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Mechanical Properties of Nano Coated Niti Arch Wires: An In-Vitro Study

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ABSTRACT:
OBJECTIVE: The aim of the study is to compare and evaluate the effects of ZnO, TiO2, Ag nanoparticles coating on mechanical properties of NiTi arch wires.
MATERIALS AND METHODS: A sample of 60 rectangular NiTi arch wires were taken and divided into 4 groups with uncoated arch wires as control group and the arch wires coated with ZnO, Ag , TiO2 by sol gel dip coating method as study groups, all the groups are assessed for tensile strength, load deflection and friction resistance properties using universal testing machine and the results obtained were statistically analyzed.
RESULTS: ZnO nanoparticle coated arch wires showed significant difference when compared with uncoated and TiO2, Ag coated arch wires
CONCLUSION: Nanoparticle Coating of NiTi wires showed significant improvement in the friction resistance and tensile strength.

1. In the present study ZnO nano-coated arch wires showed a significant decrease in friction, increase in the tensile strength,increase in the load-deflection properties when compared to TiO2, Ag, and uncoated arch wires.
2. It is concluded that ZnO nanocoating is more recommended than TiO2 and Ag coated for better mechanical properties.

KEYWORDS: Frictional resistance, Nanoparticle coating, Silver nanoparticles, Titanium oxide nanoparticles, Tensile strength, ZnO nanoparticles, 3-point bending.

I. INTRODUCTION

Nickel Titanium (NiTi) wires are flexible wires used in orthodontic treatment during initial phase of levelling and alignment .Niti wires have super elastic property , biocompatibility , corrosion resistance and low modulus of elasticity.It delivers light continuous force with wide elastic range of movements when compared with other wires. Disadvantages of NiTi wires include poor formability, high friction resistance and high surface roughness[1]. To overcome these properties, various approaches are laid out. Few commonly used approaches are by modifying the arch wires by ion implantation method and surface treatment of arch wires with nanoparticle coating. For coating the arch wires, various techniques have been introduced, such as electro deposition method, sol gel method, chemical vapor deposition, and physical vapor deposition. The most commonly used method for nanoparticle coating for the arch wires is sol gel dip coating method. Various nanoparticles are :Zinc Oxide ,Silver , Titanium Oxide ,Gold ,Silicon Dioxide ,Copper Oxide , Aluminium Oxide ,Tungsten Disulfide , other materials like Chitosan (Biosynthetic ,Bio-Poly amino saccharide) material can also be used for nanocoating of arch wires. Studies done by Ghasemi et.al[2],Khurana et.al[3] , Math et.al[4] showed that nanocoating of NiTi wires has significantly improved the mechanical, anti-bacterial and surface roughness properties. The aim of the study is to compare and evaluate the effects of ZnO, TiO2, Ag nanoparticles coating on mechanical properties of NiTi arch wires.

II. MATERIALS AND METHODOLOGY

A sample of 60 Rectangular NiTi (0.017×0.025) arch wires of length 8 cm were selected and divided into 4 groups of 15 each as follows; GROUP A: consists of 15 rectangular NiTi arch wires as received by manufacturer (CONTROL GROUP), GROUP B: consists of 15 rectangular NiTi arch wires coated with ZnO nanoparticles, GROUP C: consists of 15 rectangular NiTi arch wires coated with TiO2 nanoparticles, GROUP D: consists of 15 rectangular NiTi arch wires coated with Ag

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nanoparticles. For all the samples nano coating was done by sol gel dip coating method.GROUP A (control group) : Initially uncoated wires are evaluated for the following mechanical properties : tensile strength , frictional resistance, three point bending test using a universal testing machine. After nanocoating, the samples of the test groups were tested for the same mechanical properties .The results obtained were assessed and compared among the groups and subjected for statistical analysis.


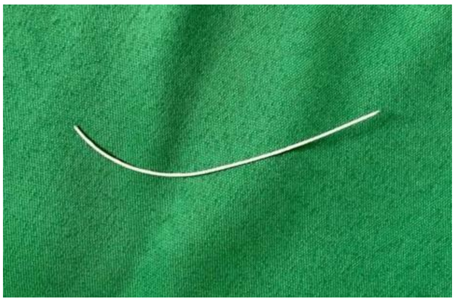

Fig -1 UNCOATED -GROUP A Fig 2 ZnO COATED -GROUP B

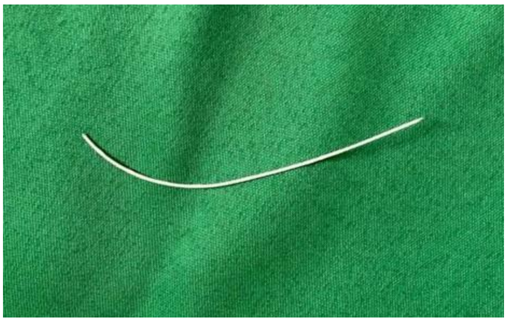
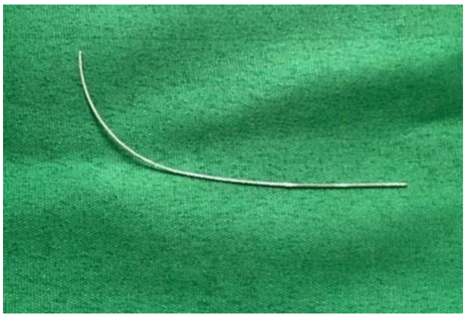

Fig -3 TiO2 COATED – GROUP CFig-4 Ag COATED-GROUP D

Fig -5 UNIVERSAL TESTING MACHINE

Statistical Analysis

The data was statistically analysed in Statistical Package for Social Sciences (SPSS) version 22. One Way ANOVA test was carried out for comparison of groups. The pairwise comparison of groups was done using Tukey’s post hoc test. $P<0.05$ was considered statistically significant.

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III. RESULTS

Table 1:Pairwise Comparison Tensile Strength Between Uncoated And Each Coated Arch Wire By Tukey's Post Hoc Test

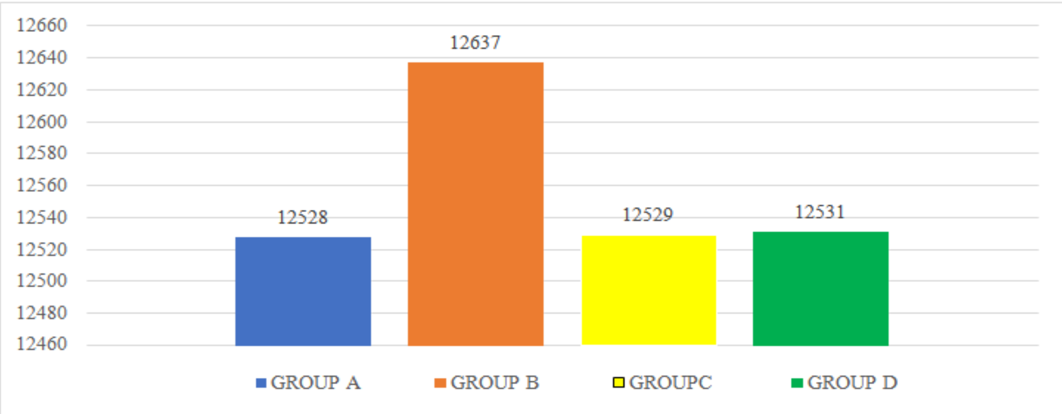
Groups	Mean Difference	Std Error	P value
GROUP A v/s GROUP B	-11.36	0.77	0.000*
GROUP A v/s GROUP C	2.00	0.77	0.065
GROUP A v/s GROUP D	1.36	0.77	0.312

Table 1 shows there is statistically significant difference in between group A and group B .Highest value is found in group B and lowest value is found in group A. the sequence for following groups are group B> group D> group C> group A.

Table 2 :Comparison Of Tensile Strength In Between The Groups By Tukey Post Hoc Test.

GROUPS	Mean Difference	Std Error	P value
GROUP B /s GROUP C	14.71	0.77	0.000* (<0.005)
GROUP B v/s GROUP D	13.40	0.77	0.055
GROUP C v/s GROUP D	-1.6	0.77	0.415

Table 2 shows there is statistically significant difference found between the group B and C. Highest to lowest value for tensile strength among the coated groups as follows: group B> group D> group C .



Graph 1 :Comparison Of Tensile Strength of Coated and Uncoated Groups

Table 3: Comparison Of 3 Point Bending Test Of Uncoated And Each Coated Arch wire By Tukey's Post Hoc Test

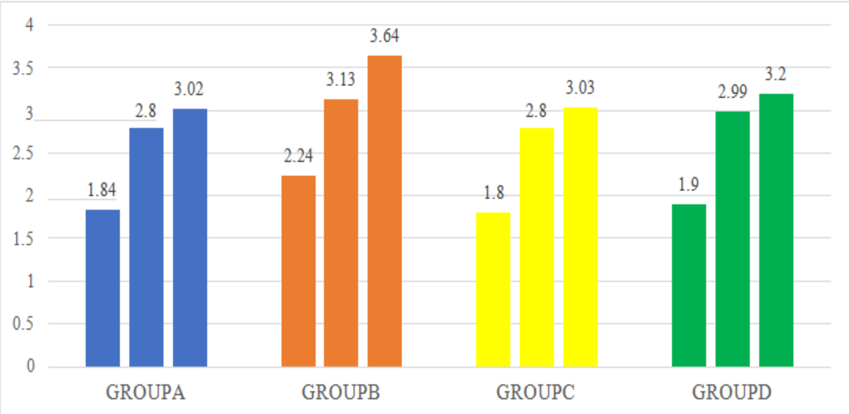
	Groups	Mean difference	Std Error	P value
1 mm	Group A v/s Group B	-0.34	0.047	0.000*
	Group A v/s Group C	0.40	0.047	0.100
	Group A v/s Group D	0.19	0.047	0.091
2 mm	Group A v/s Group B	-0.236	0.039	0.000*
	Group A v/s Group C	0.309	0.039	0.090
	Group A v/s Group D	0.063	0.039	0.380
3 mm	Group A v/s Group B	-0.436	0.042	0.000*
	Group A v/s Group C	0.090	0.042	0.162
	Group A v/s Group D	0.118	0.042	0.151

Table 3 shows there is statistically significant difference in group B when compared with group A at 1mm, 2mm, 3mm.Comparison of 3-point bending test in all the groups from highest to lowest as follows group B> group D > group C> group A.

Table 4 :Comparison Of 3 Point Bending Test Between the Coated Groups by Tukey hoc Test.

	Groups	Mean difference	Std Error	P value
1mm	Group B v/s Group C	0.71	0.047	0.000*
	Group B v/s Group D	0.54	0.047	0.000*
	Group C v/s Group D	0.20	0..047	0.061
2mm	Group B v/s Group C	0.536	0.039	0.000*
	Group B v/s Group D	0.331	0.039	0.000*
	Group C v/s Group D	0.211	0.0039	0.071
3mm	Group B v/s Group C	0.521	0.042	0.000*
	Group B v/s Group D	0.514	0.042	0.000*
	Group C v/s Group D	0.014	0.042	0.791

Table 4 shows there is statistically significant difference in group B with group C and group D at 1mm, 2mm, 3mm .values for 3 point bending test from highest to lowest among the groups as follows group B> group D> group C.



Graph 2 : Comparison Of Three Point Bending Test Between Coated and Uncoated Groups

Table 5: Comparison Of Friction Between Uncoated And Each Coated Groups By Tukeys Post Hoc Test

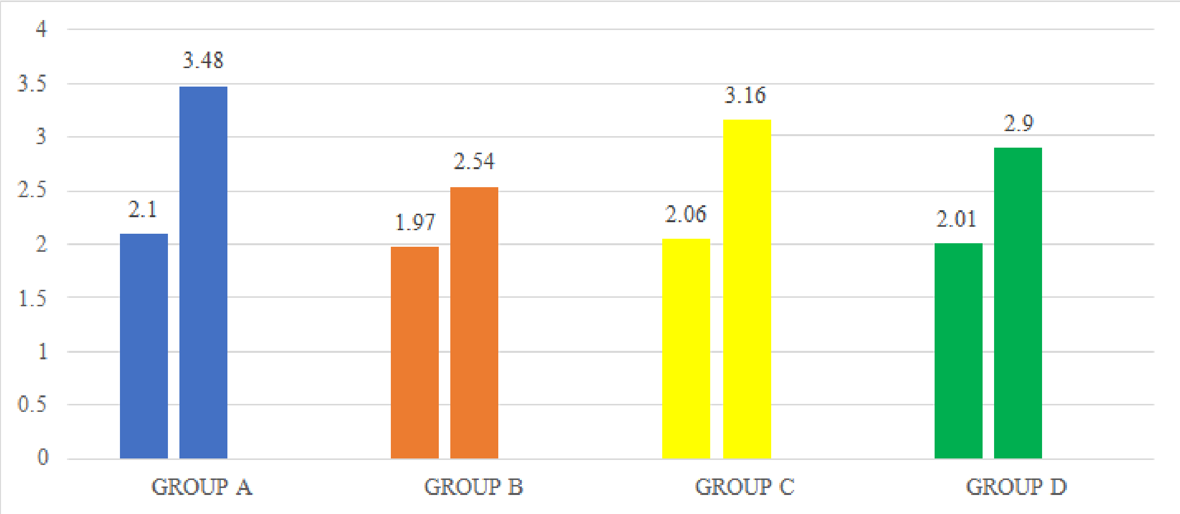
Friction	Groups	Mean difference	Std Error	P value
0	Group A v/s Group B	0.131	0.023	0.000*
	Group A v/s Group C	0.093	0.023	0.071
	Group A v/s Group D	0.049	0.023	0.210
10	Group A v/s Group B	0.942	0.035	0.000*
	Group A v/s Group C	0.326	0.035	0.080
	Group A v/s Group D	0.528	0.035	0.150

Table 5 shows there is statistically significant difference in group B when compared with group A at 0˚ and 10̊,Values for friction resistance as follows : group A > group C> group D> group B.

Table 6: Comparison Of Friction Between the Coated Groups By Tukey's Post Hoc Test

	Groups	Mean difference	Std Error	P value
0 °	Group B v/s Group C	0.041	0.023	0.347
	Group B v/sGroup D	0.094	0.023	0.001*
	Group C v/s Group D	0.049	0.023	0.210
10 °	Group B v/s Group C	0.624	0.035	0.000*
	Group B v/sGroup D	0.397	0.035	0.000*
	Group C v/s Group D	0.212	0.035	0.104

Table 6 shows there is statistically significant difference in group B compared with group A at 0° and 10°,Values for friction resistance as group A > group C> group D> group B.



Graph 3 : Comparison Of Friction Test Between Coated And Uncoated Groups

Table 7 :Comparison Of Frictional Difference At 0° And 10° Between Uncoated And Each Coated Group By Tukey's Post Hoc Test.

Groups	Mean Difference	Std Error	P value
GROUP A v/s GROUP B	0.81	0.77	0.000*
GROUP A v/s GROUP C	0.28	0.77	0.321
GROUP A v/s GROUP D	0.41	0.77	0.065

Table 7 shows there is statistically significant difference in group A and group B. highest value is found in group A and lowest value is found in group B .Highest to lowest value of friction as follows group A> group C> group D> group B.

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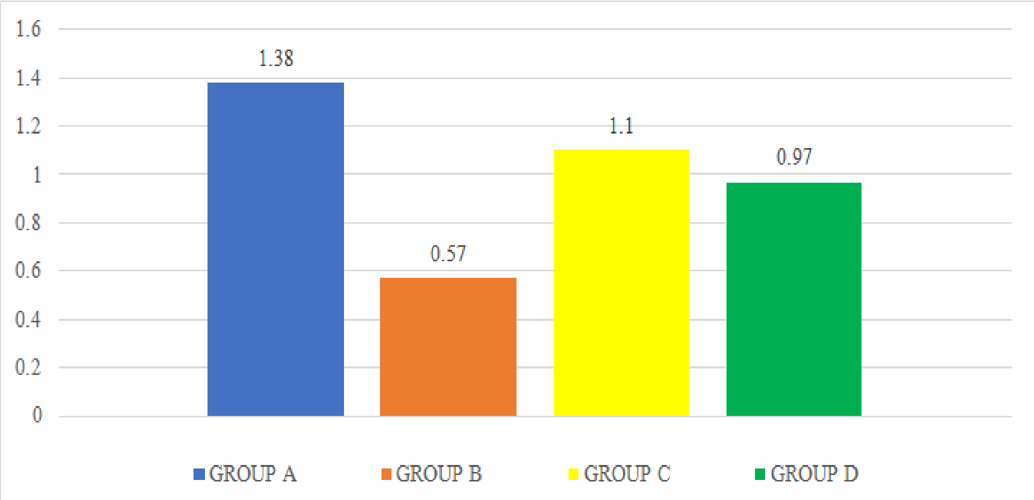
Table 8 : Comparison Of Friction At 0 And 10 Among The Coated Groups By Tukey Post Hoc Test.

GROUPS	Mean Difference	Std Error	P value
GROUP B /s GROUP C	0.53	0.047	0.000*
GROUP B v/s GROUP D	0.45	0.037	0.055
GROUP C v/s GROUP D	0.13	0.07	0.415

table 8 shows there is statistically significant difference found between the group B and C. Highest to lowest value for frictional force at 0˚ and 10˚ among the coated group as follows: group C> group D> group B.



Graph 4 : Comparison Of Frictional Force At 0 And 10

IV. DISCUSSION

In the present study, coating of all the arch wires was done by sol gel dip coating method, as sol gel method has advantages like better homogeneity of structure, higher purity of starting material, sol gels are obtained at low temperatures, control of the porosity and structure of fixed three-dimensional networks of gel nanoparticles according to Bacela et.al[5].It is the novel method of coating the orthodontic arch wires with a uniform and smooth nanoparticle film as mentioned by Syed et.al (2015)[6]. As suggested by previous studies the average particle size and thickness of coating on arch wires using sol gel method was 1-100 nm.In the present study the thickness of coating was 0.25 µm, with particle size of 20-30 nm similar to the study conducted by Karandish et.al[7] where they coated SS wires with ZnO by physical vapour deposition method and obtained a thickness of 0.28 µm. Hammad et.al9 coated NiTi wires with ZnO by chemical deposition method and found that particle size of 40-60 nm obtained >>>>>>>>>.Coating with nanoparticles minimizes the friction between arch wires and brackets and can reduce the required force up to 50%, and significantly fasten the tooth movement , decrease the treatment duration and reduce the risk of apical root resorption. Nanoparticle coating increases the tensile strength and flexural properties of wire by maintaining the structural integrity and resist deformation or breakage, during the orthodontic force application.

Goje et.al[8] (2022) assessed tensile strength and load deflection properties on silver nanoparticle coated NiTi (0.016) wires and found that there is no change in the properties ,but in the present study there is increase in the tensile strength and load deflection properties of ZnO coated arch wires, whereas silver and Tio2 coated arch wires showed no significant difference.

Khurana et.al[9](2022) assessed frictional resistance on silver nanoparticle coated NiTi wires (0.019× 0.025) and found that there is decrease in the friction , in the present study there is decrease in the friction in ZnO coated wires ,where as in silver and TiO2 coated arch wires showed no significant difference.

Karandish et.al[10] (2021) assessed frictional resistance ,tensile strength and load deflection properties on ZnO nanoparticle coated SS wire (0.019× 0.25) and found that there is decrease in friction resistance , and increase in the tensile strength and load deflection properties , In the present study there is decrease in the friction and increase in the load deflection and tensile strength in ZnO coated wires , where as in silver and TiO2 coated arch wires showed no significant difference.>>>>>>>>>>>>

Kachoie et.al[11] (2016) assessed frictional resistance and tensile strength and load deflection properties on ZnO nanoparticle coated NiTi wires(0.016) and found that there is decrease in the friction , no change in the tensile strength and load deflection , in the present study there is decrease in the friction and increase in the tensile strength and load deflection in ZnO coated wires , where as in silver and TiO2 coated arch wires showed no significant difference.

Shah et .al[12] (2018) assessed frictional resistance on silver nanoparticle coated on Stainless steel wires (0.017× 0.025) and found that there in no change in the friction after coating , in the present study there is decrease in the friction in ZnO coated arch wires, where as in silver and TiO2 coated arch wires showed no significant difference.

Hammad et.al[13](2020) assessed frictional resistance on ZnO nanoparticle coated on NiTi wires (0.016 ×0.022) and found that there is decrease in the friction after coating , in the present study there is decrease in the friction in ZnO coated arch wires, where as in silver and TiO2 coated arch wires showed no significant difference.

Palanivel et.al[14] (2022) assessed frictional resistance on ZnO nanoparticle coating on NiTi wires (0.016)and found that there is decrease in friction after coating ,in the present study there is decrease in the friction in ZnO coated arch wires, where as in silver and TiO2 coated arch wires showed no significant difference.

Silveira et.al[15] (2022) assessed frictional resistance on TiO2 nanoparticle coated on SS wires (0.019 ×0.025) and found that there is no change in the friction after coating , in the present study there is decrease in the friction in ZnO coated arch wires, where as in silver and TiO2 coated arch wires showed no significant difference.

Study done by Pinchani et.al[16] ,Gursoy et.al[17] (in vivo study) showed nanoparticle coating on arch wires has few disadvantages such as presence of surface irregularities, leaching of ion particles in animal study.

The present study of nanoparticle coating on arch wires signifies that they can be used as an alternative choice in adult patients with periodontally compromised teeth with poor oral hygiene maintenance.

In the present study, the sol-gel dip coating method was used for coating the arch wires, while other methods like physical vapor deposition, chemical vapor deposition, and electro-deposition were not been tested. The results of present in-vitro study on Mechanical properties on nano coated wires can vary in oral environment as changes in the salivary pH, microbial flora, oral hygiene maintenance, food habits may have an effect. The size of the sample is limited.

Further studies are to be done to evaluate the nanoparticle coating of arch wires for varying thickness ,particle size and surface irregularities ,studies of nanoparticle coating on brackets and stainless-steel wires with different coating procedures has to be assessed.Anti-bacterial and anti-adherent properties of green synthesis coating has to be done. To determine the silver, zinc ,titanium blood levels to estimate the cytotoxicity and contingent side effects of nanocoated metals.

V. CONCLUSION

Nanoparticle Coating of NiTi wires showed significant improvement in the friction resistance and tensile strength.

1. In the present study ZnO nano coated arch wires showed significant decrease in friction , increase in the tensile strength ,increase in the load deflection properties when compared to TiO2 , Ag and uncoated arch wires.
2. It is concluded that ZnO nanocoating is recommended than TiO2 and Ag coated for better mechanical properties.

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