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Comparative evaluation of frictional characteristics between nano coated and non coated orthodontic brackets and arch wire configuration-An experimental *in vitro* study

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Abstract

OBJECTIVE: To compare and assess the coefficient of frictional resistance between nano-coated orthodontic brackets and orthodontic archwires with conventional orthodontic brackets and archwires

METHODOLOGY: In this experimental study, 128 samples were divided into 4 groups consisting of 32 orthodontic wires and brackets in each group. The samples were randomly allocated into GROUP A- ZNO nanoparticle coated archwires and brackets, GROUP B ZNO nanoparticle coated bracket and conventional archwire, GROUP C-ZNO nanoparticle coated archwire and conventional bracket, and GROUP D- conventional archwire and bracket after positioning them on special jigs frictional resistance was studied and evaluated. Bon – Ferroni test was used for inter group comparison and one way ANOVA was used for intr-group comparison.

RESULTS: The lowest mean frictional resistance is seen with Group A (nanocoated archwire with nanocoated bracket) N = 0.3401 ± 0.420; and highest with Group D (conventional brackets with conventional archwires) N = 0.8413 ± 0.60. a significant difference in mean frictional resistance was observed between the groups ($P \leq 0.01$). The frictional resistance for the groups was in the following order from lowest to highest: group A < B < C < D.

CONCLUSION: The study showed decreased friction in ZNO nanoparticle coated archwires and brackets than conventional archwires and brackets.

Keywords:

Arch wires, brackets, frictional resistance, Zno nanoparticles

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Introduction

The orthodontic fixed appliance consists of brackets and arch wires. The bracket or archwires slide over each other during the treatment and create friction.[1] This friction between the arch wire and bracket is the main drawback of the sliding technique particularly in extraction cases or spacing cases which takes time for space closure and can tax the anchorage

During space closure orthodontists usually use 19 × 25 stainless steel arch wire, there is a need to apply a higher force of 12% to 60% to overcome friction in space closure,[2] This friction depends on the inert properties of the materials used in manufacturing archwire and bracket, saliva, pellicle formation, deformation of the wire-like notching, the critical angle that the wire has with the bracket.

Minimizing friction will result in reduced levels of the clinically applied orthodontic

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force. Such a reduction might improve both anchorage control and the direction of tooth movement. It can also reduce the risk of apical root resorption and may even shorten the treatment duration.[3]

Various methods to reduce friction like changing the dimension or shape of the wire, using low friction brackets, as well as application of loop mechanics or TADS are being used,[3] further coating the wire and bracket with nanoparticles have proven to reduce friction as economically feasible solution Kachoei *et al*. revealed that there is a reduction in friction by coating the SS wires with ZnO nanoparticles. ZnO nanoparticles exhibit low toxicity and biocompatibility, making them appropriate for biomedical applications.[2,3]

Coating of the arch wires and reduction in friction has been observed in various studies but very few studies have been done on Coating of the bracket and its contribution to reduction of friction.

Hence the objective of this study is to assess the friction by coating the arch wires and brackets with zinc oxide nanoparticles and to determine whether coating either the bracket or the archwire or coating both can produce any significant decrease in frictional resistance.

Material and Method

ZnO nanoparticles particles (30-50 mn) purity (99.9%), MBT metal SS brackets (0.022 × 0.028) slot prescription, and 19 × 25 SS (3M UNITEK) arch wires were coated [Figure 1]

Coating procedure

Straight pieces of 19 × 25 orthodontic SS wires and metal brackets were ultrasonically cleaned with ethanol solution for 10 min at 30°C followed by immersing in a 4 M potassium hydroxide at 100°C for 30 min. This surface treatment enhances the film adhesion by the dissolution of the surface oxides. The wires were placed in the bathtub containing the 100 ml of either ZnO nanoparticle solution for 30 min, then they were removed from the tub and kept in a hanger and the brackets were put in a colander and painted with a solution of nanoparticle, and air-dried for 2 min. Finally, they were placed in a hot air oven at 160°C for 3 min[4] [Figure 2]

A 150 × 3 × 20 mm SS plate jig was prepared on which brackets were bonded with cold cure epoxy resin adhesive [Figure 3]

A total of 128 samples were prepared and orthodontic wires and brackets were coated with zinc oxide nanoparticles the wires and orthodontic brackets will be organized as groups mentioned in Table 1.

Coefficient of friction was measured with a universal testing machine (model 5582, MECMESIN) at a room temperature of 25-degree Celsius in the dry state. Each bracket was tested only once, and each wire specimen was drawn through 1 bracket only, to eliminate the influence of wear.

The bracket-wire Jig was positioned vertically in the universal testing machine [Figure 4]. The 10-N load cell will be calibrated, and the arch wires was drawn through the brackets as the crosshead moves up and down at a rate of 0.5 mm per minute. The resulting frictional force was recorded on a computer in the form of. Peak values in the graphs represent friction. Similarly, friction was measured and recorded on a graph for all bracket and archwire combinations.

Statistical analysis

SPSS software was used to calculate the sample size, A total of 128 samples with 32 samples per group was estimated (α-0.01)

Table 1: Configuration of arch wires and brackets

Groups	Component-1 Brackets	Component-2 Arch wires
A	Nano-coated	Nano-coated
B	Nano-coated	Conventional
C	conventional	Nano-coated
D	conventional	Conventional

Figure 1: Metal bracket MBT and 19 × 25 SS wire

Figure 2: Coating of brackets and wires with ZNO nanoparticles

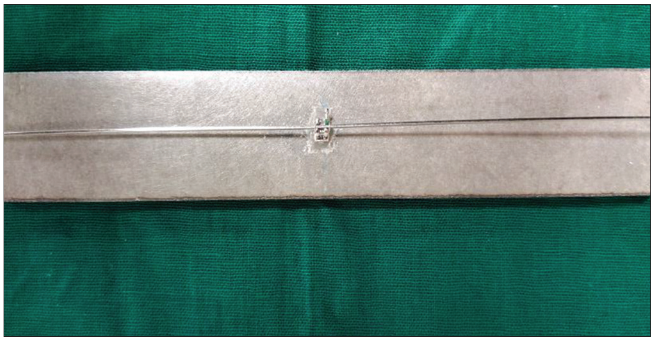

Figure 3: Metal jig

A statistical significance of 0.01 is considered for this research. The cut-off for P from 0.05 to 0.01 specifically for this research because there are 5 research questions followed by 5 research hypotheses. in the wake of multiple hypotheses

BON-FERRONI correction was done for the P value using the following formula

$$\text{Considered (p) cutoff} = \frac{\text{conventional P value} = 0.05 = 0.01}{\text{Number of hypotheses 5}}$$

The data of coefficient of friction so collected from the samples in each group was entered into the spreadsheet of SPSS software and subjected to statistical analysis

ONEWAY ANOVA that is an analysis of variance is used to test whether the difference in surface roughness and coefficient of friction between the groups are statistically significant at ($P \leq 0.01$) provided the data from each group shows a normal distribution.

After doing ANOVA or Kruskalwallis test if the result is statistically significant at ($P \leq 0.01$) appropriate posthoc tests would be done to find out between which groups the difference is statistically significant at ($P \leq 0.01$). (A to B),(B to C),(C to D), (D to A),(A to C),(B to D)

This study is approved by INSTITUTIONAL REVIEW BOARD, (REFERENCE -11-IRB-2021)

Results

The mean frictional resistance values of the groups were determined using descriptive statistics. The coefficient of friction was determined between the interface of groups A, B, C, and D using one-way ANOVA [Table 2] and intergroup comparison have done using the Bon Ferroni *post hoc* test. [Table 3]. P value ≤ 0.01 is considered to be significant. The lowest mean frictional resistance is seen with Group A (nanocoated archwire with nanocoated bracket) N = 0.3401 ± 0.420; and highest with Group D (conventional brackets with conventional arch wires) N = 0.8413 ± 0.60. a significant difference in mean frictional resistance was observed between the groups ($P \leq 0.01$). The frictional resistance for the groups was in the following order from lowest to highest: group A < B < C < D. [Figure 5]

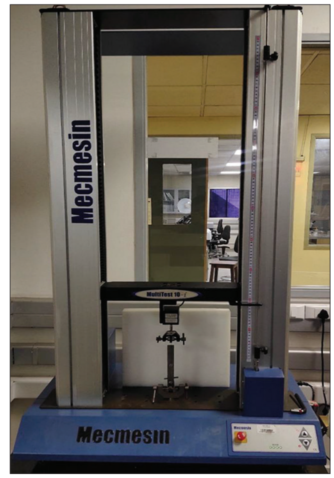

Figure 4: Universal testing machine

Discussion

Friction between wire and bracket depends on several variables, such as bracket width, wire size, and material of bracket and wire, have been investigated and several frictional studies have been published. Nanoparticles have been utilized to coat orthodontic brackets and wires to improve their properties and surface characteristics. According to Rapoport *et al*. and Cizaire *et al*. NP decreases the friction by acting as a spacer and improving the surface topography of the wires. This decreased friction can reduce the side effects of orthodontic treatment and also decreases treatment time.[5-7]

Although many *in vitro* studies were conducted no qualitative analysis was performed. Among the studies included in this review, eight of them reported a significant reduction in the friction of orthodontic arch wires coated with NP.[7-9]

The studies by Redlich *et al*.[10,11] and Samorodnitzky Naveh *et al*.[12] have not mentioned the sample size evaluated, and sample size calculation was also not performed; thus, these studies were assigned a moderate quality of methodology. In the study by Kachoei *et al*.,[9] a moderate quality of evidence was assigned as the study failed to clearly state the statistical significance of the evaluated outcome. In the study by Shah *et al*.,[8] the sample size calculation based on the reference article has been clearly mentioned. In the studies by., Behroozian *et al*., and Kachoei *et al*.[3,4,9] Sample size calculation was

Table 2: Mean frictional resistance values of the groups

Groups	Sample size	Mean frictional resistance (*n*) values (mean±S.D)	Minimum	Maximum	*F*	d.f	*P*
Group A	32	0.3401±0.420	0.0	1.28	4.898	3	0.001**
Group B	32	0.4341±0.480	0.01	1.76			
Group C	32	0.652±0.59	0.11	2.38			
Group D	32	0.8413±0.60	0.10	2.62			

S.D = standard Deviation; d.f = degree of freedom; **= Highly significant (GROUP A shows least frictional resistance

Table 3: Intergroup comparison of frictional resistance using Bon Ferroni test

Group	Comparison	Mean difference	Standard error	*P*
Group A	Group B	-0.09400	0.14371	1.000
	Group C	-0.31259	0.14371	0.189
	Group D	-0.50125*	0.14371	0.004**
Group B	Group A	0.09400	0.14371	1.000
	Group C	-0.21859	0.14371	0.785
	Group D	-0.40725*	0.14371	0.032**
Group C	Group A	0.31259	0.14371	0.189
	Group B	-0.21859	0.14371	0.785
	Group D	-0.18865	0.14371	1.000
Group D	Group A	0.50125*	0.14371	0.004**
	Group B	0.40725*	0.14371	0.032**
	Group C	0.18865	0.14371	1.000

*= mean difference is significant at 0.01 level; **= significant The frictional resistance for the groups was in the following order from lowest to highest: group A<B<C<D

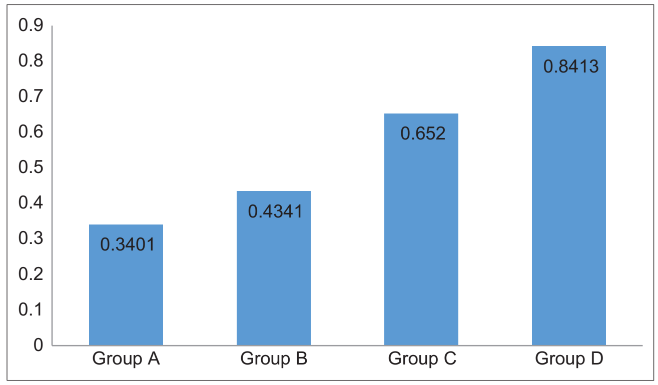

Figure 5: Mean frictional resistance among 4 groups

not performed, but the sample size was mentioned, so it becomes difficult to assess whether the sample size is sufficient or not.

The coating technique used in this study was a sol-gel thin film dipping process, which has advantages like greater structural homogeneity, and high purity that can be obtained at lower temperatures with lower chemical durability. In addition, this technique can be performed in a clinic chairside.

The mechanism of frictional reduction after the deposition of nanoparticles was explained by Rapoport *et al*.[5] and Cizaire *et al*.,[6] when the wire and the bracket slot are parallel to each other, nanoparticles function as a spacer, and friction decreases. Increasing the angle between the wire and the slot increases frictional forces. At this stage some of these nanoparticles become flaked and disintegrated under the application of force and sliding becomes smooth. Further ZnO nanoparticles decrease friction as a mechanism protecting wires against oxidation of metallic surfaces.[3,13]

Among many coatings, ZnO is advantageous the fact that it is biocompatible and tests have not shown any toxicity of ZnO on human cells.[14]

According to a study done by Gandini *et al*.,[15] the metal ligature produces less frictional force than elastomeric ligatures, hence ligature wires are used for ligation in this study.

ZnO nanoparticles when coated with bracket and wire showed a significant decrease in friction (N = 0.3401 ± 0.420 than conventional brackets and wires.

This study has also shown coating just brackets reduces friction than coating only the archwire in contrast to previous studies by Kachoei *et al*.[4] Redlich M *et al*.[11]

Conclusion

This study shows a significant reduction in friction when both bracket and wire are coated with zno nanoparticles.

Limitation

It must be remembered in any *in vitro* study, this investigation cannot reproduce what occurs clinically during orthodontic tooth movement, And the use of artificial saliva negating the oral environment at least must be experimented with before the nanotoxicity study is complete, in upcoming further studies, Evaluating the ceramic brackets by coating with ZnO nanoparticles, self-ligation brackets in comparison with ZNO coated metal brackets and ceramic self-ligation braces is needed.

List of legends

Abbreviation	Expanded form
ANOVA	ANALYSIS OF VARIANCE
MBT	MCLAUGHLIN BENNETT TREVISI
MG	MILLIGRAM
NP	NANOPARTICLE
SS	STAINLESS STEEL
UTM	UNIVERSAL TESTING MACHINE
ZNO2	ZINC OXIDE

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Nil.

Conflicts of interest
There are no conflicts of interest.

References

1. Doshi UH, Bhad-Patil WA. Static frictional force and surface roughness of various bracket and wire combinations. Am J Orthod Dentofacial Orthop 2011;139:74-9.
2. Elhelbawy N, Ellaithy M. Comparative evaluation of stainless-steel wires and brackets coated with nanoparticles of Chitosan or Zinc oxide upon friction: An *in vitro* study. Int Orthod 2021;19:274-80.
3. Kachoei M, Behroozian A. Comparison of friction between ceramic brackets and ZnO nanoparticle coated wires. Iran J Orthod 2010;5:77-84.
4. 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;11:2511-27.
5. Rapoport L, Leshchinsky V, Lapsker I, Volovik Y, Nepomnyashchy O, Lvovsky M, *et al*. Tribological properties of WS2 nanoparticles under mixed lubrication. Wear 2003;255:785-93.
6. Cizaire L, Vacher B, Le Mogne T, Martin JM, Rapoport L, Margolin A, *et al*. Mechanisms of ultra-low friction by hollow inorganic fullerene-like MoS2 nanoparticles. Surf Coat Technol 2002;160:282-7.
7. Maliael MT, Jain RK, Srirengalakshmi M. Effect of nanoparticle coatings on frictional resistance of orthodontic archwires: A systematic review and meta-analysis. World J Dent 2022;13:417–24.
8. Shah PK, Sharma P, Goje SK. Comparative evaluation of frictional resistance of silver-coated stainless steel wires with uncoated stainless steel wires: An *in vitro* study. Contemp Clin Dent 2018;9(Suppl 2):S331.
9. Kachoei M, Divband B, Eskandarinejad F, Khatamian M. Deposition of ZnO nano-particles on stainless steel orthodontic wires by chemical solution method for friction reduction propose. Res J Pharm Biol Chem Sci 2015;6:104–12.
10. Redlich M, Katz A, Rapoport L, Wagner HD, Feldman Y, Tenne R. Improved orthodontic stainless steel wires coated with inorganic fullerene-like nanoparticles of WS (2) impregnated in electroless nickel-phosphorous film. Dent Mater 2008;24:1640–6.
11. Redlich M, Gorodnev A, Feldman Y, Kaplan-Ashiri I, Tenne R, Fleischer N, *et al*. Friction reduction and wear resistance of electro-co-deposited inorganic fullerene-like WS2 coating for improved stainless steel orthodontic wires. J Mater Res 2008;23:2909–15.
12. Samorodnitzky-Naveh GR, Redlich M, Rapoport L, Feldman Y, Tenne R. Inorganic fullerene-like tungsten disulfide nanocoating for friction reduction of nickel–titanium alloys. Nanomedicine (Lond) 2009;4:943–50.
13. Friedman H, Eidelman O, Feldman Y, Moshkovich A, Perfiliev V, Rapoport L, *et al*. Fabrication of self-lubricating cobalt coatings on metal surfaces. Nanotechnology 2007;18:115703.
14. Schilling K, Bradford B, Castelli D, Dufour E, Nash JF, Pape W, *et al*. Human safety review of “nano” titanium dioxide and zinc oxide. Photochem Photobiol Sci 2010;9:495-509.
15. Gandini P, Orsi L, Bertoncini C, Massironi S, Franchi L. *In vitro* frictional forces generated by three different ligation methods. Angle Orthod 2008;78:917-21.