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ORIGINAL ARTICLE

The Effect of ZnO Nanoparticles on Resistance to Sliding of Nickel Titanium Orthodontic Wires

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Abstract

Introduction: NiTi wires which are considered the ideal alloys used during the alignment and leveling stage of comprehensive orthodontic treatment exhibit very high frictional resistance. Therefore, overcoming such resistance to sliding results in a rapid tooth movement and proper anchorage control. Recently, coating the wires with nanoparticles has been introduced to decrease resistance to sliding. The aim of this invitro study was to evaluate effect of ZnO nanoparticles on resistance to sliding of nickel titanium orthodontic wires.

Materials and methods: 40 straight pieces of 0.016-inch NiTi wires were evaluated in two groups with and without spherical ZnO nanoparticle coating, along with 40 standard system 0.018 stainless steel brackets. ZnO nanoparticles were deposited on NiTi wires and analyzed by SEM. A universal testing machine was used to determine friction between the wires and brackets at an angle of 5°. Student’s t-test were used for data analysis.

Results: The SEM results confirmed the homogeneous deposition of ZnO nanoparticles on NiTi wires. At 5º angle between the wires and brackets the means of frictional forces were 1.2475±0.13 and 1.5075±0.12 N with and without ZnO nanoparticle deposits on the wires, respectively, revealing a significant decrease of 17.24% in frictional forces in coated wires ($P<0.001$).

Conclusion: Based on the results of this study, ZnO nanoparticle coating reduces the resistance to sliding of nickel titanium orthodontic wires.

Key words: ZnO nanoparticles, resistance to sliding, NiTi wires, orthodontic brackets.

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Introduction

In order to move teeth, the wire should be able to slide through the bracket; resistance to sliding counteracts this ability of the wire (1). several factors affect Resistance to sliding, including wire and bracket materials (2–6), bracket and wire surface characteristics (4,7), the angle between the wire and bracket slot (8–10), bracket type (11,12) and wire size (13).

Of all the wires, NiTi wires are considered the ideal orthodontic arch-wires for the alignment and leveling stage of comprehensive orthodontic treatment due to their ability to produce a light force in a large range of action (14). However, the principal drawbacks of NiTi wires are their higher friction coefficient and surface roughness, leading to high frictional resistance (2,14). As a result, higher orthodontic forces should be applied to achieve the desired tooth movement and overcome resistance to sliding (15–17). Such excessive forces result in an increased risk of anchorage loss, which is a very important problem in orthodontic treatment; in addition, such forces increase the risk of root resorption(15,18) and lengthen the treatment time(19). To date , several techniques have been proposed to overcome resistance to sliding, including altering the size and shape of the wire, altering the bracket design and coating the wire surfaces with different materials(18). Although some of these techniques have been successful to some extent, no satisfying technique has been introduced for reducing the friction in NiTi wires, necessitating introduction of newer techniques in this regard(10,17,20).

The proper tribologic properties of nanoparticles have been suggested that when an angle is created between the bracket and the wire, resulting in greater resistance to sliding, the nanoparticles are released and function as a solid lubricant on the surfaces, reducing frictional forces (16,21–23).

Redlich et al (2008) evaluated the effect of nanoparticle coating on decreasing frictional forces and reported a significant decrease in friction after coating stainless steel wires with inorganic fullerene-like nanoparticles of tungsten disulfide (WS_2) (16). Samorodnitzky et al (2009) reported a decrease in frictional forces after coating NiTi wires with spherical WS_2 nanoparticles (24).

It is obvious that the biocompatibility of nanoparticles is important for their future use in the clinic. Since the biocompatibility of WS_2 nanoparticles is not certain, it is necessary to use different nanoparticles that are biocompatible such as ZnO nanoparticles(25,26). Therefore, the aim of present study was to determine the effect of coating nickel titanium wires with spherical ZnO nanoparticles on resistance to sliding of the wire.

Material &Methods

In the present *in vitro* study, 40 straight pieces of 0.016-inch NiTi wires were evaluated in two different groups with and without ZnO nanoparticle coatings. In addition, 40 maxillary central incisor stainless steel brackets of the 0.018 standard system (Ultratrimm, Dentaurum, Germany) were used. The friction test was carried out at an angle of 5° between the bracket and the wire to simulate the 2nd-order bends created during alignment and leveling stage of orthodontic treatment.

In order to coat wires with ZnO nanoparticles, the wires were first stored in an ultrasonic bath of ethanol solution for 30 min at 30°C. Then, 0.1 g of ZnO nanoparticles was added to the experimental tube containing ethanol solution and transferred to the water bath at 50°C after mixing. Nanoparticles were evenly distributed in the ethanol solution, followed by immersion of the wires in the solution separately (Figure 1). SEM (scanning electron microscopy) was used to evaluate the adhesion of nanoparticles to the wire and the distribution of the precipitated nanoparticles.

A universal testing machine (Hounsfield Test Equipment, Model H5K, England) was used to evaluate resistance to sliding. First the bracket was fixed in a precise position on the aluminum plate using cyanoacrylate glue. The hole on each side of the aluminum plate provided in a manner that aluminum plate could be adjusted by the screw to the special device designed for bracket holding to create angle of 5 degree. Then the bracket holding device was fixed on the base of the universal testing machine (Figure 2). The upper end of each NiTi wire was inserted in to a tension load cell of the universal testing machine, with the lower end being connected to a 150-g weight. The orthodontic wires were engaged to the brackets using the elastomers (American Orthodontics Company). The wires were pulled through the bracket at a strain rate of 0.5 mm/s for 25 seconds under the adjusted angle and the force was measured by the universal testing machine(20). The brackets and the wires were replaced after each sliding to provide an identical condition for all the samples.

The means, standard deviations and standard errors of the frictional forces were evaluated. Student's t-test was used for two-group comparisons of frictional forces based on nanoparticle coating status.

Figure1.deposition of zno nanoparticles on nickel titanium orthodontic wires.

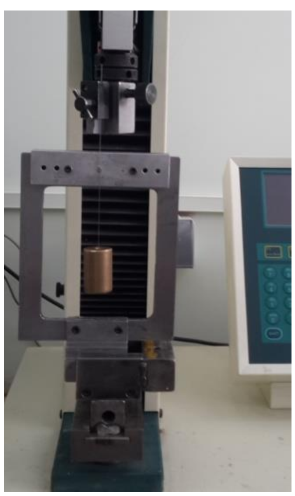
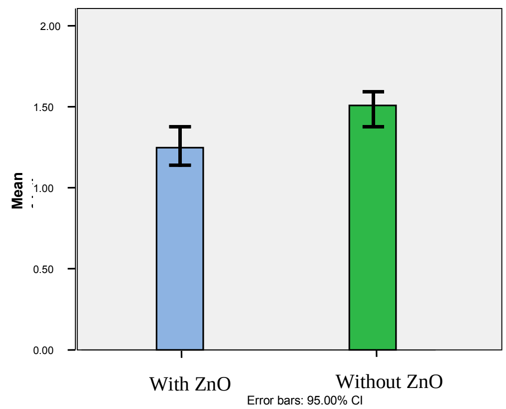


Figure2. assessment of friction by means of universal testing machine.

Results

Scaning electron microscopic images of sections of NiTi wires coated with ZnO nanoparticles showed a homogeneous layer of nanoparticles on the wires. The wires with nanoparticle deposits were manually bent and the subsequent SEM analysis showed a homogeneous layer of nanoparticle deposits without any damages, cracks or scratches, simulating the effect of second order angulation on the wire.

At 5º angle between the wires and brackets the means of frictional forces were 1.2475±0.13 and 1.5075±0.12 N with and without ZnO nanoparticle deposits on the wires, respectively, revealing a significant decrease of 17.24% in frictional forces in ZnO-coated wires (Student's t-test; P<0.001). (Graph 1).



Graph 1. The means of frictional forces in 0.016-inch wires and 0.018 orthodontic bracket system, with and without ZnO nanoparticle coatings on wires at 5º angle.

At combined coated and uncoated wires of 0.018 bracket system, the means of frictional forces at 5º angle between the wires and brackets were 1.3775±0.18 N.(Table 1).

Table 1. Central distribution parameters (means, standard errors and standard deviations), frictional forces in 0.016-inch wires and 0.018 orthodontic bracket system with and without ZnO nanoparticle coatings on wires at 5º angle

Angulation	ZnO coating	Mean	Std. Deviation	Std. Error
5º	With ZnO	1.2475	.13715	.0307
	Without ZnO	1.5075	.12384	.0277
	Total	1.3775	.18430	.0291

Discussion

Nanoparticles are the first and most important elemental particle with sizes less than 100 nm. The size in case of ZnO nanoparticles is in the range of 10–20 nm. The physical and chemical properties of nano-scale elements are different from those at larger scales(27). Given the theory about a decrease in frictional forces between the orthodontic wires and brackets after coating orthodontic wires with nanoparticles, the present study evaluated the effect of Coating NiTi Wires with Spherical ZnO Nanoparticles on resistance to sliding. The results showed a significant decrease in mean frictional forces in ZnO-coated wires at 5º angle compared to conventional wires without ZnO coating.

In round 0.016-inch wires and orthodontic brackets of the 0.018 system the mean frictional forces with and without nanoparticle coating were 1.2475±0.13 and 1.5075±0.12 N, respectively, indicating a significant decrease of 17.24% in frictional force in nanoparticle-coated wires compared to uncoated wires. Rapoport et al (2003) and Cizire et al (2002) explained the mechanism through which the frictional forces decrease between the wire and the bracket after deposition of nanoparticles on wires as follows (28,29):by increasing the angle between the wire and bracket, resistance to sliding increases consequently. Therefore. It appears that at this stage in coated wires some of the nanoparticles are exfoliated, resulting in dry lubrication along the wire sliding path. In addition, the condensed nanoparticles are gradually dissociated under the force applied and undergo free fracture at interfacial areas. When the nano-sheets are subjected to excessive forces at interfacial areas, sliding occurs in these areas between the thin sheets, and the nanoparticles are flaked. As a result, the coefficient of friction decreases.

Redlich et al (2008) evaluated the decrease in frictional forces between stainless steel orthodontic wires and brackets after precipitating inorganic fullerene-like nanoparticles of tungsten disulfide (WS_2 on wires and showed that after precipitating nanoparticles there was a significant decrease in frictional forces. The frictional forces decreased significantly, with decrease of 46% in 5º angle. In the present study, too, after precipitating nanoparticles on wires the frictional forces deceased but different wires and nanoparticles were used in the present study (16).

Samorodnitzky et al (2009) evaluated the effect of coating NiTi rectangular orthodontic wires with inorganic fullerene-like nanoparticles of tungsten disulfide (WS_2) on reduction of frictional forces. After precipitating the nanoparticles, frictional forces decreased. In the present study, after precipitating ZnO nanoparticles decrease were observed in frictional forces between the brackets and wires (24).

Katz et al (2006) used self-lubricant coating containing fullerene-like WS_2 nanoparticles on stainless steel orthodontic wires at 5º angle between the wires and bracket slots, which resulted in a decrease in friction(30).

In recent research studies, fullerene-like WS_2 nanoparticles have been used, which are different from the ZnO nanoparticles used in the present study; however, their effect on decreasing friction were similar. One of the advantages of ZnO nanoparticles, compared to WS_2, is their biocompatibility and safety for human health.

Frictional forces are a combination of static and kinetic frictional forces, which resist tooth movement and since during the dental alignment and leveling with the use of NiTi wires, the kinetic frictional forces are more important than the static frictional forces(20), in the present study the frictional forces measured were the kinetic frictional force.

Conclusion

Coating NiTi wires with ZnO nanoparticles resulted in a significant decrease in friction at 5º angle between the wires and the brackets. Considering the positive effect of ZnO nanoparticles on decreasing the resistance to sliding, NiTi wires coated with nanoparticles can be used to decrease complications resulted from friction during the first stage of orthodontic treatment, including anchorage loss, a high risk of root resorption and lengthening of treatment time.

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