ISSN: 2581-5989
PubMed - National Library of Medicine - ID: 101738774

International Journal of Dental Science and Innovative Research (IJDSIR)

IJDSIR : Dental Publication Service

Available Online at: www.ijdsir.com

Volume – 5, Issue – 2, March - 2022, Page No. : 264 - 271

Nanoparticles for The Reduction in Frictional Resistance During Sliding Mechanics in Fixed Orthodontic Therapy

[1]Dr. Sudha R. Halkai, Reader, Department of Orthodontics and Dentofacial Orthopedics, H.K. E's S. N Institute of Dental Sciences and Research, Kalaburagi, Karnataka, India.

[2]Dr. Muhammed Faseehuddin, Post graduate student, Department of Orthodontics and Dentofacial Orthopedics, H.K.E's S. N Institute of Dental Sciences and Research, Kalaburagi, Karnataka, India.

[3]Dr. Vishwanath Patil, Professor, Department of Orthodontics and Dentofacial Orthopedics, H.K.E's S. N Institute of Dental Sciences and Research, Kalaburagi, Karnataka, India.

[4]Dr. Basanagouda C. Patil, Professor & HOD, Department of Orthodontics and Dentofacial Orthopedics, H.K.E's S. N Institute of Dental Sciences and Research, Kalaburagi, Karnataka, India.

[5]Dr. Anamika Jha, Post graduate student, Department of Orthodontics and Dentofacial Orthopedics, H.K.E's S. N Institute of Dental Sciences and Research, Kalaburagi, Karnataka, India.

[6]Dr. Bhavani Aspalli, Post graduate student, Department of Orthodontics and Dentofacial Orthopedics, H.K.E's S. N Institute of Dental Sciences and Research, Kalaburagi, Karnataka, India.

Corresponding Author: Dr. Muhammed Faseehuddin, Post graduate student, Department of Orthodontics and Dentofacial Orthopedics, H.K.E's S. N Institute of Dental Sciences and Research, Kalaburagi, Karnataka, India.

Citation of this Article: Dr. Sudha R. Halkai, Dr. Muhammed Faseehuddin, Dr. Vishwanath Patil, Dr. Basanagouda C. Patil, Dr. Anamika Jha, Dr. Bhavani Aspalli, "Nanoparticles for The Reduction in Frictional Resistance During Sliding Mechanics in Fixed Orthodontic Therapy", IJDSIR- March - 2022, Vol. – 5, Issue - 2, P. No. 264 – 271.

Type of Publication: Original Research Article

Conflicts of Interest: Nil

Abstract

Aim: The aim of this study is to estimate the extent of frictional resistance of Zinc Oxide (ZnO) nanoparticles coating on the orthodontic wires and ceramic brackets with metal inserts using in vitro method.

Objectives of the study: 1. To coat the stainless-steel arch wires and ceramic brackets with metal slots with ZnO nanoparticles. 2. To check the presence of ZnO nanoparticles coating on the surface of stainless-steel wires and ceramic brackets with metal inserts using SEM analysis. 3. To subject the coated arch wires and brackets to frictional resistance test using a universal testing machine.

Materials & Methods: 0.22 slot MBT Ceramic brackets with metal slots and 19x25 SS wires were coated with ZnO nanoparticles using an ultrasonicator. Coated and uncoated wires and brackets were evaluated under SEM for confirming the deposition of nanoparticles. Coated wires and brackets were subjected to frictional test using a UTM to compare the frictional resistance of different groups. Statistical tests were done to evaluate the results.

Results: Mean friction resistance in Group A1 was found to be 2.18±0.76N, in Group A2 it was found to be 1.86±0.53 N, in Group B1 it was found to be 1.79±0.85 N and in Group B2 it was found to be 1.76±0.79 N.

Conclusion: The frictional resistance was found to be the lowest for the coated stainless-steel wires and coated brackets. Uncoated wires and brackets appeared to be the smoothest among the test samples. Nanoparticle coating makes the surface irregular. The material used for nanoparticle coating has a high impact on the frictional properties of the coated arch wires. Zinc oxide nano particle coating is an effective method to reduce friction.

Keywords: Arch wires, Ceramic brackets with metal slots, Friction, Nanoparticles.

Introduction

Orthodontists have to contend with mechanical problems that resist every procedure used to move teeth. This resistance that influences the force that's transmitted to the tooth is called Resistance to sliding. When straight wire mechanics are utilized in orthodontics, the resistance to sliding generated at the wire-bracket interface greatly influences the character of the force transmitted to teeth. This resistance is believed to reduce the effectiveness of orthodontic appliances and hence affect in slower tooth movement.[2]

Friction is the force that retards or resists the relative motion of two objects in contact. As two surfaces in touch slide against one another, two factors of total force arise the frictional force factor (F) and the normal force factor (N) perpendicular to the contacting surfaces and to the frictional force factor. (Fig 1)

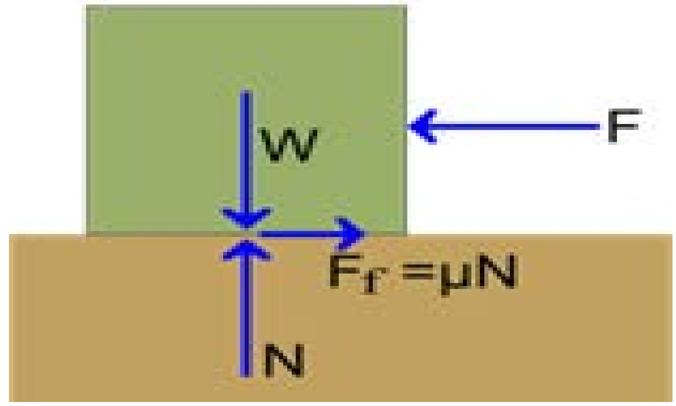

Fig 1: Different components of frictional force.

Among the various factors that affect friction, bracket and arch wire material is an important one. Tooth movement using sliding mechanics involves a dynamic relationship among the archwires, brackets and ligation type.

Frictional characteristics of sliding mechanics and the role of the orthodontic wire alloys in it has been extensively studied, and it has been reported that when compared to the other orthodontic alloys, stainless steel offers the least frictional resistance.[3]

At present the use of ceramic brackets which are more aesthetic than steel brackets is on the increase but these brackets exhibit significantly higher frictional resistance compared to stainless-steel brackets.[4]

Until now, various techniques have been introduced to overcome such a problem, including the use of wires with different sizes and shapes or different chemical compositions and also the use of temporary implants and extraoral forces.[5]

Use of spherical structured nanoparticles as solid lubricants was introduced in 1990s. This technological advancement is considered to decrease friction between metallic surfaces.

The present study was carried out to investigate the effect of depositing ZnO nanoparticles upon ceramic brackets with metal inserts and stainless-steel orthodontic wires on frictional forces between the wires and brackets.

Methodology

We used 19x25” stainless steel straight wires (American Orthodontics) and ceramic brackets with metal slots (Garmy Orthodontics) for the present study.

For evaluating the frictional resistance, samples were divided into groups as follows - GROUP A_1: Uncoated stainless-steel arch wires and brackets, GROUP A_2: Coated stainless-steel arch wires and uncoated ceramic bracket with metal inserts, GROUP B_1: Uncoated stainless-steel arch wires and coated ceramic bracket with metal inserts, GROUP B_2: Coated stainless-steel arch wires and ceramic bracket with metal inserts.

ZnO nanoparticles were immersed in ethanol for 30 minutes in an ultrasonic bath at 30°C then transferred into a water bath at 80°C (Fig 2). The ceramic brackets with metal slots were used as it is from the manufactured packing, whereas the stainless-steel wires were cut into 3” pieces. The nanoparticles were completely dispersed within ethanol then wires and brackets were placed in this solution one by one and kept in the solution for 30mins.

Scanning electron microscope was used to assess the micro morphological characteristics of the archwires and brackets. The average Surface Roughness of the wires was evaluated on the basis of a visual evaluation of the surface irregularities.

Fig 2: Preparation of ZnO nanoparticle bath in ethanol and ultrasonicator

For frictional resistance test the brackets were fixed on a glass plate (3” × 6”) using cyanoacrylate adhesive. The wires were ligated on the brackets with elastomeric modules, Universal testing machine was used for pulling wires and creating sliding movements between the wires and brackets under a 150-g weight. To simulate the oral conditions, artificial saliva was poured on the wire bracket assembly every 3 seconds by a dropper. (Fig 3)

Fig 3: Frictional resistance test setup

Results

Mean friction resistance in Group A1 was found to be 2.18 ± 0.76N, in Group A2 it was found to be 1.86 ± 0.53 N, in Group B1 it was found to be 1.79 ± 0.85 N and in Group B2 it was found to be 1.76 ± 0.79 N (Table 1). Differences were seen in the friction resistance when Group A1 was compared with Group A2, B2 and B1, also when Group A2 was compared with B2 and B1, when group B2 was compared with B1 as p > 0.05 when compared Tukey's test (Fig 4).

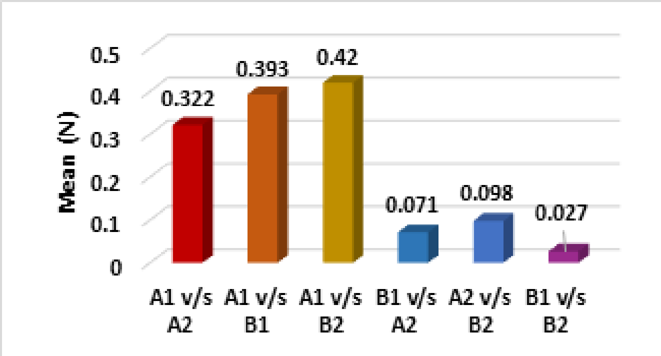

Fig 4: Pairwise comparison of friction resistance.

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Group A1	20	2.1850	.76519	.17110	1.8269	2.5431	1.05	3.34
Group A2	20	1.8630	.53186	.11893	1.6141	2.1119	.90	2.63
Group B1	20	1.7920	.85597	.19140	1.3914	2.1926	.60	3.46
Group B2	20	1.7650	.79399	.17754	1.3934	2.1366	.60	3.23

Table 1: Mean Friction resistance among study groups.

Discussion

Tooth movement is a critical part of orthodontic treatment. Sliding the tooth on an orthodontic wire is one of the ways in this context, with advantages including a reduction in chair time, patient comfort and 3-dimensional control of tooth movements. On the other hand, one of the major disadvantages of this approach is the wire- bracket friction, needing application of high forces to overcome it, which endangers the anchorage.1 To overcome such a problem, the applied force should increase up to 40–60% of the initial force. On the other hand, any increase in the amount of applied force increases the risk of anchorage loss, which is an unfavorable event in orthodontic treatment.

ZnO has been used as a biocompatible material in many areas of dentistry. Studies have shown that ZnO

After application of forces on the tooth, tipping movements commence, creating an angle between the bracket and the wire. When such an angle reaches a verge, a contact is created between the wire and bracket interface, causing adherence between metallic surfaces. Also, the wire little by little undergoes notching and plastic de-formation. All these phenomena, in turn, avert continuous tooth movements, leading to recurrent halts in tooth movement. 6

nanoparticles coating on stainless steel wires and brackets reduced the friction during sliding mechanics.[8]

The SEM results in our study showed that the surface of Group A1 (uncoated) generally appeared smooth (Fig 5-7) and this uncoated arch wire's SEM images looks comparable to the previous studies. Though all samples appear smooth at 100 X magnification, the coated samples generally had a coarse granular, patchy and irregular at 500 X and 2000 X (Fig 6,7). Appearance of coated arch wires look similar to previous studies where nano coating has been done[1, 5, 9, 10].

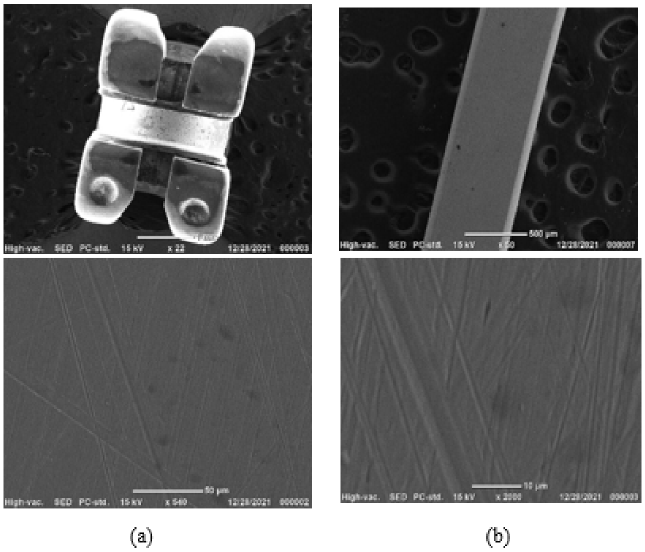

Fig 5: SEM images of uncoated (a) brackets and (b) wires.

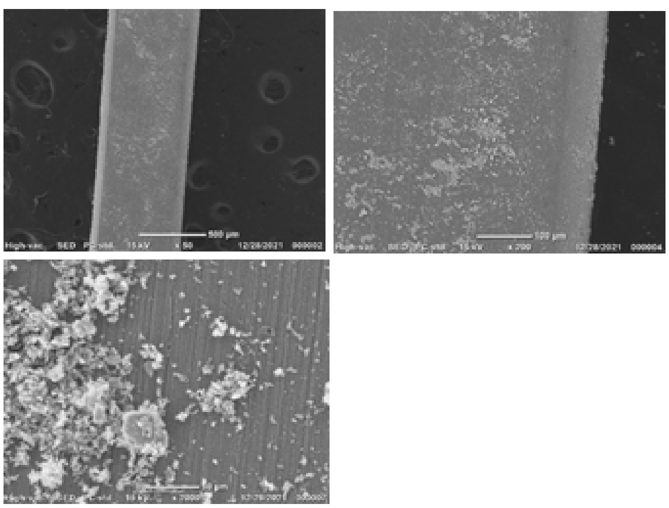

Fig 6: SEM images coated wires.

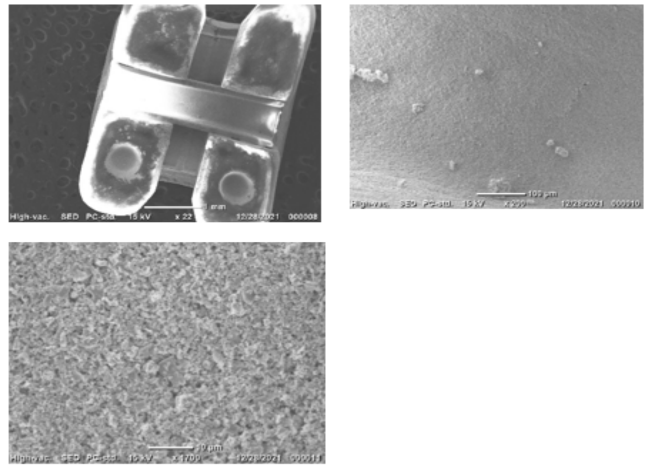

Fig 7: SEM images coated brackets.

We should note that SEM is a qualitative study and a true surface roughness cannot be studied by SEM, and the true surface roughness can be studied quantitatively by means of profilometer, hence we must indeed conclude that surface roughness is not directly related to frictional properties of the wire and the material property affects friction more importantly than the surface roughness. But it must also be kept in mind that a smooth surface is preferred clinically, as a rough surface leads to plaque accumulation and poor performance. Considering that ZnO nano particle has shown less friction than the uncoated wires, a thin uniform Zinc oxide nano particle coating may be beneficial for the orthodontist. Because orthodontic treatment is a long-term procedure, it is necessary to evaluate the effects of coated wires over a longer period of time.

The mean static friction is an important parameter of friction, which is the resistance to initiate tooth movement. So, overcoming the static friction is important to initiate the tooth movement during sliding [11-13].

On examination of friction during sliding in our study, the results obtained on mean static friction was showed that there was reduction in friction of coated wires compared to uncoated wires.

The result of our study shows that nanoparticle coated wires Group A2 showed a reduction in frictional resistance when compared with uncoated wire and brackets Group A1. Coated brackets Group B1 showed a better reduction in frictional resistance than coated wires Group A2. The Group B2 had the least of all frictional resistance and was statistically significant from Group A1. So, it could be safely said that ZnO nanoparticle coating of the archwire and brackets lowered the frictional forces encountered during sliding. The results of this study are in agreement with the studies done by Behroozian A et al.[1] and Kachoei M et al. [14, 15]

The Group B1 had lesser frictional resistance than Group A2. So, it can be said that coating the brackets gives a better reduction in frictional forces when compared with only coating the wires.

The Group B2 had the least frictional resistance of all the groups. So, it can be said that coating both the wires and the brackets gives the best results and can be used in the future to make better orthodontic appliances which could benefit in sliding mechanics by reducing the frictional forces.

Conclusion

Friction is a function of multiple factors, and is not necessarily dependent on surface roughness. Sometimes, despite surface coating providing a smoother surface, it narrows the gap between the bracket and arch wire, and thus increases friction. This is why the topic is controversial, and while some studies have found positive correlations between friction and surface quality,[17-20] others have failed to do so.[21-24]

Based on the data from this study it can be concluded that Zinc oxide nano particle coating is an effective method to reduce friction. The study adds up valuable information regarding the importance of choosing an appropriate material for nanoparticle coating. Nanoparticle coatings also have antimicrobial effect. The clinical applications of this study are numerous, like selective coating of arch wires and brackets can be taken up to differentially reinforce anchorage or reduce friction as required in a particular area. Future studies on these aspects can maximize the efficiency of orthodontic treatment.

References

1. Behroozian A, Kachoei M, Khatamian M, Divband B. The effect of ZnO nanoparticle coating on the frictional resistance between orthodontic wires and ceramic brackets. Journal of dental research, dental clinics, dental prospects. 2016;10(2):106.

2. Articolo LC, Kusy RP. Influence of angulation on the resistance to sliding in fixed appliances. American Journal of Orthodontics and Dentofacial Orthopedics. 1999 Jan 1;115(1):39-51.

3. Kapila S, Angolkar PV, Duncanson Jr MG, Nanda RS. Evaluation of friction between edgewise stainless-steel brackets and orthodontic wires of four alloys. American Journal of Orthodontics and Dentofacial Orthopedics. 1990 Aug 1;98(2):117-26.

4. Nanda R, editor. Biomechanics in clinical orthodontics. WB Saunders company; 1996.

5. Thorstenson GA, Kusy RP. Resistance to sliding of self-ligating brackets versus conventional stainless steel twin brackets with second-order angulation in the dry and wet (saliva) states. American Journal of Orthodontics and Dentofacial Orthopedics. 2001 Oct 1;120(4):361-70.

6. Chen WX, Tu JP, Xu ZD, Tenne R, Rosenstveig R, Chen WL, Gan HY. Wear and friction of Ni-P electroless composite coating including inorganic fullerene-WS2 nanoparticles. Advanced Engineering Materials. 2002 Sep 16;4(9):686-90.

7. Angolkar PV, Kapila S, Duncanson Jr MG, Nanda RS. Evaluation of friction between ceramic brackets and orthodontic wires of four alloys. American Journal of Orthodontics and Dentofacial Orthopedics. 1990 Dec 1;98(6):499-506.

8. Kachoei M, Eskandarinejad F, Divband B, Khatamian M. The effect of zinc oxide nanoparticles deposition for friction reduction on orthodontic wires. Dental research journal. 2013 Jul;10(4):499.

9. Ghasemi T, Arash V, Rabiee SM, Rajabnia R, Pourzare A, Rakhshan V. Antimicrobial effect, frictional resistance, and surface roughness of stainless-steel orthodontic brackets coated with nanofilms of silver and titanium oxide: a preliminary study. Microscopy research and technique. 2017 Jun;80(6):599-607.

10. Sugisawa H, Kitaura H, Ueda K, Kimura K, Ishida M, Ochi Y, Kishikawa A, Ogawa S, Takano-Yamamoto T. Corrosion resistance and mechanical properties of titanium nitride plating on orthodontic wires. Dental materials journal. 2018 Mar 26;37(2):286-92.

11. Taylor NG, Ison K. Frictional resistance between orthodontic brackets and archwires in the buccal segments. The Angle Orthodontist. 1996 Jun;66(3):215-22.

12. Pizzoni L, Ravnholt G, Melsen B. Frictional forces related to self-ligating brackets. The European Journal of Orthodontics. 1998 Jun 1;20(3):283-91.

13. Kim Y, Cha JY, Hwang CJ, Yu HS, Tahk SG. Comparison of frictional forces between aesthetic orthodontic coated wires and self-ligation brackets. The Korean Journal of Orthodontics. 2014 Jul 1;44(4):157-67.

14. Kachoei M, Behroozian A. Comparison of friction between ceramic brackets and ZnO nanoparticle coated wires. Iran J orthod. 2010 Dec 1; 5:77-84.

15. Kachoei M, Nourian A, Divband B, Kachoei Z, Shirazi S. Zinc-oxide nanocoating for improvement of the antibacterial and frictional behavior of nickel-titanium alloy. Nanomedicine. 2016 Oct;11(19):2511-27.

16. Doshi UH, Bhad-Patil WA. Static frictional force and surface roughness of various bracket and wire combinations. American Journal of Orthodontics and Dentofacial Orthopedics. 2011 Jan 1;139(1):74-9.

17. Imaia T, Watarib F, Yamagatac S, Kobayashid M, Nagayamae K, Nakamuraf S. Effects of water immersion on mechanical properties of new esthetic orthodontic wire. American journal of orthodontics and dentofacial orthopedics. 1999 Nov 1;116(5):533-8.

18. Talass MF. Optiflex archwire treatment of a skeletal class III open bite. J Clin Orthod. 1992; 26:245-52.

19. Lim KF, Lew KK, Toh SL. Bending stiffness of two aesthetic orthodontic archwires: an in vitro comparative study. Clinical materials. 1994 Jan 1;16(2):63-71.

20. D'Antò V, Rongo R, Ametrano G, Spagnuolo G, Manzo P, Martina R, Paduano S, Valletta R. Evaluation of surface roughness of orthodontic wires by means of atomic force microscopy. The Angle Orthodontist. 2012 Sep;82(5):922-8.

21. Ghafari J. Problems associated with ceramic brackets suggest limiting use to selected teeth. The Angle Orthodontist. 1992 Jun;62(2):145-52.

22. Saunders CR, Kusy RP. Surface topography and frictional characteristics of ceramic brackets. American Journal of Orthodontics and Dentofacial Orthopedics. 1994 Jul 1;106(1):76-87.

23. Chng CK, Foong K, Gandedkar NH, Chan YH, Chew CL. A new esthetic fiber-reinforced polymer composite resin archwire: a comparative atomic force microscope (AFM) and field-emission scanning electron

microscope (FESEM) study. Progress in orthodontics. 2014 Dec;15(1):1-9.

24. Prososki RR, Bagby MD, Erickson LC. Static frictional force and surface roughness of nickel-titanium arch wires. American Journal of Orthodontics and Dentofacial Orthopedics. 1991 Oct 1;100(4):341-8.