantation radically reduces TMA’s high frictional coefficient to about the same level as that of the stainless steel.

This comparison between the three groups gives us a conclusion that Group III (0.019” × 0.025” honey dew-coated TMA archwires) exhibited less friction when compared to the other two groups. Group II exhibited more friction when compared to Group III (0.019” × 0.025” honey dew-coated TMA wires) but exhibited less friction when compared with Group I (0.019” × 0.025” regular TMA wires). Group I (0.019” × 0.025” regular TMA archwires) which are supposed to be a control group exhibited high frictional characteristics when compared with both the other groups that is Group II and Group III.

**Conclusion**

Honey dew-coated rectangular 0.019” × 0.025” TMA wires exhibited superior quality having lesser kinetic friction compared to the other two groups. Purple-coated rectangular 0.019” × 0.025” TMA wires showed an improved kinetic friction when compared to the regular 0.019” × 0.025” rectangular TMA wires, but when it is compared with honey dew TMA archwires, the frictional values are increased. Regular 0.019” × 0.025” TMA wire showed very high frictional characteristics compared to both purple-coated and honey dew-coated TMA archwires. Hence, honey dew-coated TMA wires are recommended in situations where the frictional characteristic influences the treatment outcome and can replace the stainless steel wire during retraction in space closure procedure.

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**Conflicts of interest**

There are no conflicts of interest.

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