International Journal of Recent Advances in Multidisciplinary Topics
Volume 3, Issue 1, January 2022
https://www.ijramt.com | ISSN (Online): 2582-7839

Nanotechnology- A Review on Application of Nanotechnology in Orthodontics

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***Abstract*: Nanotechnology in dentistry has evolved since last few years. Nanotechnology is manipulating matter at nanometer level. This concept is applied to the field of dentistry with the term Nano-dentistry. Nanotechnology has been boon to entire field of dentistry. Nano-dentistry is the science and technology of maintaining near-perfect oral health through the use of nanomaterials includes tissue engineering nano-robotics. Nano-sized materials have been used in various fields of dentistry; it is employed in orthodontics to enhance the quality of treatment. This review article provides the most recent and known innovation about the application of nanotechnology in orthodontics and its use in various treatment modalities.**

***Keywords*: Adhesives, archwires, brackets, dentistry, nanotechnology, nanoparticles, nanodentistry, silver nanoparticles.**

1. Introduction

Nanotechnology is defined as the design, characterization and application of structures, devices and systems by controlling shape and size at a nanoscale level (from1nmto 100 nm) [1]. The concept and origin of nanotechnology has been attributed to the American physicist and Nobel Laureate Richard Feynman in the year 1959 [2, 3]. This was made possible by Eric Drexler in the middle of 1980s when he pointed up the potential of molecular nanotechnology [4, 5]. Nanotechnology has been entering in the most scientific communities with increasing vigor over more than two decades. The word "Nano" is derived from the Greek word which means dwarf [6]. The term nanotechnology was coined by N. Taniguchiin 1974 [7]. Nanotechnology is applicable in the various fields of dentistry such as orthodontic, endodontic and restorative dentistry [8, 9].

Nanotechnology can make the clinic procedures simpler and easier, but some authors point out that there are certain limitations relating to the topic of safety [10]. Nanomaterials refer to tiny solid particles with a diameter of 1–100 nm. Nanomaterials are promising in antibacterial therapies because of their enhanced physicochemical properties such as ultra-small sizes, large surface-area-to-mass ratio and increased chemical reactivity [11]. Nano-sized materials and instruments have been broadly used in various medical aspects for better Treatment and diagnosis [12]. Nanomaterial's are used widely in the dentistry. They improve various properties, such as antimicrobial properties and durability of materials. These particles do not exceed100 nm, hence they obtain a better ratio between the surface and mass [13]. Orthodontics is a branch of dentistry which deals with improving the occlusal conditions and aesthetics in children and adults, the orthodontists are the one who is capable to improve the patient's comfort of life [14].

Nanotechnology can be used in brackets, arch wires, elastomeric ligatures and orthodontic adhesives. It improves the microbicidal properties thus reducing friction [13]. Till date, more researches and studies are needed to be carried out for the application of this field as regards dentistry [10]. Some of the nanotechnology application in the dentistry have already been tested and are now being used in various sectors [15].

2. Methodology

A structured literature search for articles written in the English language in PubMed/MEDLINE, EBSCOhost, Google Scholar, Scopus, and Web of Science databases was retrieved by using MeSH terms "Nanotechnology" OR "Nanotechnology in Orthodontics" OR "Nanomaterials in Orthodontics" and Nanotechnology Clinical Study, Clinical trials OR 'All Metadata", Dental, Nanotechnology, Orthodontics, Nanomaterials.

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1) Coated Orthodontic Archwires

Orthodontic treatment consists of an archwire sliding along the brackets; however, this implies that a friction force develops between the surfaces of the archwire and the bracket, which opposes the therapeutic movement of the teeth. For dental movement to happen, the force applied by the orthodontic appliance, has to overcome this resistance. It has been measured that more than 60% of the orthodontic force applied to obtain dental movement is expected to be lost due to frictional forces [16]. When employing sliding mechanics, friction between the archwire and the bracket is one of the primary factors that influences the tooth movement [17]. It is evident that the reduction of friction force would reduce the treatment times and the risk of root resorption, allowing greater control of the movements and the anchorage [16, 18, 19]. The use of nano-particles for reduction of friction has leaded to the development of dry lubricants. Dry lubricants are solid phase materials, they have a capacity to reduce the friction between two surfaces sliding against each other without the use of any liquid media [17]. It was suggested that the best solution is coating of orthodontic archwires with nanoparticles.

The best Nanomaterials for achieving this goal of reducing friction are considered to be MoS2 (molybdenum disulfide) and W2 (tungsten disulfide) [15, 18]. In a study [20], three wires which is made of stainless steel, nickel-titanium and titanium molybdenum alloy were coated with nanoparticle (nanoceramics) which was smooth and uniform. It was seen that using the coating has enhanced the surface topology; as a consequence, problems related to friction reduced.

In other Study Redlich et al [21] coated stainless steel wire with nickel– phosphorous electroless film that was impregnated with inorganic fullerene-like nanoparticles of tungsten disulfide (IF-WS2) by inserting the stainless-steel wires into the electroless solutions of nickel–phosphorus (Ni–P) and tungsten disulfide (IF-WS2). Friction tests simulating archwire functioning of the coated and uncoated wires were carried out by an Instron machine and SEM/EDS analysis of the coated wires gave the clear impregnation of the IF-WS2 nanoparticles in the Ni–P matrix. The friction forces were reduced by up to 54% on the coated wire.

2) Coated Orthodontic Adhesives

Orthodontic adhesives show a higher capacity to retain cariogenic streptococci than the bracket materials [13]. Composite and glass ionomer cements (GIC) are used commonly as an adhesive agent for securing brackets and bands with tooth surface [17]. Nanomaterials can be used as adhesives in orthodontic in order to achieve higher mechanical strength or to reduce the risk of enamel damages [22]. Resin composites containing fillers implanted with silver ions showed an antibacterial property against oral streptococci [23]. The addition of silver nanoparticle shows the reduction in adhesion of cariogenic streptococci to orthodontic adhesive compared to traditional adhesives, without compromising physical properties (shear bond strength) [13].

Chalipa et al. [24] evaluated the shear bond strength of brackets which bonded with nano-filled composites. In that study, three composites were applied to bond the brackets. In the group one, Transbond XT as a conventional bond was utilized. Two nano composites such as FiltekTM, SupremeXT and AELITEA esthetic Enamel were employed in the second and third groups accordingly. The shear bond stress values were equal in the first, second and third composites in relation to MPa. Therefore, by using specific types of nanocomposites, higher shear stress bond can be achieved in comparison with the conventional composites.

3) Orthodontic bands

Fixed orthodontic treatment mostly requires the insertion of dental bands, which are essential for the orthodontic movements. However, these may cause the retention of bacterial plaque [25]. Prolonged accumulation of plaque around the orthodontic brackets and bands has been confirmed to regulate a rapid shift in the bacterial flora, leading acidogenic bacteria such as Streptococcus mutans and Lactobacilli, with the increase in risk of demineralization of enamel, white spot lesions and the cavities [26]. Technology had made it possible by the addition of antimicrobial agents to the dental resins and to the cement for reducing the incidence of white spot lesions and cavities and, also to maintain unchanged the adhesion properties [25]. Antibacterial releasing materials such as Silver nanoparticles which is an antibacterial releasing material helps in maintaining the good oral hygiene during orthodontic treatment [27].

4) Orthodontic Elastomeric ligature

Orthodontic elastomeric ligatures (OEM) are synthetic elastic modules of polyurethane material, their advantages are quicker of application and patient's comfort; they are often a wise solution in clinical practice because they are inexpensive [25]. Ligatures are used for securing the arch wire in the bracket slots during the treatment process [17]. Formerly, it was reported that the ligation along with elastomeric rings has shown a with increased in microbial load while comparing with ligation using steel wires [28]. Nowadays newer methods of ligation have come like self-ligating brackets, but studies says that these innovations are also not risk free. [29]

Elastomeric ligatures can serve as a carrier for delivery of nanoparticles, which is anti-cariogenic, anti-inflammatory and antibiotic drug molecules embedded in the elastomeric matrix. The release of anticariogenic fluoride from elastomeric ligatures has been reported in the literature previously [30,31,32].It has been proposed that elastomeric ligatures are been acting as a support for the delivery of nano particles, which can be molecules with either anticariogenic or anti-inflammatory characteristics and/or antibiotic drugs(such as benzocaine)incorporated into the elastomeric matrix [25]. Incorporation of nanoparticles in elastics has considerable scope in reducing enamel decalcification and oral biofilm accumulation during orthodontic therapy. [17]

It is evident that silver has a superior antibacterial property in comparison with other metals; it has a strong cytotoxic effect on a wide range of microorganisms: even though the mechanism is not very clear; it possibly acts by the action of denaturing the enzymes of the respiratory cycle and by the DNA synthesis. [25]

5) Nanomaterial's in Orthodontics

Friction is one of the major factors during retraction or alignment of teeth. Such action can be overcome by the application of higher forces during treatment with the disadvantage of undesirable anchorage loss [33]. To overcome this disadvantage coating of nanoparticles or addition of nanoparticles becomes the advanced option. To reduce the biofilm formation and benefit the antibacterial properties of the nanoparticles two methods have been used. One method is coating the nanoparticles on the surface of orthodontic brackets or wire [34]. The one more method is, the nanoparticles are combined with orthodontic adhesives or acrylic materials to reduce friction. [35]

6) Silver Nano-Particle

Silver nanoparticles is considered as one of the most effective type of nanoparticles for preventing the growth of Streptococcus mutans [36]. Silver because of its antimicrobial effect, it has been used to treat burns and wounds. The silver nanoparticles when added to orthodontic adhesives it shows a significant reduction in the Streptococci adhesion to the composites.[22]. When Nano-silver was coated to orthodontic brackets, less adherence of plaque was noted, along with the reduction of demineralization and occurrence of white spot lesions [37]. It is proven by many studies, that the addition AgNPs in dentin prevents biofilm formation, together with bacterial inhibition on the dentin surface of teeth. [38,39,40]. Bürgers et al confirms that even a small amount AgNPs have the ability to release more silver ions, which leads to their antimicrobial effect [41].

7) Chitosan

Chitosan is formed by the deacetylation of chitin; it is a naturally acquired polysaccharide [42]. Mirhashemi et al. in a study demonstrated that when Chitosan is added to composite with zinc oxide with a 10% concentration composite has shown a decrease in biofilm formation [22]. The application of chitosan as an antibacterial chemical agent in mouthwashes has been limited because of its reduced solubility nature in water. Even so, its characteristics are highly advantageous in dental materials [13].

8) Copper Oxide

It was proved by Yassaei et al. [43], that there is no significant difference was seen between silver and copper oxide (CuO) nanoparticles, but curing time was increased with the use of copper material while comparing with the silver. Toodehzaeim [46] proven that the addition CuO nanoparticles to Transbond XT in the concentration of 0.01%, 0.55%, and 1% by weight has shown the reduction in the growth of S. mutans, and it was also noted the improved antimicrobial effect with the increasing concentration. CuO is capable of reducing biofilm formation by 70 up to 80% [44]. Similarly, it was seen even when CuO particles were incorporated into adhesive materials [45].

3. Conclusion

The scope of engineering science within the field of orthodontics is limitless, particularly with new progressive fabrication techniques inside one's simple reach. As we tend to skim through the newest literature, we tend to observe the areas wherever nanotechnology is providing promising outcomes, ends up in the sphere of orthodontics starting from enhancements in biomaterials, acceleration techniques for tooth movement to even future attainable applications in the sequence of medical aid that ultimately build treatment procedures easy for the practician and at identical time reasonable for patients. The safety of created nanomaterials will raise queries and there are not much of studies available for strong evidence and that concerns a lot of studies to determine their pharmacology within the oral surroundings. even so as its continually fore mentioned regarding novel nano, 'small is that the next massive thing'.

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