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# The Optimal Parameter for Coating ZnO Nanoparticle on Orthodontic Molar Tube by Electrophoretic Deposition Method (An Invitro Study)

**Ahmed K. Al-Murshady** [1,*], **Dheaa H. Al-Groosh** [1], **Kamil J. Kadhim** [2]

[1] College of Dentistry, University of Baghdad, Baghdad, Iraq
[2] Al-Mussaib Technical Institute, Al-Furat Al-Awsat Technical University, Al-Najaf, Iraq

## ABSTRACT

The fixed orthodontic appliance may enhance devious pathogens and increase biofilm accumulation around the orthodontic molar tube (OMT) surface, which may cause demineralization of the tooth surface. However, the stainless-steel OMT coated with ZnO nanoparticles may enhance antimicrobial efficacy and reduce biofilm accretion. The study aimed to identify the optimal parameter for coating orthodontic molar tubes with antimicrobial ZnO nanoparticles by the electrophoretic deposition (EPD)cell. 36 orthodontic molar tubes were included in this study. The coating process was carried out using an EPD cell. Various concentrations (7.5, 10, 20, 33) g/L of ZnO nanoparticles suspension were conducted in this study, in addition to multiple times and voltages. After the coating process, the samples were left to dry for 24 hours at room temperature. To confirm the coating and adhesion a qualitative tape test and the Scanning Electron microscope were used to study the morphological, topographical, and surface characteristics and the size of nanoparticles on the surface of the coated OMT. The innovative ZnO nanoparticles exhibit promising antibacterial properties against oral pathogens, leading to a decrease in plaque buildup, which may decrease tooth cavities and gingival irritation through orthodontic treatment. There was an increase in nanoparticle surface adhesion on the orthodontic molar tube surface at 2 mins deposition time while reduced surface adhesion as increased deposing time. The coating process was verified at a currency voltage of 30V, reducing nanoparticle agglomeration. A concentration of 10g/L of ZnO suspension shows the most stable and homogenous suspension.

**Keywords:** Zinc oxide nanoparticles, Orthodontic molar tube, Scanning electron microscopy, Electrophoretic deposition cell.

## 1- INTRODUCTION

Nanomedicine refers to using nanoparticles in healthcare, which has led to a new era in diagnosing and treating human diseases. Nanoparticles abound in nature and are handled

*Corresponding author
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daily; for instance, Titanium dioxide particles are employed as ultraviolet light filters and in coating, cleaning, and impregnating sprays **(Talib et al., 2023)**. Overall, the use of nanotechnology offers considerable potential for enhancing daily living. Nanoparticles are incorporated in dentistry through two major mechanisms: first, the incorporation of nanoparticles (NPs) with dental materials, such as incorporation with dental composite to treat dental hypersensitivity and to optimize the characteristics of bonding agents **(Hailan and Al-Khatieeb, 2019)**; and second, the incorporation of nanoparticles (NPs) with bonding agents and luting cement **(Bhushan and Maini, 2019; Alobiedy et. al, 2019)**. third, covering dental equipment surfaces with nanoparticles (NPs) inhibits microbiological adhesion, similar to the nanoparticle coating of titanium implants **(Kadhem and Al Haidar, 2023; Aldabagh et al., 2023)**. The antibacterial mechanism of nanoparticles is still under question. Still, intriguing evidence suggests that when nanoparticles come into contact with microorganisms, they can pass through the microbial membranes, inhibit metabolic processes, and cause membrane function and shape changes. While inside the cells, these nanoparticles inhibit the production of enzymes, disrupt proteins, induce electrolyte imbalance and oxidative stress, and change gene expression levels **(Xu et al., 2016)**. It has been reported that NP size influences cellular cytotoxicity. For instance, it has been reported that silver nanoparticles with a size of 3 nm are more harmful than those with a size of 25 nm **(Yen et al., 2009)**. This factor requires careful consideration when evaluating nanoparticle content (NP). However, there are several metallic nanoparticles and their oxides with proven antimicrobial properties, such as Titania ($TiO_2$), silver (Ag), gold (Au), silica ($SiO_2$), copper (CuO), and zinc (ZnO), that could be a more effective alternative to antibiotic treatment with less likelihood of bacterial resistance. It was hypothesized that metallic nanoparticles with a diameter of less than 10 nm had increased bactericidal action **(Allaker, 2010; Monteiro et al., 2009)**.

Electrostatic attraction between the positively charged NPs and the microbial cell wall and biomolecules accounts for the increased antibacterial activity of these NPs, which in turn limits or eliminates the development of resistant microorganisms. Direct interaction with the bacterial cell wall and selective targeting of several biomolecules constitute the mechanism of action **(Slavin et al., 2017; Rashid, 2022)**. Furthermore, it is possible to enhance the physical attributes of objects by modifying or manufacturing them using a combination of two or more materials **(Jani and Fatalla, 2022; Mohammed and Hamad, 2021)**. The expeditious advancement of nanotechnology in biological applications has yielded substantial implications for medicine. The field of nanotechnology facilitates the precise manipulation of materials at the nanoscale level, leading to the development of novel instruments to diagnose, monitor, treat, and manage biological systems.

ZnO nanoparticles (ZnO NPs) are a novel form of promising candidate widely used due to their high safety and advantageous physicochemical properties. In addition, ZnO nanoparticles have demonstrated promising biomedical applications due to their biocompatibility, high stability, low cost, and low toxicity **(Moradpoor et al., 2021; Jabbar, 2020)**. When the particle size of ZnO is reduced to the nanometer range, it possesses substantial antimicrobial properties by interacting with the bacterial surface and/or with the bacterial core when it penetrates the cell wall and subsequently exhibiting distinct bactericidal mechanisms. ZnO resists microorganisms effectively by generating reactive oxygen on their surface **(Mirzaei and Darroudi, 2017)**. ZnO NPs have been applied on clear aligners to evaluate the antimicrobial effect of zinc oxide nanoparticles, and there was significant antimicrobial efficacy against S. mutans and less impact on C. albicans **(Anita et al., 2022)**.

Furthermore, it has been effectively incorporated into orthodontic adhesives to enhance the antibacterial properties against cariogenic bacteria **(Hailan and Al-Khatieeb, 2019)**. In addition, it has been used as a coating over porcelain bracket surfaces to reduce the friction in the sliding technique between the brackets and the wire **(Behroozian et al., 2016)**. It was hypothesized that the orthodontic appliance and wire may have harbored dental calculus, biofilm, and pathogens that could lead to periodontal disease and caries **(Kučera et al., 2021)**. Introducing orthodontic brackets and molar tubes can microbiologically alter the oral ecosystem. Some of these changes include an uptick in cariogenic microbes, including Streptococcus mutants and Lactobacillus acidophilus, an increase in plaque buildup, an uptick in Candida albicans colonization, and a downtick in plaque Ph **(Anhoury et al., 2002)**. To the best of the authors' knowledge, no implication has been drawn regarding coating orthodontic molar tubes using electrophoretic deposition (EPD) technology. This in vitro investigation aimed to determine the most influential parameter for applying ZnO nanoparticles onto orthodontic molar tube surfaces using an electrophoretic deposition (EPD) device.

## 2. MATERIAL AND METHODS

The orthodontic molar tube is a tubing length inserted on the buccal surface of the anchor molar instead of an edgewise bracket. The initial buccal tube of an edgewise appliance was a piece of 0.22 0.028". The OMT is used to insert and stabilize the archwire, which is placed horizontally into the tube and is thereby entirely enclosed by the sheath-like construction. Molar tubes may have a round or flat-oval cross-section. They may be bonded directly to the anchor molars or welded to bands cemented to the anchor molars. In this invitro study, 36 orthodontic molar tubes (advance series, orthometric, Brazil) were coated with ZnO NPs in addition to the 7-piece substrate of 316L stainless steel. The OMT surface was coated by an electrophoretic deposition (EPD) method from a suspension of nanoparticles (NPs). After completing the coating procedure, the samples were left to dry for 24 hours at room temperature. To confirm the coating, the OMT samples were weighed before and after coating, using a calibrated microbalance (precise, model 125A, Switzerland), and the Scanning Electron microscope (SEM) was used to study the morphological and topographical surface characteristics and the size of nanoparticles on the surface of the coated orthodontic molar tubes **(Hasan and Alhuwaizi, 2022; Salman, 2018)**

### 2.1 Preparation of Suspension

Preparing the suspension is the step that requires high accuracy when done because of its great importance in achieving the required results. Preparing the aqueous suspensions is an essential phase in the experimental procedure of EPD. Variable suspension concentrations of ZnO NPs (7.5, 10, 20, 33) g/L were prepared to obtain optimal parameters and to be consistent with prior investigations **Table 1**. **(Abdulhussein and Al-Groosh, 2022; Abdulkareem and Abdulateef, 2017; Tanbakuchi et al., 2022)**.
The ZnO NPs suspension was prepared by dissolving 0.5 g/L of chitosan in 1% vol acetic acid. After that, 94% vol ethanol and 5% vol water were introduced to the mixture. The prepared suspension was stirred for 15 minutes at room temperature using a magnetic stirrer. A homogeneous mixture was achieved with a concentration of 7.5, 10g/L of ZnO NPs added to the prepared suspensions. In contrast, in the other concentrations, we could not establish stable and homogeneous suspension due to agglomerations of NPs, which also conform to

the Zeta potential measurement. The mixture of ethanol and water increases the colloidal stability of inorganic particles **(Cordero-Arias et al., 2013)**. The equipped mixtures were stirred for 6 hours, and then the suspensions were ultrasonically dispersed for 30 minutes to disperse particulates and break up delicate aggregates, resulting in a homogenous suspension.

**Table 1.** Shows the different suspension concertation prepared and the optimal concertation.

| Samples | Concertation (g/L) | Optimal Concertation (g/L) |
|---|---|---|
| Sample 1 | 33 | 10 |
| Sample2 | 20 | |
| Sample3 | 10 | |
| Sample4 | 7.5 | |

15 minutes were then spent using a high-energy sonicator (MSE Soniprep150, lab exchange, Germany). pH meter with acetic acid was used to adjust the range of pH value of solutions by using (COND5-tester kit, mess Technik, Germany). To accomplish a uniform dispersion of the particles, they are aged for 24 hours to permit full charging of the dispersed particles and form a stable suspension. The mixtures were then magnetically mixed for 10 minutes to achieve homogeneity before coating. Adjusting the pH of the suspensions to 4-4.5 **(Abdulhussein and Al-Groosh, 2022)**.

### 2.2 Zeta Potential Measurement

It was crucial to assess the stability of the suspension by considering its zeta potential. This tool can enhance the optimization of suspension formulations, accurately predict surface interactions, and optimize the formation of films and coatings. The zeta potential magnitude indicates the level of electrostatic repulsion between neighboring particles within a dispersion, mainly when they carry similar charges. Colloids exhibiting a high zeta potential value, whether negative or positive, are known to possess electrical stabilization, whereas colloids characterized by a low zeta potential are prone to coagulation.

### 2.3 Coating of the Orthodontic Molar Tube

The electrodes utilized in the experiment were orthodontic molar tubes made of stainless steel. To optimize the coating process using the electrophoretic deposition (EPD) technique, Before the application of the coating, the samples underwent a drying process at ambient temperature after being rinsed with ethanol 99.9% and acetone 99.5% in an ultrasonic bath for 15 minutes **Fig. 1 (Abdulhussein and Al-Groosh, 2022; Kaya and Boccaccini, 2017)**.

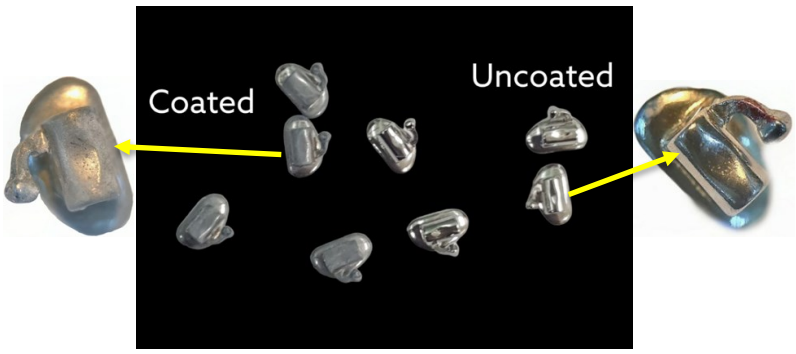


**Figure 1.** Coated & uncoated orthodontic molar tube

### 2.4 Electrophoretic Deposition (EPD) Cell

The electrophoretic deposition (EPD) cell is composed of a glass beaker supplied with a direct current power supply (DC) through two poles where the voltage can be altered according to demand **Fig. 2.** The molar tube samples were set in the EPD cell as the cathode. The anode electrodes were separated by a 10 mm distance **(Abdulhussein and Al-Groosh, 2022)**. Both electrodes were submerged parallel to each other in the suspension inside a 250ml glass beaker **Fig. 2.** To achieve the best deposition parameters, various deposition time and current voltage were processed according to previous studies **Table. 2 (Abdulhussein and Al-Groosh, 2022; Tanbakuchi et al., 2022; Abdulkareem and Abdulateef, 2017; Jaffar et al., 2018; Mohammed et al., 2022)**; a concentration of 10 g/L, deposition time of 2 min, and cell voltage of 30 kV were applied which consistent with the previous study **(Abdulhussein and Al-Groosh, 2022)**.

**Table 2.** The variable samples coating with different deposition times and voltages, and optimal parameter

| Samples | Deposition Time (min) | Voltage (V) | Optimal Parameter |
|---|---|---|---|
| Sample 1 | 1 | 30 | 2 mins 30 V |
| Sample 2 | 2 | 30 | |
| Sample 3 | 5 | 30 | |
| Sample 4 | 5 | 40 | |
| Sample 5 | 10 | 30 | |
| Sample 6 | 30 | 8 | |
| Sample 7 | 30 | 30 | |

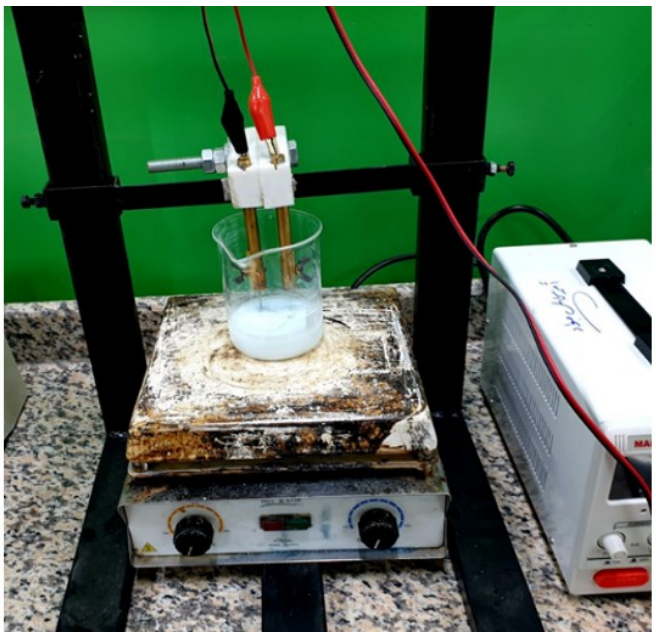

**Figure 2.** Electrophoretic deposition (EPD) cell

### 2.5 Visual Observation

Following the completion of the EPD-coating process, the samples are allowed to dry for a duration of 24 hrs at room temperature to achieve the initial characteristics of the coating layer. Using a Stereo microscope 10x (Bio vision, Hamilton, USA) and Visual observation is a critical and significant measure in assessing the layer quality produced during the EPD operation. Additionally, samples that did not yield satisfactory coating layers were excluded from the basic evaluation process. Meanwhile, progress is made on the samples that are deemed satisfactory.

### 2.6 Qualitative Tape Test

This test was done to evaluate the quality of coating layers, so it was important to investigate the strength adhesion of these layers. Therefore, the method of tape testing was used for this purpose. It was according to ASTM "D 3359-B" standard classification **(AL-Ali et al., 2021)**.

## 3. RESULTS AND DISCUSSION

Preserving oral hygiene has posed a notable difficulty within the realm of fixed orthodontic treatment for an extended duration. This circumstance has led clinicians to pursue alternate methodologies less dependent on patient compliance. Fluoride-releasing materials are appropriate for persons with a heightened vulnerability to dental caries. Unfortunately, these developments are primarily designed for usage in dental clinics, which limits their applicability **(Tavassoli-Hojjati et al., 2012)**. This study aimed to novelty the optimum parameter for a coating of zinc oxide nanoparticles (ZnO NPs) onto stainless-steel orthodontic molar tubes (OMT). As an attractive method for coating dental equipment, the Electrophoretic Deposition (EPD) procedure was applied in this trial. Among the many advantages highlighted by the EPD is the fact that it is possible to achieve a uniform and necessary thickness throughout the outcome layer by adjusting the coating parameters. Furthermore, it is easy to use, along offers setup and implementation freedom, all while being able to be done at room temperature. Moreover, this method offers a price-effective and quick deposition rate allowing the creation of many layers **(Cannio et al., 2021).** The biomedical, dental, ophthalmological, personal health, hygiene, veterinarian, and alcoholic beverage industries are among the most popular using chitosan. This emphasis is probably due to its antibacterial characteristics. As a material, chitosan is typically considered biocompatible, and the FDA has awarded it the GRAS approval **(Morin-Crini et al., 2019)**.
Films can be formed by chelating metal ions, which chitosan can do **(Guibal et al., 2014)**. Coating chitosan nanoparticles with hydroxyapatite is one way to employ them as a binding agent for nanocoating, this substance is applied on titanium micro-implants **(Alhazmi et al., 2022)**. Employing sintering or any other preparatory technique to coat materials is unnecessary when employing chitosan nanoparticles, which is a major advantage **(Heise et al., 2019)**. This matters because sintering can alter stainless steel's desirable characteristics, which are essential for the material to resist occlusal force when retained **(Abdulhussein and Al-Groosh, 2022)**. This invitro analysis confirmed that an optimized set of EPD parameters, a concentration of 10g/L of ZnO NPs, a deposition duration of 2 minutes, and a currency voltage of 30V were sufficient.

### 3.1 Zeta Potential Measurement

Zeta potential measurement was used to characterize the suspension homogeneity. **Fig. 3** shows the zeta potential curve for ZnO NPs with a 10g/L concentration. The zeta potential values for the ZnO NPs suspension were +35. The zeta potential value reflects how stable the suspensions are for ZnO NPs. The data showed that the zeta potential of the 10g/L suspensions of the NPs was +35 for ZnO NPs; that indicates suspension stability that resulted in very good adhesion of the coated layer to the underlying substrate. Additionally, it showed a superior adhesion for ZnO NPs coating, as **(Xiao and Liu, 2006)** claimed that the suspension with higher zeta potential value promotes better coating adhesion.

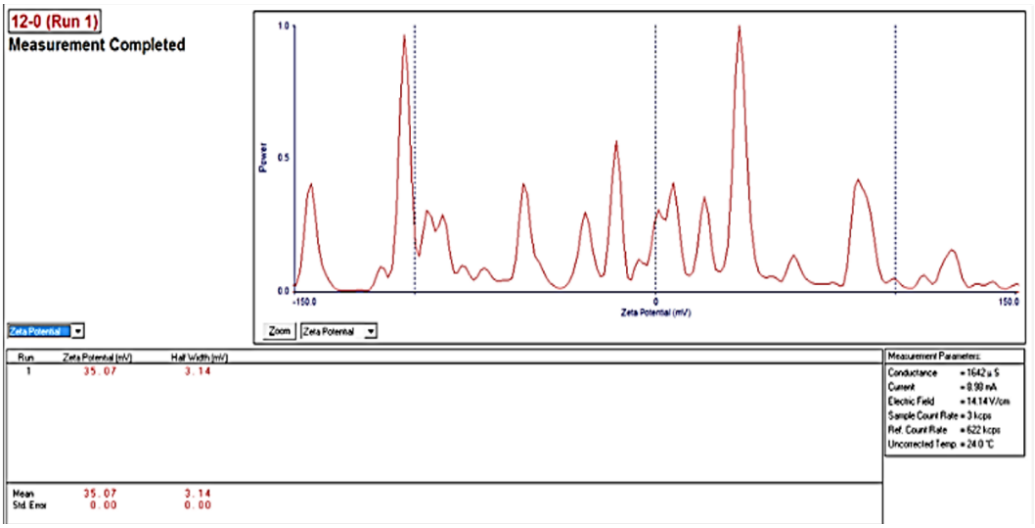


**Figure 3.** The zeta potential value for ZnO NPs 10g/L suspension.

### 3.2 Scan Electron Microscopy and Atomic Force Microscopy of Nanoparticles

The SEM and AFM images of the ZnO nanoparticles are shown in **Figs. 4 and 5**. The ZnO NPs were 20-40nm.

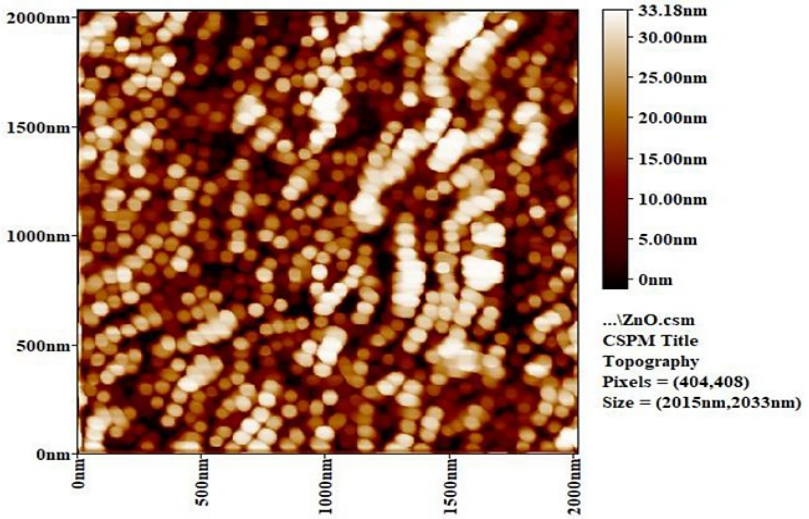


**Figure 4.** AFM of the ZnO nanoparticles

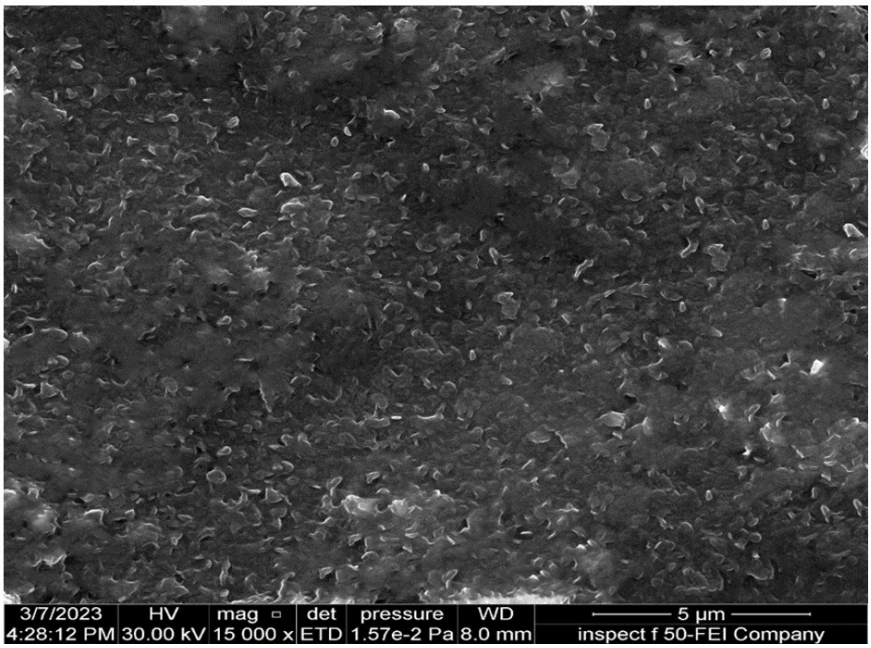


**Figure 5.** SEM of the ZnO nanoparticles

### 3.3 Qualitative Tape Test (Scratch test)

The adhesion failure percentage of the coated layer was qualitatively evaluated using a tape test of the coated samples (7). The calculation of the percentage of the coating layer area that was removed was performed using a scale of 2 mm. **Table. 3** shows the percentage of coating removal area using different concentrations of ZnO NPs and different deposition times. There was a marked reduction in adhesion failure rates with 2-minute deposition times, with a concentration of 10 g/L.

Additionally, there is a positive correlation between the duration of deposition time and the occurrence of adhesion failure rates. The results of the adhesion test conducted on various coatings indicate a decrease in adhesion strength as the voltage and time applied to the coating increase. The results of the adhesion test suggest that the application of a high concentration of nanoparticles (33g/L), regardless of their specific types, and/or the use of high voltage resulted in the formation of a nonhomogeneous coated layer that exhibited poor adhesion and was susceptible to peeling. This finding aligns with the research conducted by **(Abudalazez et al., 2012)**, who posited that this phenomenon can be attributed to the increased agglomeration of nanoparticles in the suspension.

This agglomeration leads to the formation of cracks and alterations in the morphology of the coated surfaces, particularly as the concentration of nanoparticles increases. These results are compatible with a previous study by Abdulhussein and Al-Groosh (**Abdulhussein and Al-Groosh, 2022)** concluded that the optimal parameter for coating stainless steel (SS) substrate with ZnO NPs was (7.5g/L and deposition time of 2 min).

Furthermore, our findings align with the conclusive results of the study conducted by **(Jaffar et al., 2018)**. The founder of the aforementioned thin and uniform coating obtained at 30 V, while at higher voltages, a thicker, non-uniform, and non-adhesive coating is obtained, is unknown. The adhesive coating is achieved through a brief deposition period **(Jaffar et al., 2018)**.

**Table 3.** Qualitative tape test

| ZnO NPS coated Samples | Results of the adhesion test | |
|---|---|---|
| | Classification | Percent Area Removed (%) |
| Sample 1 | 3B | 5-15 |
| Sample 2 | 3B | 5-15 |
| Sample 3 | 1B | 35-65 |
| Sample 4 | 1B | 35-65 |
| Sample 5 | 1B | 35-65 |
| Sample 6 | 0B | >65 |
| Sample 7 | 0B | >65 |

### 3.4 Scanning Electron Microscopy (SEM) with Dispersive X-Ray Spectrometry (EDS) Detector

This technique was used to characterize the surface microstructures and coated layer thickness, in addition to the distribution of different elements of the deposited layer using SEM with EDS detector **Fig. 7.** The SEM images of the ZnO NPs coated samples are shown in **Fig. 6** illustrated the coating layer thickness that was about 6.67 µm. The homogeneity of the surface coating was verified through elemental analysis conducted using scanning electron microscopy (SEM) with energy-dispersive X-ray spectroscopy (EDS). The examination of the substrate surface's composition indicates that the predominant element present is iron (Fe), along with chromium (Cr) and nickel (Ni), alongside trace amounts of other elements **Fig. 8**. The coated sample containing ZnO nanoparticles displayed the presence of Zn and Ni elements, along with Fe and Cr. The elements H, O, and C were also detected, associated with chitosan **Fig. 9**.

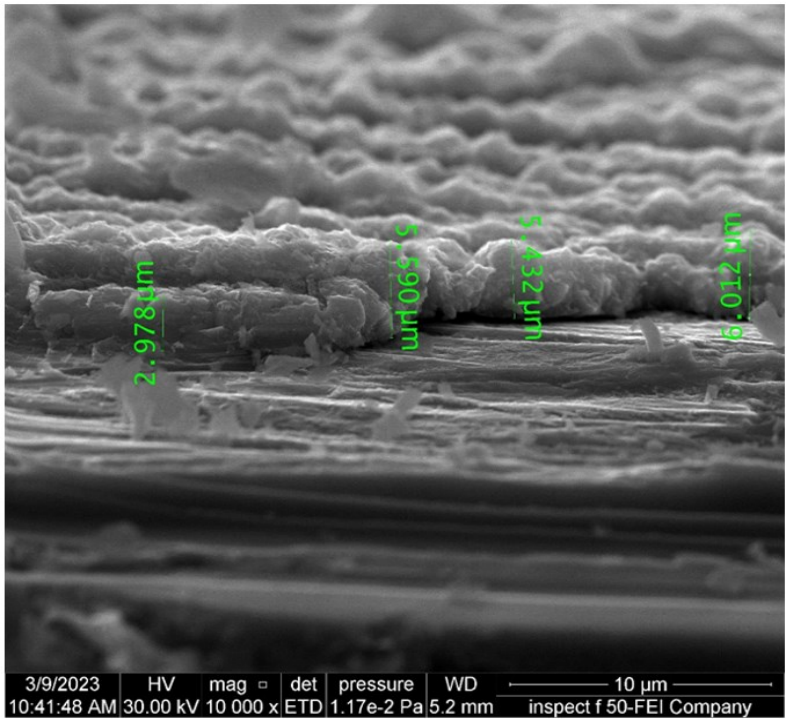


**Figure 6**. SEM of a coated SS 316L sample (cross-sectional view) with 10 g/L at 2 min illustrating coated layer thickness

The elements observed in the analysis were identical to those present in the NPs coating. This observation indicates that the deposited layer exhibits a high degree of homogeneity without any evidence of the formation of new chemical compounds.

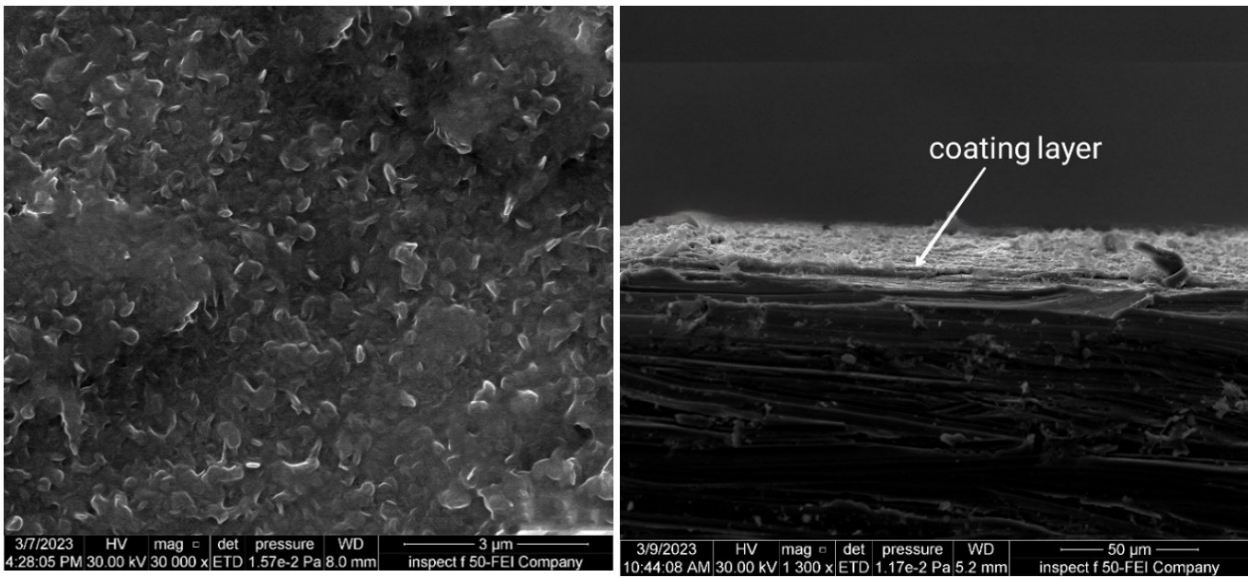


**Figure 7.** SEM of a coated SS 316L sample with 10 g/L at 2 min

3.4.1 Elemental Analysis of OMT

The EDS detector confirmed the chemical composition of the stainless-steel orthodontic molar tube, as seen in **Fig. 8**.

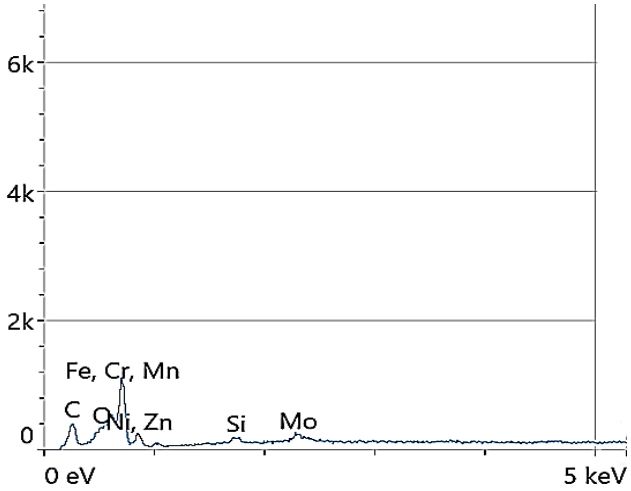


**Figure 8.** Elemental analysis of OMT using SEM with EDS detector.

3.4.2 Elemental analysis of ZnO NPs coating on OMT

The chemical composition of ZnO NPs coating on OMT revealed that the main element was Zn with the premier compositions of the underlying substrates (Fe, Cr, and Ni), in addition to O, which are linked to the binder chitosan polymer **Fig. 9**. The homogenously distributed

ZnO NPs was confirmed by a duplicate assessment of the ZnO NPs coating layer per sample as shown in the EDS mapping analysis. This analysis affirmed the homogeneity and clarity of the coating layer.

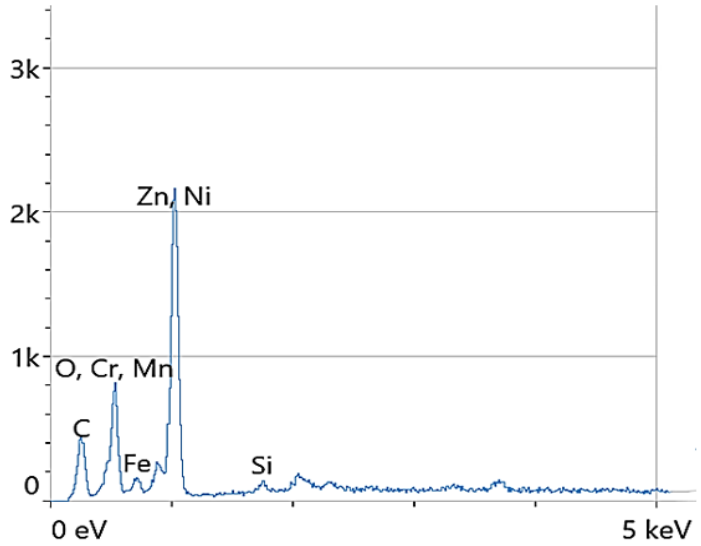


**Figure 9.** Elemental analysis of ZnO NPs coating on OMT using SEM with EDS detector.

Nevertheless, the selection of 30V in conjunction with lower concentrations of ZnO NPs (10g/L) yielded a coating layer that exhibited homogeneity and strong adhesion, as indicated by the low percentage of peeling. This aligns with the findings of **(Jia et al., 2021)**, who asserted that the deposition of a layer on an electrode is a kinetic process, and the rate at which deposits accumulate affects the behavior of the coating layer **(Jia et al., 2021)**. The observed relationship between the process and the applied voltage indicates that the thickness of the coated layer increases in proportion to the applied voltage. However, two potential scenarios may arise upon the application of high voltage. Firstly, there is a possibility that the deposition rate will increase, but at the expense of the quality, ultimately leading to the formation of a porous layer. Furthermore, it is important to note that this phenomenon can potentially lead to an elevation in the level of agitation among the nanoparticles in the suspension **(Abdulkareem and Abdulateef, 2017)**.

As a result, this can lead to an uneven distribution of these nanoparticles on the substrate's surface. As mentioned in an earlier study, the main reason for this uneven deposition is the disruption the suspension particles generate when they pass **(Saxena, 2011)**. Another important finding was that the adherence of the ZnO nanoparticle-coated layer decreased noticeably when the deposition duration was increased. This confirms the concept put out by **(Lau, 2012)**, which states that the deposition rate drops with increasing deposition time. We found a linear association between the deposition rate and the deposition length in the early phase of the deposition procedure. The deposition rate decreases as the deposition time increases.

Conversely, beyond a certain threshold of deposition length, the coating rate tends to approach a steady state value of zero. The observed result can be ascribed to the development of a substantial accumulation of nanoparticles, which functions as a hindrance, impeding the suspension particles from accessing the substrate. As a result, the applied electric field experiences a reduction in strength, impeding the deposition process **(Maciąg et al., 2021)**.

## 4. CONCLUSION

Utilizing the novel Zinc oxide nanoparticles can reduce tooth cavities and gingival irritation for patients throughout the fixed orthodontic treatment. There was an increase in nanoparticle surface adhesion on the orthodontic molar tube surface at 2 mins deposition time while reduced surface adhesion as increased deposing time. The coating process was verified at a currency voltage of 30V, reducing the agglomeration of nanoparticles on the orthodontic molar tube surface and giving a uniform coating thickness layer. A concentration of 10g/L of ZnO NPs suspension shows the most stable and homogenous suspension. Electrophoretic deposition technology might potentially revolutionize the surface treatment of several materials used in dentistry.

## NOMENCLATURE

| Symbol | Description | Symbol | Description |
|---|---|---|---|
| NPs | Nanoparticles | OMT | Orthodontic molar tube |
| EPD cell | Electrophoretic deposition cell | COMT | Coated orthodontic molar tube |
| μm | Micrometer | V | Voltage |
| ZnO | Zinc oxide | SEM | Scanning electron microscopy |
| EDS | Dispersive x-ray spectrometry | AFM | Atomic force microscopy |

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## Credit Authorship Contribution Statement

Ahmed K. Al-Murshady: Writing – original draft, Editing, writing review, Methodology, Experimental endeavors and administration of projects, Investigation. Dheaa H. Al-Groosh: Methodology, design of the work, Supervision, Writing Review, and Editing. Kamil J. Kadhim: Experimental works, design of the work, lab supervision, Writing Review and Editing.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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# المعلمة المثلى لطلاء جسيمات أوكسيد الزنك النانوية على أنبوب الضرس التقويمي بواسطة خلية الترسيب الكهربائي (دراسة مخبرية)

**أحمد كامل جواد[1]*، ضياء حسين عبد عون[1]، كامل جواد كاظم[2]**

[1]كلية طب الأسنان، جامعة بغداد، بغداد، العراق

[2] معهد المسيب التقني، جامعة الفرات الأوسط التقنية، النجف، العراق

**الخلاصة**

قد يؤدي جهاز تقويم الأسنان الثابت إلى تعزيز مسببات الأمراض الملتوية وزيادة تراكم الأغشية الحيوية حول سطح أنبوب الضرس التقويمي لتقويم الأسنان مما قد يتسبب في إزالة المعادن من سطح الأسنان. ومع ذلك، فإن انبوب الضرس التقويمي المصنوعة من الفولاذ المقاوم للصدأ المطلية بجسيمات أوكسيد الزنك النانوية قد يعزز من الفعالية المضادة للميكروبات ويقلل بشكل كبير من تراكم الأغشية الحيوية حول سطح الأنبوب التقويمي. هدفت الدراسة إلى تحديد المتغير الأمثل لتغليف أنبوب الضرس التقويمي بخصائص مضادة للميكروبات لجسيمات أوكسيد الزنك النانوية بواسطة خلية الترسيب الكهربائي. تم تضمين 36 أنبوب تقويمي لتقويم الأسنان في هذه الدراسة. تم تنفيذ عملية الطلاء باستخدام خلية الترسيب الكهربائي. تم أستخدام تراكيز مختلفة في هذه الدراسة (7.5، 10، 20، 33) جرام/لتر من معلق جزيئات أوكسيد الزنك النانوية، بالإضافة إلى أزمنة وجهود مختلفة. تركت العينات لتجف لمدة 24 ساعة في درجة حرارة الغرفة. لتأكيد الطلاء والالتصاق، تم تقييم العينات عن طريق اختبار الشريط النوعي وتم استخدام المجهر الإلكتروني الماسح لدراسة الخصائص السطحية المورفولوجية والطبوغرافية وحجم الجسيمات النانوية على سطح الأنبوب التقويمي المطلي. قد يعاني المرضى الذين يستخدمون أجهزة تقويم الأسنان الثابتة من انخفاض في تجاويف الأسنان وتهيج اللثة من خلال استخدام جزيئات أكسيد الزنك النانوية المبتكرة. كانت هناك زيادة في التصاق سطح الجسيمات النانوية على سطح الأنبوب التقويمي عند زمن ترسيب لمدة دقيقتين بينما انخفض التصاق السطح مع زيادة وقت الترسيب. تم التحقق من عملية الطلاء بجهد عملة يبلغ 30 فولت مما قلل من تكتل الجسيمات النانوية. يُظهر تركيز 10 جم / لتر من معلق الزنك النانوي التعليق الأكثر ثباتًا وتجانسًا.

**الكلمات المفتاحية:** جسيمات أوكسيد الزنك النانوية، أنبوب الضرس التقويمي، المجهر الإلكتروني الماسح، خلية الترسيب الكهربائي.