International Journal of Recent Trends in Science And Technology, ISSN 2277-2812 E-ISSN 2249-8109, Volume 10, Issue 2, 2014 pp 233-238

An Evaluation and Comparison of Composition and Surface Characteristics of Different Orthodontic Wires – Energy Dispersing Spectrometry and SEM Study

P. Premanand[1*], S. Saravana Kumar[2], A. Jegadesh Shankar[3]

{[1]Associate Professorand Head, [3]Assistant Professor} Department of Dentistry, Chennai Medical college Hospital and Research centre (SRM Group), Irungalur, Manachanallur (T.K), Trichy - 621105, Tamil Nadu, INDIA.

[2]Associate Professor, Department of orthodontics and dentofacial orthopedics, Chettinad Dental College and Research Institute, Rajiv Gandhi Salai, Kelambakkam, Kancheepuram Dist, Chennai - 603 103, Tamil Nadu, INDIA.

[*]Corresponding Address:

drpremortho@gmail.com

Research Article

Abstract: **Aim:** To evaluate and to understand the composition and surface characteristics of different orthodontic wires. **Materials and method:** Six different orthodontic wires 1) stainless steel wires, 2)TMA wires 3) low friction TMA wires, 4) colored low friction TMA wires aqua, 5) colored low friction TMA wires purple, 6) colored low friction TMA wires honey dew were evaluated in this study. Surface characteristics of the orthodontic wires before and after the sliding process were evaluated using SCANNING ELECTRON MICROSCOPE (SEM). Composition of orthodontic wires was evaluated using ENERGY DISPERSING SPECTROMETRY (EDS). **Results:** SEM study clearly illustrates the variation in surface roughness of all the orthodontic wires. Untreated TMA wires exhibit the maximum surface roughness before and after sliding. Colored low friction TMA exhibit relatively smooth surface before and after sliding, with honey dew variety of TMA exhibiting the least noticeable change. Elemental analysis by EDS reveals the presence of oxygen in low friction colored TMA wires. **Conclusion:** The surface roughness is highest in TMA and the surface roughness is lowest in colored low friction TMA honeydew

Keywords: Surface roughness, SEM, EDS, Stainless Steel Wire, TMA Wire, Low Friction TMA Wire.

Introduction

The percentage of adult patients who seek orthodontic treatment has increased significantly in the recent decades[1].Most of the orthodontic mechanism for anterior tooth retraction is based upon sliding mechanics. Hence it is essential to evaluate the surface roughness and composition of orthodontic wires in order to produce effective tooth movement. Garner *et al* (1986)[2] used one hundred eighty bracket and arch wire combinations of nitinol, beta titanium, and stainless steel and compared as to the amount of force (grams) required to overcome a simulated canine retraction assembly. Results showed a significantly larger force required during canine retraction using beta titanium and nitinol when compared with stainless steel. Kusy *et al* (1988)[3] conducted laser spectroscopy studies on four principal alloy groups to determine the surface roughness and concluded that stainless steel appeared the smoothest, followed by cobalt-chromium, beta titanium and nickel titanium alloys. They suggested further studies to be undertaken to obtain clinical relevance between surface roughness of orthodontic wires and coefficient of friction Drescher *et al* (1989)[4] constructed a friction-testing assembly simulating three-dimensional tooth rotations to study factors affecting friction magnitude. Five wire alloys (standard stainless steel, Hi-T stainless steel, Elgiloy blue, nitinol, and TMA) in five wire sizes (0.016, 0.016 x 0.022, 0.017 x 0.025, 0.018, and 0.018 x 0.025 inch) were examined with respect to three bracket widths (2.2, 3.3, and 4.2 mm) at four levels of retarding force (0, 1, 2, and 3 N). They concluded from their study that the following factors affected friction in decreasing order: retarding force, surface roughness of wire, wire size, bracket width, and elastic properties of wire. The effective force of this arrangement has to increase twofold to overcome the friction. For TMA wire, however, the effective force must increase six fold, resulting in a hazardous overload of the anchorage units. Kusy and Whitley (1990)[5] evaluated the surface roughness and the coefficients of friction for sixteen arch wire-bracket combinations. The sample included one rectangular arch wire product from each of the four principal alloy groups and one bracket product from among the stainless steel and polycrystalline alumina inventory. The roughness of the stainless steel, cobalt-chromium, beta-titanium, and nickel-titanium arch wire surfaces averaged 0.053, 0.129, 0.137, and 0.247 µm, respectively. The coefficients of friction ranged from stainless steel (lowest) to cobalt-chromium, nickel-titanium, and beta-titanium (highest) regardless of bracket product or slot size. Prososki *et al* (1991)[6] measured the surface roughness and static frictional force resistance of orthodontic arch wires (Nickel-titanium, beta-titanium, stainless steel and cobalt-chromium). Frictional force resistance was quantified by pushing wire segments through the stainless steel self- ligating brackets of a four-tooth clinical model. The cobalt-chromium alloy and the nickel-titanium alloy wires, with the exception of Sentalloy and Orthonol, exhibited the lowest frictional resistance. The stainless steel alloy and the beta-titanium alloy wires showed the highest frictional resistance. Kula *et al* (1998)[7] conducted a randomized clinical trial to determine whether ion implantation of β -titanium archwire would facilitate sliding space closure. After bilateral maxillary first premolar extractions, 0.19 ´ 0.025-inch β -titanium archwires, ion-implanted on one half only, were placed. Nickel-titanium springs (150 g) were placed bilaterally to close the extraction spaces. Space closure was measured intraorally at monthly intervals until either the space on one side closed or 6 months had elapsed. The median rates of space closure were not significantly different between the ion-implanted and the unimplanted sides. The average rate of space closure on these b-titanium wires, with or without ion implantation, was similar to the rate reported on stainless steel archwires. Michelberger *et al* (2000)[8] investigated the coefficients of friction of titanium and stainless steel brackets used in conjunction with stainless and ion-implanted beta-titanium archwires using a single contact interface between the brackets and archwires. Stainless steel brackets tested with 0.016” flat stainless steel wire surfaces recorded the lowest coefficient of static friction mean (0.289), whereas titanium brackets paired with 0.016” flat ion-implanted beta-titanium wire surfaces produced the highest mean (0.767). Ion-implanted beta-titanium wires generally had significantly larger coefficients of friction than stainless steel wires. Curtis *et al* (2004)[9] did a comparative study of the static friction and kinetic frictional resistance of titanium molybdenum arch wires in stainless steel brackets. The wires that were studied are TMA, low friction coloured TMA (aqua, honey dew, purple and violet), ion implanted TMA, timolium and a stainless steel control. They ranked the wires as follows: stainless steel produced the lowest frictional resistance followed by honeydew, ion-implanted TMA, and Timolium. Aqua, purple and violet generated friction as high as the standard TMA. Since ion implantation can take place at relatively low temperatures from subzero to 700°C, it allows improvement of surface characteristics without degradation of other mechanical properties. The thickness of the implanted surface layer can be precisely controlled and its properties engineered to affect characteristics such as hardness, friction, wear resistance, ductility, and fatigue resistance. Varying the type and thickness of ions two varieties of TMA: low-friction and colored TMA were produced. Low-friction TMA has a light golden hue, and the different wire colors are aqua, purple, and honey dew.

Aims and Objectives

To compare the *SURFACE CHARACTERISTICS* of the Stainless Steel, TMA, Low Friction TMA, Colored Low Friction TMA Aqua, Colored Low Friction TMA Purple and Colored Low Friction TMA Honey Dew wires before and after the process of sliding using a *SCANNING ELECTRON MICROSCOPE.* To evaluate the composition of the Stainless Steel, TMA, Low Friction TMA, Colored Low Friction TMA Aqua, Colored Low Friction TMA Purple and Colored Low Friction TMA Honey Dew wires using the *ENERGY DISPERSING SPECTROMETRY.*

Materials and Method

The present study was conducted in the Department of Dentistry, Chennai Medical college Hospital and Research centre, along with the collaboration of Centralised Special Instruments Laboratory (CSIL), Annamalai University.

Materials used in the study

1. 0.016” x 0.022” Stainless steel (ORMCO, California, U.S.A)
2. 0.016” x 0.022” TMA (ORMCO, California, U.S.A)
3. 0.016” x 0.022” Low Friction TMA (ORMCO, California, U.S.A)
4. 0.016” x 0.022” Colored Low friction TMA AQUA (ORMCO, California, U.S.A)
5. 0.016” x 0.022” Colored Low friction TMA PURPLE (ORMCO, California, U.S.A)
6. 0.016” x 0.022” Colored Low friction TMA HONEY DEW (ORMCO, California, U.S.A)
7. Cuspid brackets Roth prescription 90 nos (3M UNITEK, Monrovia, U.S.A)

8. Stainless steel ligatures 0.10” (Ortho Organizers)
9. Pharmacological weight 150 gms
10. Scanning electron microscope (JEOL JSM-5610 LV) (Fig. 1)
11. Energy dispersing spectrometer

Figure 1: Scanning Electron Microscope

Surface Charecteristics

To examine the change in the surface morphology of the archwires, each wire was studied before and after sliding through the bracket with the help of a scanning electron microscope. A 5mm specimen of each wire was mounted on aluminum studs (Fig. 2), which were later placed in the vacuum chamber (Fig. 3) of the scanning electron microscope. The accelerating voltage, angle of hit and aperture were adjusted to optimize the quality of the micrograph. The wires were then scanned and viewed on the monitor at 300 X magnification and representative micrographs of the wires were taken.

Elemental Analysis

All the groups were subjected to elemental analysis by means of an energy dispersing spectrometer and the composition of each wire was evaluated.

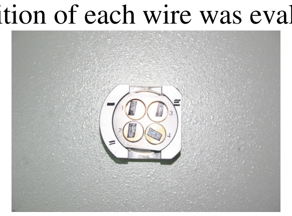


Figure 2: Wire Samples Being Loaded Onto the Studs

Figure 3: Samples Being Loaded Into the Vacuum Chamber of the Scanning Electron Microscope

Results

Surface Characteristics

The wire samples when viewed under the scanning electron microscope under a magnification of 300 X revealed the following results (Fig. 4 – 9):

STAINLESS STEEL (Fig. 4)

The micrograph obtained prior to sliding of the wire revealed a relatively smooth surface with very few surface irregularities. When the wire sample tested after sliding, there were very few noticeable changes of the surface topography.

TMA (Fig. 5)

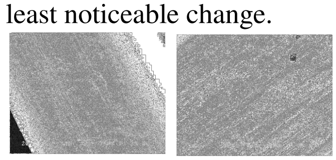
The micrograph obtained prior to sliding of the wire revealed a rough surface with many surface irregularities. When the wire sample tested after sliding, there was a further increase in the surface irregularities

LOW FRICTION TMA (Fig. 6)

The micrograph obtained prior to sliding of the wire revealed a relatively rough surface when compared with that of TMA. When the wire sample tested after sliding, there were noticeable changes of the surface topography denoting some amount of wear of the material.

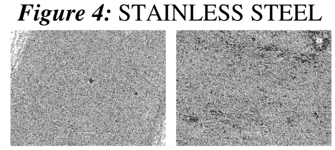
COLOURED LOW FRICTION TMA (Fig. 7-9)

The micrograph obtained prior to sliding of the wire revealed a relatively smooth surface with few surface irregularities. When the wire sample tested after sliding, there were minimal noticeable changes of the surface topography, with honey dew variety of the TMA exhibiting the least noticeable change.



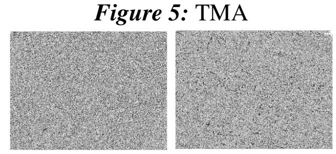
Before retraction After retraction

Figure 4: STAINLESS STEEL



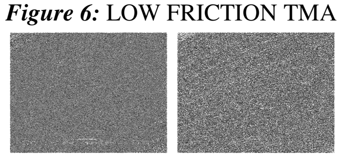
Before retraction After retraction

Figure 5: TMA



Before retraction After retraction

Figure 6: LOW FRICTION TMA

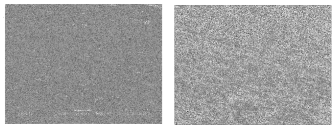


Before retraction After retraction

Figure 7: COLOURED LOW FRICTION TMA – AQUA

Before retraction After retraction

Figure 8: COLOURED LOW FRICTION TMA – PURPLE



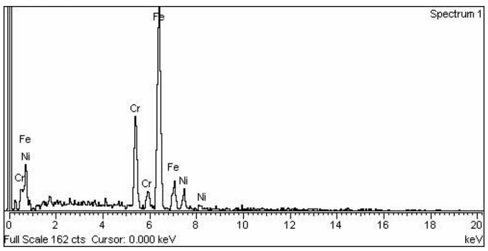
Before retraction After retraction

Figure 9: COLOURED LOW FRICTION TMA – HONEY DEW

ELEMENTAL ANALYSIS

All the wire samples were subjected to elemental analysis to find the correlation between the composition and the material properties; the results were obtained in the form of a graph, and represented as below:

STAINLESS STEEL

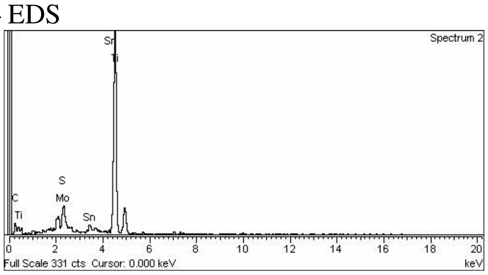


Element	Weight%	Atomic%
Cr K	20.18	21.44
Fe K	71.74	70.96
Ni K	8.08	7.60
Totals	100.00	

INFERENCE

The stainless steel wires were subjected to electron dispersing spectrometry to analyze the composition. The results show that they are made of 71.74% of iron, 20.18% of chromium and 8.08% of nickel.

TMA – EDS

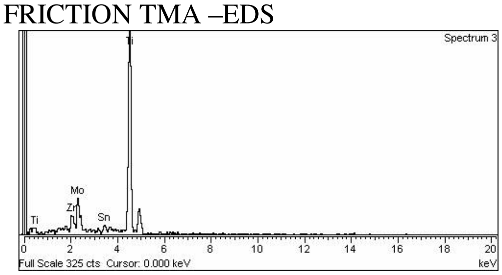


Element	Weight%	Atomic%
C K	14.51	42.39
S K	1.27	1.39
Ti K	70.21	51.43
Mo L	9.16	3.35
Sn L	4.85	1.43
Totals	100.00	

INFERENCE

The TMA wires were subjected to electron dispersing spectrometry and their compositions were found. The components are titanium 70.21%, carbon 14.51%, molybdenum 9.16% and tin 4.85%.

LOW FRICTION TMA –EDS

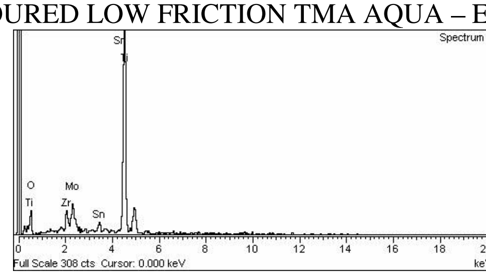


Element	Weight%	Atomic%
Ti K	70.36	82.94
Zr L	7.42	4.60
Mo L	16.80	9.89
Sn L	5.41	2.58
Totals	100.00	

INFERENCE

The low friction TMA wires were subjected to electron dispersing spectrometry to analyze the composition. Titanium 70.36% was the major component followed by molybdenum 16.8% and then zirconium 7.42%. A small amount of tin 5.41% was also present.

COLOURED LOW FRICTION TMA AQUA – EDS

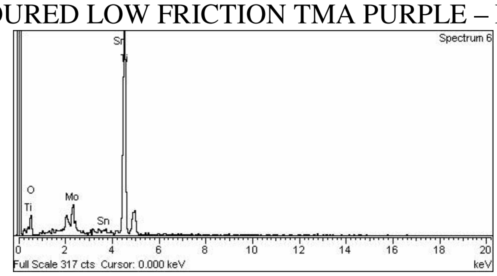


Element	Weight%	Atomic%
O K	29.57	58.90
Ti K	53.48	35.57
Zr L	6.54	2.28
Mo L	7.03	2.34
Sn L	3.38	0.91
Totals	100.00	

INFERENCE

The coloured low friction TMA aqua was subjected to elemental analysis. The major component is titanium 53.48% followed by molybdenum 7.03%, zirconium 6.54% and a small amount of tin 3.38%. A large amount of oxides 29.57% were found.

COLOURED LOW FRICTION TMA PURPLE – EDS

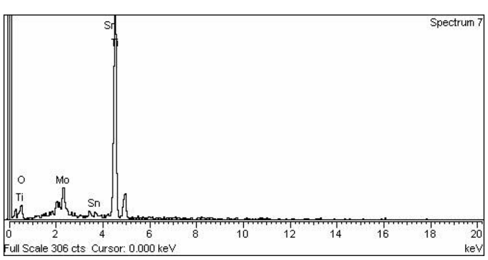


Element	Weight%	Atomic%
O K	32.45	61.16
Ti K	56.32	35.45
Mo L	9.03	2.84
Sn L	2.20	0.56
Totals	100.00	

INFERENCE

The colored low friction TMA purple was subjected to elemental analysis. The major component is titanium 56.32% followed by molybdenum 9.03%, and a small amount of tin 3.38%. A large amount of oxides 32.45% were found.

COLOURED LOW FRICTION TMA HONEY DEW – EDS



Element	Weight%	Atomic%
O K	26.08	53.93
Ti K	60.25	41.61
Mo L	9.76	3.37
Sn L	3.91	1.09
Totals	100.00	

INFERENCE

The colored low friction TMA honeydew was subjected to elemental analysis. The major component is titanium 60.25% followed by molybdenum 9.76%, and a small amount of tin 3.91%. A large amount of oxides 26.08% were found.

Discussion

Orthodontic tooth movement consists of repeated movements of tipping and uprighting. In clinical situations, however, additional factors might be involved; for example, masticatory impediment can break this cycle by causing a permanent set in the wire. It has been suggested that saliva may reduce friction by acting as a lubricant film. However, a preliminary study has shown no difference between dry models and wet models. This supports the findings of Andreasen *et al*[10] and Riley *et al*[11]. Hence the present study was aimed at evaluating the surface roughness between an 0.016" x 0.022" Stainless Steel, TMA, low friction TMA and colored TMA archwires and an 0.018" slot canine bracket in a dry state. Rectangular wire was chosen for this study because it offers control in all three planes of space, whereas round wire gives control only in two planes[12, 13]. As with other studies [5, 12] on comparison of the frictional resistance between stainless steel and TMA wires the present study also confirms the comparatively higher frictional resistance of the TMA wires. The ion implanted varieties of the TMA archwires exhibit statistically lower frictional resistance than the untreated TMA archwires, and in some cases (Purple) statistically similar or even lesser (Aqua, Honey Dew) frictional resistance than Stainless steel. To confirm the reasons for the increased friction of the TMA and the decreased frictional resistance of the ion-implanted TMA archwires, scanning electron micrographs were taken of the test wires, prior to and following sliding through the canine bracket, which allowed surface evaluation of all wires tested. Since the protocol required wires to be tested as they were obtained from the vendors, they were not altered by anodic or physical polishing. The purpose of the study was to ascertain the effects, if any, the wires, as received, would have on sliding mechanics. The electron photomicrographs clearly illustrates the variation in the surface roughness of all the wires. The untreated TMA wires exhibit the maximum alteration of the surface morphology with an increase in the surface roughness following sliding, followed by the low friction TMA archwire. Changes in surface morphology of the stainless steel wires are notable with a slight increase in the surface roughness, the alterations of the surfaces in the coloured TMA archwires were found to be minimal. These differences in surface smoothness may be accounted for the differences in friction resistance by the materials. The elemental analyses revealed the presence of Oxygen in the low friction coloured TMA archwires, the presence of this element is as a result of the ion-implantation process. The process resulted in the formation of oxides which lead to increase in the hardness[14] of the material which could be the reason for the reduction in the frictional resistance of these wires, which was evident in the electromicrographs demonstrating relatively few surface irregularities in comparison with that of TMA.

Conclusion

The results of the SEM study indicate:

- The surface roughness is highest in TMA
- The surface roughness is lowest in colored low friction TMA honeydew,
- The surface roughness of colored low friction TMA aqua is similar to that of stainless steel.

The results of EDS (elemental analysis) indicate:

- The presence of oxides on the surface as result of ion implantation could have increased the surface hardness of the material which would have led to the reduction in the frictional resistance of the coloured low friction TMA arch wires.

These results confirms the findings of earlier study[15] that comparatively higher frictional resistance of TMA wires. As with any in vitro study, this investigation does not replicate what actually occurs intraorally during tooth movement. This study provides a means by which to compare different wires under similar testing conditions. Some principles and conclusions can be drawn from the results, but one must be careful about applying this information to clinical situations.

References

1. Oppenhiem A, Tissue changes, particularly of the bone incident to tooth movement. International Journal of orthodontia 1911, Volume 3: 57-58.
2. Garner. L. D, Allai. W. W and Moore. B. K, A comparison of frictional forces during simulated canine retraction of a continuous edgewise arch wire, American J Orthodontics 1986 Volume 90 no3 (199–203).
3. Kusy. R. P, John Q. Whitley. J. Q, Michael J. Mayhew. M. J, Surface Roughness of Orthodontic Arch wires via Laser Spectroscopy, Angle Orthodontist 1988 Volume 1 (33 – 45).
4. Drescher.D, Bourauel. C and Schumacher. H. A, Frictional forces between bracket and arch wire, American J Orthodontics 1989 Volume 96 no5 (397-404).
5. Kusy .R. P and Whitley. J. Q, Coefficients of friction for arch wires in stainless steel and polycrystalline alumina bracket slots- The dry state, American J Orthodontics 1990 Volume 98 no4 (300-312).
6. Prososki..R. R, Bagby. M. D and Erickson. L. C, Static frictional force and surface roughness of nickel-titanium arch wires, American J Orthodontics 1991 Volume 100 no4 (341-348).
7. Kula. K, Phillips. C, Gibilaro. A, and Proffit. W. R, Effect of ion implantation of TMA archwires on the rate of orthodontic sliding space closure, American J Orthodontics 1998 volume 114 no5 (577-580).
8. Michelberger. D .J, Eadie. R. L, Faulkner. M .G, Glover. K. E, The friction and wear patterns of orthodontic brackets and arch wires in the dry state, American J Orthodontics Dentofacial Orthopedics 2000 Volume 118 (662-74).
9. Cash. A, Curtis. R, A comparative study of the static and kinetic frictional resistance of titanium molybdenum alloy arch wires in stainless steel brackets, European Journal of Orthodontics 2004 Volume 26 (105-111).
10. Andreasen, G. F., and Quevedo, F. R, Evaluation of frictional forces in the 0.022", 0.028" edgewise bracket in vitro, J Biochem 1970 no3 (151-160).
11. Riley, J. L., Garrett, S. G., and Moon, P. C, Frictional forces of ligated plastic and metal edgewise brackets, J Dental Research 1979 volume 58 A21.
12. Kapila.S, Angolkar. P.V, Duncanson. M.G, and Nanda.R.S, Evaluation of friction between edgewise-stainless steel brackets and orthodontic wires of four alloys, American J Orthodontics 1990 Volume 98 no2 (117-126).
13. Kusy. R. P, Comparison of nickel-titanium and beta titanium wire sizes to conventional orthodontic arch wire materials, American J Orthodontics 1981 Volume 79 no6 (625-629).
14. Ryan. R, Walker. G, Freeman. K and Cisneros. G. J, The effects of ion implantation on rate of tooth movement: An in vitro model, American J Orthodontics 1997 volume 112 no1 (64 - 68).
15. Premanand. P, Saravana Kumar. S, A Comparative Evaluation of the Frictional Resistance between Stainless Steel, TMA and Low Friction TMA Orthodontic Archwires – An In-Vitro Study.