REVIEW PAPER

A review on the applications of nanotechnology in orthodontics

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ABSTRACT

Objective (s): Nanotechnology has gained importance in recent years due to its ability in the enhancement of materials properties and other specifications such as antimicrobial properties. Nano-sized materials have been applied in various fields of dentistry. Nanotechnology can be employed in orthodontics to enhance the quality of treatment. In the current study, a comprehensive review is carried out on the applications of nanotechnology in orthodontics.

Materials and Methods: In the first step, various databases such as Scopus, Google Scholar and Pubmed were searched by using appropriate keywords for the present study. Afterwards, the related resources were selected to be reviewed. Finally, the key findings of the reviewed studies were represented and summarized.

Results: Based on the reviewed researches, nanotechnology is applicable in various aspects of orthodontics. By using nanotechnology, improved properties in mechanical and medical specifications are achievable. For instance, by using nano coating in archwires, the friction force between components can be reduced and facilitate its motion. In addition, adding some types of nano particles to the composites resulted in improvement in tensile and shear bond strength. Antimicrobial properties of specific nano particles such as silver makes them favorable for reducing microorganisms in orthodontics treatment. Moreover, nanotechnology can be used in nano-identation test to assess the tools employed in orthodontics.

Conclusion: nanotechnology can be broadly employed in orthodontics to achieve better treatment including improved strength of utilized materials, more accurate positioning and reduced microorganisms.

Keywords: *Adhesives, Archwires, Nanorobots, Nanotechnolog, Orthodontics*

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INTRODUCTION

Nanotechnology has wide usage for various medical purposes such as drug delivery, eliminating microorganisms and etc [1–3]. For instance, using nano-based antimicrobial agents can efficiently disinfect root canal of tooth. Employing nanomaterials in devices makes it possible to enhance the mechanical strength and efficiency of the systems [4,5]. Several researches have been carried out on the applications of nanotechnology in different tools and mediums to achieve more efficient and reliable performance [6–8].

Nano-sized materials and instruments have been broadly employed in various medical aspects to achieve better treatment and diagnosis [9]. Ghaziyani et al. [10] conducted a study on CT imaging nano probe and concluded that using this approach is useful for imaging the tumors of the breast. Some nano particles such as gold can be applied in radiotherapy. Zabihzadeh et al[11]. performed a research on using gold nano particles in radiotherapy to eliminate colorectal cancer cells. They observed that using these nano particles can improve radiotherapy performance.

Nanotechnology is applicable in various fields of dental sciences such as orthodontic, endodontic and restorative dentistry [12,13]. Denelon et al. [14]. added sodium trimetaphosphate nanostructures to a fluoride

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toothpaste and analyzed its remineralization influence. Obtained results revealed that adding 3% of the mentioned nano-sized material led to augment in remineralization of the toothpaste. Akbarianrad et al.[15]conducted a review study on the various applications of nanotechnology in the field of endodontics. It was mentioned that nanotechnology can be used as antimicrobial for root canal irrigation, as photosensitizer in photodynamic therapy.

Orthodontic anomaly is among the most common dental problems and its prevalence rate in children is in the range of 39% to 93% [16]which focused on Lithuanian 11–15-year-old schoolchildren, was aimed to describe the frequency of orthodontic anomalies in terms of self-reported complaints about malposed teeth and malocclusion and self-reported use of orthodontic appliances (removable or braces; therefore, it is necessary to find ways to enhance orthodontic treatment. In the current study, several studies on the applications of nanotechnology in orthodontic are reviewed.

The aim of the present article is finding various applications of nanotechnology for improving the orthodontic procedure.

METHODS

In order to cover all the related researches performed on the usage of nanotechnology in orthodontic, a primary search was performed in various databases including Google Scholar, Scopus and Pubmed. The keywords used in the search process were "nanotechnology", "orthodontic", "dental", and "antimicrobial". All the studies conducted between 1990 till 2018 were considered for analysis in this article. Afterwards, the subjects of the resources were analyzed and evaluated. The appropriate resources for the present study (applications of nanotechnology in orthodontic) were selected.

In the next step, the selected resources were studied and their outputs were analyzed. The key findings of the researches were summarized and classified in order to have well-structured study. Finally, the results and important findings of the related resources were extracted and represented here.

The process and conducted activities in each step is illustrated in Fig 1.

RESULTS

As it was mentioned previously, nanotechnology have wide applications in various fields of dentistry including endodontic, periodontics and restorative dentistry. Nano-based materials can be applied for diagnostics, delivery of drugs, dental adhesives and sensors utilized in biosciences [18–20]. The current study focuses on the field of orthodontics and nanotechnology-related aspects.

Archwires

Several studies have been carried on the materials used in orthodontic archwires and

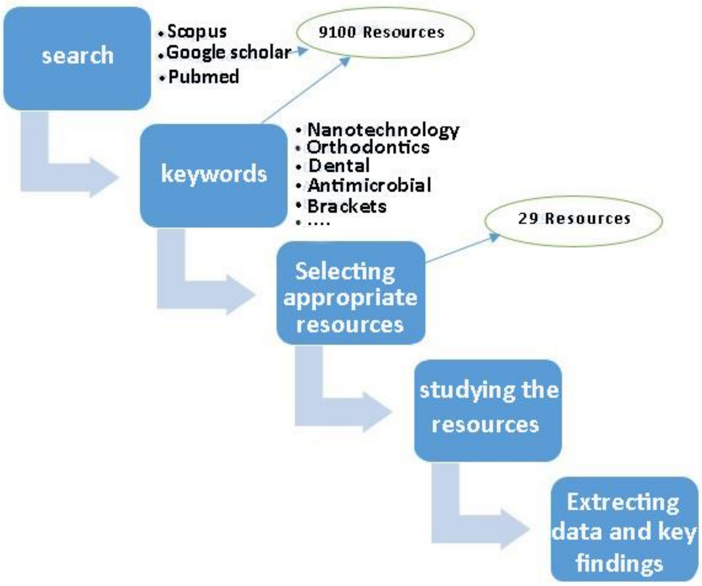

Fig 1. Review procedure[17]

brackets [21–23]. Mechanical and medical characteristics of the archwires gained importance due to their influence on probable allergic issues or corrosion during the treatment [24–26]. Nanotechnology is applicable in these wires to achieve favorable properties [27].

Frictional force against movement of archwires causes some difficulties. In addition, it can lead to dental affliction. By using appropriate lubricants, it is possible to overcome these problems. Nanotechnology has been employed in lubricants to improve their properties. Nano-based lubricants can be used in archwires to facilitate their motion Katz et al [28]. utilized a self-lubrication coating which contained fullerene-like nano-sized particles. Results indicated that employing this lubricant reduced friction, and as a consequence, more favorable movement of archwires was observed. In addition to using lubricants, appropriate coating can result in lower friction against archwires movement. In a study[29], three wires made of stainless steel, nickel-titanium and titanium molybdenum alloy were coated with nanoparticle film (nanoceramics) which was smooth and uniform. It was observed that using the coating can enhance the surface topology; as a consequence, problems related to friction reduced.

Other types of nano particles can be deposited on orthodontic wires to reduce friction force. Kachoei et al [30]. coated ZnOnano particles, in the range 40-45 nm, on orthodontic wires made of stainless steel. It was observed that the existence of nano particles resulted in 51% reduction in friction force between the wires and brackets compared with the reference wires. The decrease in friction was attributed to the nano particles which played role as lubricant.

Adhesives

Nano materials can be used as adhesives in orthodontic in order to achieve higher mechanical strength or reducing the risk of enamel damages [31]. Adhesion strength plays key role in orthodontic and must be taken into account to get reliable treatment [32,33] and subjecting to thermo-cycling. As it was mentioned, using nanotechnology in material can improve the mechanical properties such as shear strength. Chalipa et al. [34]. evaluated the shear bond strength of brackets which were bonded with nano-filled composites. In their study, three composites were applied to bond the brackets. In the first group, Transbond XT as a conventional bond was utilized. Two nano composites including Filtek TM Supreme XT and AELITE Aesthetic Enamel were employed in the second and third groups, respectively. The shear bond stress values for the first, second and third composites were equal to MPa, respectively. Therefore, it can be concluded by using specific types of nano composites, higher shear stress bond is achievable compared with conventional composites. In another study[35], application of nano-sized materials in adhesives used in orthodontic was investigated. Silver and Hydroxyapatitenano particles were added to Transbond XT which was used as adhesive. Three concentrations, 1%, 5% and 10% were evaluated to get better insight into the effect of concentration. Results showed that the shear bond strength for the control group was equal to MPa; while adding the nano particles in 1%, 5% and 10% concentrations changed the shear bond strength to MPa, MPa, and MPa, respectively. Based on the obtained values for the shear strength, it can be concluded there is an optimum concentration of nano particles to achieve the highest strength. Enhancement in strength by using the nano particles was attributed to absorbing the stress by nanofillers which plays as an elastic layer between enamel and composite.

Felemban et al. [36]. utilized a modified type of nano particles in orthodontic adhesive. In their study, nano particles in two concentrations, 0.5% and 1% wt, were added to Transbond XT, 3 M Unitek, Monrovia, USA which is used as adhesive in orthodontic. The results indicated that adding 1% wt of the nano particles to the adhesive resulted in the highest mean compressive, tensile, and shear bond strengths. Comparison between obtained values for each group is represented in Fig 2.

In addition to nano particles, other types of nano structures are applicable in orthodontic treatment. Degrazia et al [37]. investigated various properties of adhesive utilized in orthodontic which contained triclosan-loaded halloysite nanotubes(TCN-HNT). Different mass concentrations of the mentioned nanostructures including 5%, 10% and 20% were added to a resin blend as control group. It was observed that adding (TCN-HNT) led to increase in polymerization specifications without affecting the immediate bonding properties. Moreover, it was concluded that the adhesives with more than 10% concentration of the nanostructures may

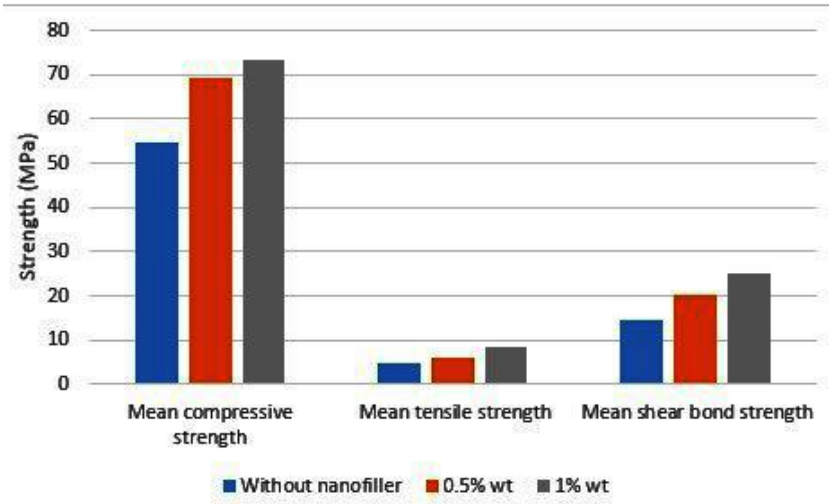

Fig 2. strength values for each group [36]

promote long-term antimicrobial performance.

Antimicrobial agents

Some of the nano-sized material have antimicrobial properties [38–40]. This specification can be useful in orthodontic treatment to reduce caries and the number of microorganisms. In a study performed by Mirhashemi et al. [41]effect of adding Zinc oxide (*ZnO*) and Chitosan (*CS*) nano particles used in dental composite for orthodontic was investigated. Three concentrations of these nano particles mixture including 1%, 5% and 10% (1:1 w/w) were considered in the study. Results revealed that using the composite which contained 10% of nanoparticle led to decrease in the formation of biofilm in comparison with unmodified composite. These results showed the efficient performance of the nano particles in elimination of microorganisms. Other types of nano particles such as can be used in orthodontic treatment due to their specification in improving antimicrobial effect. Poosti et al [42], added 1% (w/w) titanium oxide nano particles to an orthodontic composite paste and evaluated its antimicrobial properties. Bacterial growth (colony count) after curing was equal to and for conventional and nano composites, respectively. Therefore, it can be concluded that using antimicrobial nano particles in composite can reduce the colony count. In addition to the composites used as paste, antimicrobial nano particles can be coated on the orthodontic brackets. In an in vivo research [43], silver nano particles were coated on brackets used in orthodontic. It was observed that adding the nano particles was influential in *S.mutans*inhibition anddecrease in the caries of smooth surface. Other nano particles with antimicrobial properties such as CuO are applicable in orthodontic adhesives to reduce microorganisms. Toodehzaeim et al [44]. added CuO nanoparticles in three mass concentrations, including 0.01%, 0.5% and 1% wt, to composite transbond XT. Results revealed that adding nano particles prevented S. mutans growth. In addition, it was concluded that increase in the concentration of nano particles had favorable influence in antimicrobial performance of the employed adhesives.

Although adding antimicrobial nano particles such as *Ag* increases the elimination of microorganisms, it can causes some problems such as reduction in flexural of materials. In a study [45], *Ag* nano particles were added to two types of acrylic resins including *Selecta Plus* and *Rapid Repair*. The concentrations of nano particles in the utilized acrylic liquids were 0.05% and 0.2%. Based on the observations, adding 0.05% of the nano particles to *Rapid Repair* led to reduction in flexural strength, while in 0.2% concentration, its strength increased and reached approximately to its initial value. On the other hand, adding nano particles increased flexural strength of *Selecta Plus,* but adding 0.05% resulted in more significant increase. It was concluded that changes in flexural strength was dependent on some factors such as acrylic type and concentration of the nano particles. Increase in friction is another problem which can be caused due to utilization of antimicrobial nano particles. Based on a study carried out by Ghasemi et al [46], it was observed that using silver and titanium oxide film on orthodontic brackets can decrease bacterial count; however, nano-titanium oxide film coated on the brackets increased the friction which is unfavorable for orthodontic treatment.

Nano-identation tests

In addition to utilization nano materials, nanotechnology is applicable in other fields of orthodontic. For instance, nano-identation tests can be used to evaluate the mechanical properties of materials used during orthodontic treatment. For instance, Silva et al [47] utilized this type of test to evaluate hardness and modulus of elasticity of coatings used in archwires. Therefore, it can be concluded that using nano-based tests is an appropriate and precise method to assess the mechanical properties of material required for orthodontic. In addition to elastic modulus, nano-identation tests were employed to assess other mechanical properties such as surface roughness [48]hardness and surface roughness of two frequently used orthodontic archwires, namely 0.020in.×0.020in. heat activated (martensitic active. Nano-identation test can be used to evaluate the side effects of orthodontics. For instance, nano-identaton test is applicable to measure fracture roughness of dental enamel and the effects of bonding-debonding of bracket on it [49].

Nanorobots

Nanorobots have different applications in medical sciences. These devices can be employed in hypersensitivity cure, local anesthesia, and etc[50]. In addition to the mentioned applications, nanorobots are usable in orthodontics procedures. The duration of orthodontic treatment can be reduced by using nanorobots. The robots applicable in orthodontic are able to painlessly rotate and vertically reposition the tooth in few minutes while it takes hours by applying conventional methods [51,52]. In addition, nanorobots can directly manipulate parodontal tissues [53] which makes them an appropriate tools for utilization in orthodontic treatment. In Fig 3, the most important applications of nanotechnology in orthodontic are represented.

DISCUSSION

The present review article focused on the researches carried out on the applications of nanotechnology in the field of orthodontic. The most significant outcomes of the reviewed studies were assessed and extracted. According to the literature review, nanotechnology is employed in four main aspects. First of all, nano coating and lubricants, which are employed for reducing friction force against their movements. Decrease in friction, results in faster and easier treatment. In addition to archwires, nano particles can be added to composites and adhesives used in orthodontics to enhance their mechanical properties such as shear bond strength. According to reviewed articles, the type of nano structures and their concentrations are among the most principal factors affecting the mechanical properties of the nano composites. It seems that, studies should focus on finding appropriate types of nano particles and optimum concentration to obtain the most favorable outcomes.

Antimicrobial properties of some nano particles is another useful specification which makes them favorable for utilization in orthodontics. Some types of antimicrobial nano particles such as zinc oxide and silver have been tested during orthodontics treatment and have shown their ability in elimination of microorganisms. Similar to nano particles used for enhancement of

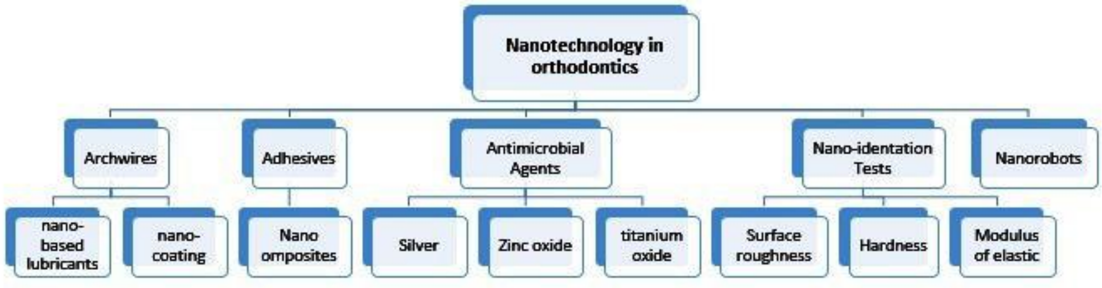

Fig 3. Main applications of nanotechnology in orthodontic

mechanical properties, type and concentration of nano particles play key role in their antimicrobial specifications.

Another application of nanotechnology in orthodontics, is nano-identation test which can be used as undestructive testing approaches to evaluate mechanical properties of tools and mediums employed in orthodontics procedures. In addition to the mentioned applications, nanorobots can be used to facilitate, accelerate and make the orthodontics treatment more accurate.

Future studies should focus on finding more applicable nano materials for utilization in orthodontics. Using nano-based lubricant for archwires, nano particle coating on brackets and nano composites as adhesives are among the most attractive and useful ideas for upcoming studies.

CONCLUSION

Nanotechnology can be used in various steps of orthodontics procedure in order to achieve more favorable treatment. By adding nano particles to the materials employed in orthodontics, their mechanical properties such as shear bonding strength can be enhanced.

For instance, adding nano particles to the adhesives can increase mean shear bond strength from 12.06 MPa to 20.66 MPa. In addition, some types of nano particles such as silver are applicable as antimicrobial agents. Utilizing these nano particles in orthodontics materials can reduce microorganisms. As an example, adding nano particles to an orthodontic composite paste can reduce average colony count from 69.1 t0 8.2. Moreover, nanotechnology has shown acceptable performance in testing properties of orthodontics tools and mediums.

Another application of nanotechnology in orthodontic is nano-identation test to assess the properties of materials, such as surface roughness, used in orthodontic.

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