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Nanotechnology in Orthodontics

A graduation project submitted to the Department of Orthodontics- College of Dentistry/ University of Baghdad in Partial fulfillment of the requirements for the degree of Bachelor of Dental Surgery

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بسم الله الرحمن الرحيم

وقل رب زدني علما

صدق الله العظيم

Certification of the Supervisor

I certify that this project entitled The "**Nanotechnology in Orthodontics**" was prepared by **Manar Ali Ahmed (Fifth year undergraduate student)** under my supervision at the College of Dentistry/ University of Baghdad in partial fulfillment of the graduation requirements for the degree of Bachelor of Dental Surgery.

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Dedication

This work is dedicated For my family for the support and encouragement they provided.

Acknowledgment

Before all, be thankful to **Allah** for his supreme greatness and full sovereignty. I would like to express my gratitude to the dean of College of Dentistry University of Baghdad prof. **Dr. Raghad Al-Hashimi.**

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Manar Ali Ahmed

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List of Abbreviations	
AgNPs	silver nanoparticles
CuO	copper oxide
DMAHDM	dimethylaminohexadecyl methacrylate
FTIR	Fourier Transform Infrared Spectroscopy
LUV'S	large unilamellar vesicles
MEMS	Micro electromechanical systems
MPC	methacryloyloxyethyl phosphorylcholine
MWNTS	Multi walled nanotubes
NACP	amorphous calcium phosphate nanoparticles
N-Doped TiO	Nitrogen-Doped Titanium Dioxide
NEMS	Nano electromechanical systems
Nha	nano-hydroxyapatite crystals
NiTi	nickel–titanium
NNI	National Nanotechnology Initiative
OEM	Orthodontic elastomeric ligatures
PMMA	poly-methylmethacrylate
RhBMP-2	recombinant human bone morphogenetic protein-2
SiO2	silicon dioxide
SS	stainless steel wires

SUV‘S	**mall unilamellar vesicles**
SWNTS	**Single walled nanotubes**
TADs	**temporary anchorage devices**
TiO_2	**titanium dioxide**
ZnO	**Zinc Oxide**

Introduction:

Nanotechnology is one of the most promising technologies of the 21st century. It is the ability to convert the nanoscience theory to useful applications by observing, measuring, manipulating, assembling, controlling and manufacturing matter at the nanometer scale. where unique phenomena enable novel applications in a wide range of fields, from chemistry, physics and biology, to medicine, engineering and electronics". **(Allhoff 2007).**

In the field of medicine, these materials have been used for active delivery of bioactive, drug discovery, bioassays, detection, imaging and many more other applications **(Kreuter and Speiser 1976)**. Furthermore, various applications of Nanoparticles (NPs) are used in the field of dentistry. Their chemical and physical properties are based on the metals or the compounds used to prepare the NPs **(Ma et al., 2003; Mcintyre, 2012)**

Similar to other dental disciplines, nanomaterials have its clinical applications in orthodontics. Nanotechnology is used in brackets, archwires, elastomeric ligatures and orthodontic adhesives **(Sharan et al., 2017)..**

Aim of study:

The aim of this review is to describe nanotechnology applications in the field of orthodontics and to highlight the importance of embracement of this relatively modern application in routine orthodontic treatment.

Chapter 1 : Review of literature

1.1 History of Nanoscience and Nanotechnology

The prefix 'nano' is referred to a Greek prefix meaning 'dwarf' or something very small and depicts one thousand millionth of a meter (10^{-9} m). We should distinguish between nanoscience, and nanotechnology. Nanoscience is the study of structures and molecules on the scales of nanometers ranging between 1 and 100 nm, and the technology that utilizes it in practical applications such as devices etc. is called nanotechnology **(Mansoori and Fauzi 2005)**. As a comparison, one must realize that a single human hair is 60,000 nm thickness and the DNA double helix has a radius of 1 nm **(Gnach *et al.* 2015)** (Figure.1).

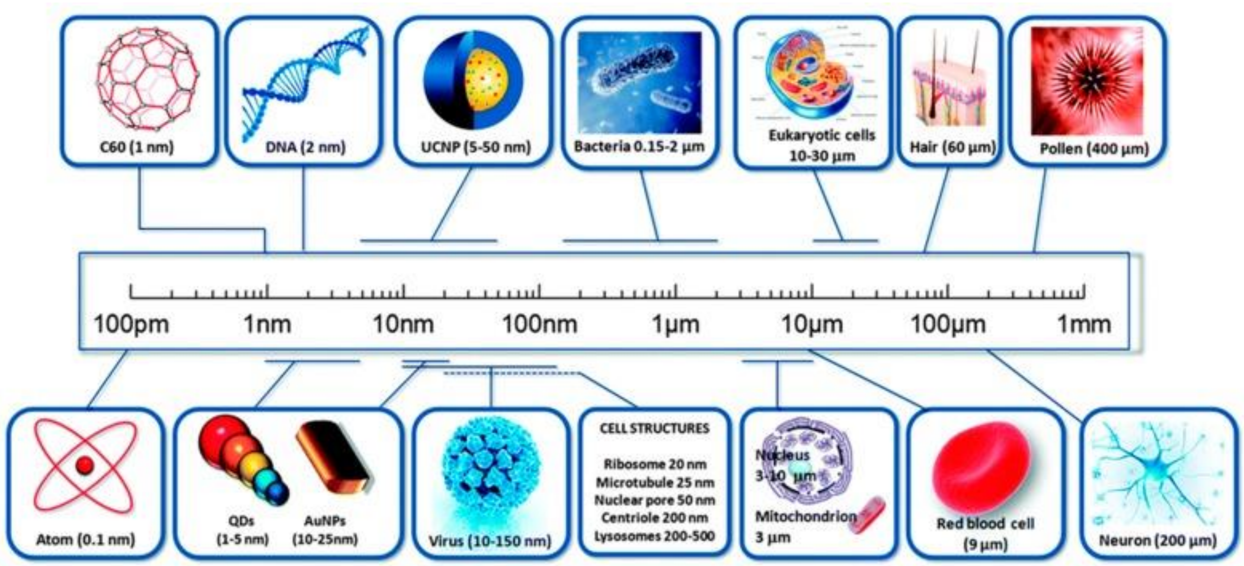

Figure.1 A comparison of sizes of nanomaterial

1.2 The Imaginative Pioneers of Nanotechnology

The American physicist and Nobel Prize laureate Richard Feynman introduce the concept of nanotechnology in 1959. During the annual meeting of the American Physical Society, Feynman presented a lecture entitled "There's Plenty of Room at the Bottom" at the California Institute of Technology (Caltech).. After fifteen years, Norio Taniguchi, a Japanese scientist was the first to use and define the term "nanotechnology" in 1974 as: "nanotechnology mainly consists of the processing of separation, consolidation, and deformation of materials by one atom or one molecule" **(Taniguchi *et al.* 1974)**.

After Feynman had discovered this new field of research catching the interest of many scientists, two approaches have been developed describing the different possibilities for the synthesis of nanostructures. These manufacturing approaches fall under two categories: top-down and bottom-up, which differ in degrees of quality, speed and cost.

The top-down approach is essentially the breaking down of bulk material to get nano-sized particles. This can be achieved by using advanced techniques such as precision engineering and lithography which have been developed and optimized by industry during recent decades **(Iqbal *et al*. 2012).**

The bottom-up approach refers to the build-up of nanostructures from the bottom: atom-by-atom or molecule-by-molecule by physical and chemical methods which are in a nanoscale range (1 nm to 100 nm) using controlled manipulation of self-assembly of atoms and molecules. Chemical synthesis is a method of producing rough materials which can be used either directly in product in their bulk disordered form, or as the building blocks of more advanced ordered materials. Self-assembly is a bottom-up approach in which atoms or molecules organize themselves into ordered nanostructures by chemical-physical interactions between them. Positional assembly is the only technique in which single atoms, molecules or cluster can be positioned freely one-by-one (**Iqbal *et al*. 2012**).

The general concept of top down and bottom up and different methods adopted to synthesized nanoparticles by using these techniques are summarized in (Figure.2) **(Drexler 1986).).**

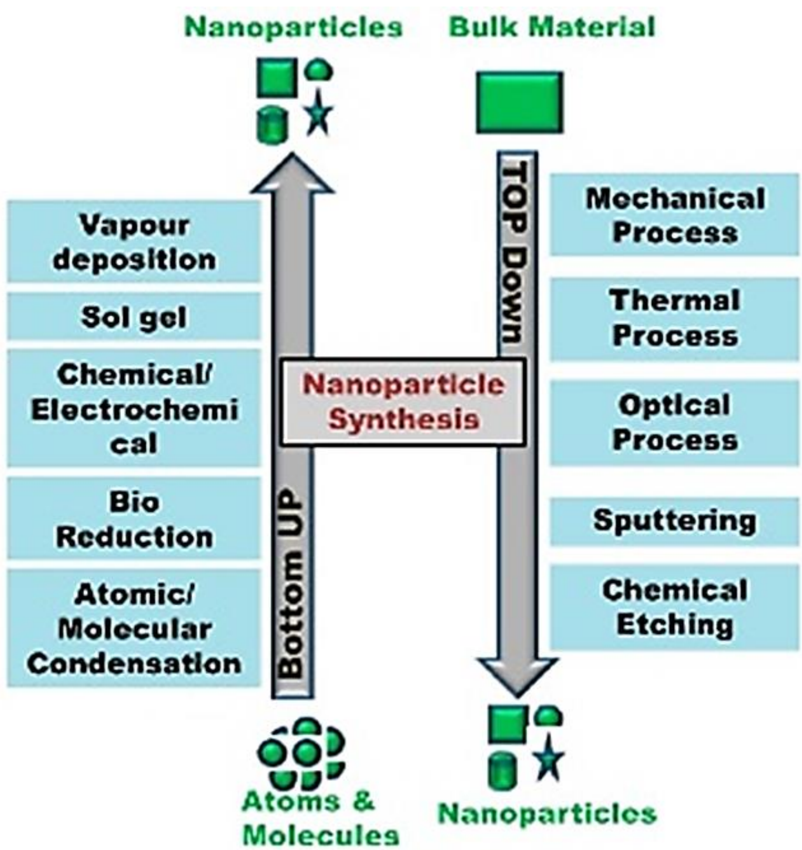

Figure. 2 The concept of top down and bottom up technology: different methods for nanoparticle synthesis.

1.3 Pharmaceutical Nanotechnology-Based Systems

Pharmaceutical nanotechnology consisting of two basic types; which are the nano-materials and nano-devices. These play a key role in pharmaceutical nanotechnology and other medical fields.

1. Nano-materials

These biomaterials are used in orthopedic or dental implants or as scaffolds for tissue engineered products. Their surface can be modified or coatings can be done which enhances biocompatibility with the living cells. These are further classified into two types: nano-crystalline and nano-structure materials.

A. Nano-crystalline material

These materials are readily manufactured and can substitute the less performing bulk material. Nono-crystalline bimaterials are directly used in drug encapsulation, bone replacement, protheces and implants.

B. Nano-structured material

Nano-structured material is a processed form of nano-materials with special shapes and functions. These include quantum dots, dendrimers, fullerenes and carbon nanotubes.

2. Nano-devices

These are small devices in a nano scale such as nano- and micro-electromechanical systems (NEMS/MEMS), micro fluidics and micro assays. Furthermore, nano-devices include biosensors and detectors, which are used in diagnosis **(Drexler, 1986)**.

1.3.1 Types of Pharmaceutical Systems :-

1. Carbon nano-tubes

These are hexagonal networks of carbon atoms that have unique size, shape and remarkable physical properties. The length and diameter of the nano-tubes are 1 nm and 1-100 nm in length. Nano-tubes are of two types: single walled nanotubes (SWNTS) and multi walled nano-tubes (MWNTS) (Figure.3) **(Sinha and Yeow 2005).**

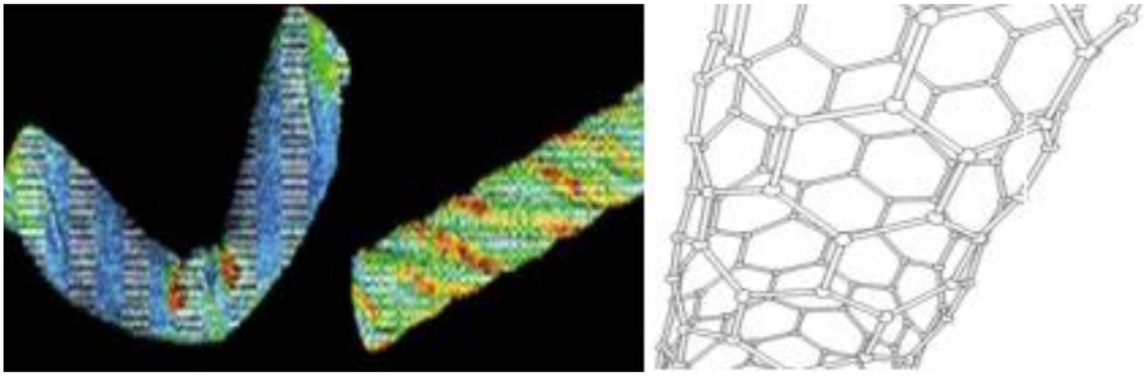

Figure 3: Carbon nanotubes (Sinha and Yeow 2005).

2. Quantum Dots

Quantum dots, semi-conducting materials, consist of a semi-conductor core coated by a shell to improve optical properties. Their properties originate from their physical size which ranges from 10-100 A^{0} in radius. It has main function in labeling of cells and therapeutic tools for cancer treatment (Figure. 4) **(Bailey *et al*. 2004).**

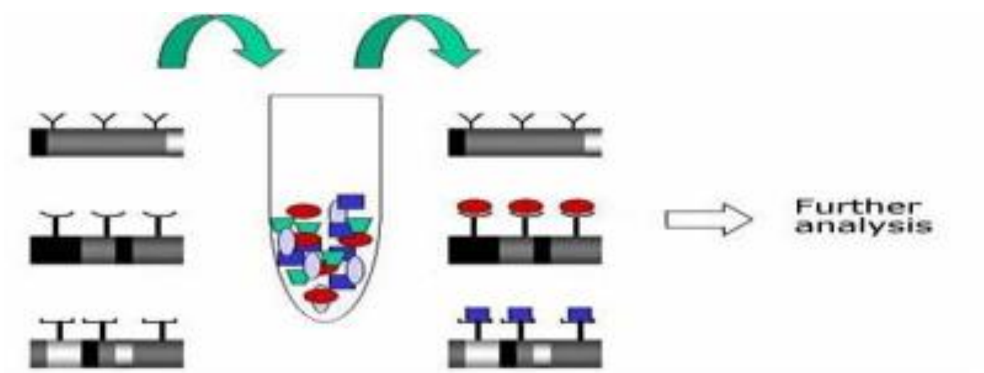

Figure 4: Quantum dots

3. Dendrimers

Dendrimers are hyper branched, tree-like structures that have compartmentalized chemical polymer. It contains of three different regions: the core, branches and the surface. The core forms the central part and the branches are radiates from forming an internal cavity and a sphere of groups. The branches can be altered or modified according to requirements. The dendrimers can be made more biocompatible compounds with low cytotoxicity and high biopermeability according to the requirements. These can deliver bioactive materials like drug, vaccines, materials and genes to the desired sites. The space between the core and the branches accommodates drugs or bioactive products (Figure. 5) **(Kreuter and Speiser 1976).**

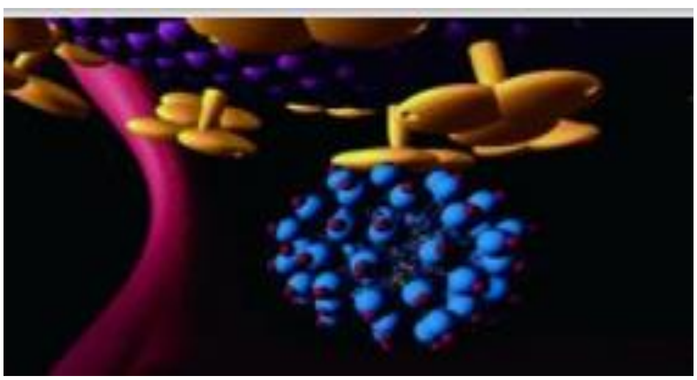

Figure 5: Dendrimers (Kreuter and Speiser 1976)

4. Polymeric nano-particles

These are colloidal carrier of 10 nm-1 µm in size consisting of synthetic or natural polymers. They provide alternative to the above mentioned nanosystems due to inherent properties like biocompatibility, non-immunogenicity, non-toxicity and biodegradability. Polymeric nanoparticles are classified and comprised of nanocapsules and nanosphere. The nanocapsules are systems in which drug is confined to a cavity surrounded by unique polymeric membrane, whereas the nanospheres are systems in which the drug is dispersed throughout the polymer matrix **(Maincent *et al.* 1992)** (Figure. 6)

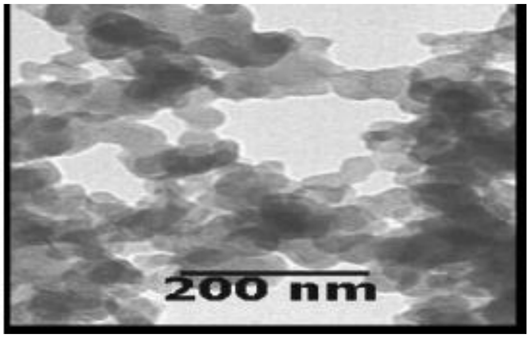

Figure 6: Nanoparticles

5. Metallic nanoparticles

Metallic nanoparticles are more favor in the good delivery as carrier for drug and biosensor. Nanoparticles of various metals have been made, however, silver and gold nanoparticles are of prime importance for biomedical use. These are used for active delivery of bioactive, drug discovery, bioassays, detection, imaging and many more other applications.) **(Kreuter and Speiser 1976).**

6. Liposomes

Liposomes are the closed vesicles forms of hydrated dry phospholipids. There are 3 types of liposomes based on the size and number of their bi-layers.

A. Multilamellar vesicles

These consist of several lipid bi-layers separated from one another by aqueous spaces. The A.   Multilamellar vesicles are heterogeneous in size, ranging from few hundreds to thousands of nm in diameter.

B. Small unilamellar vesicles (SUV'S) and large unilamellar vesicles (LUV'S)

These consist of a single bi-layer surrounding the entrapped aqueous space. SUV'S are less than 100nm whereas the LUV'S are more than 100nm. Drug is either entrapped in the aqueous space or intercalated into lipid bi-layer of liposome's, depending on physicochemical characteristics of the drug. They are used in cancer therapy, carrier for antigens, pulmonary delivery, leishmaniasis, ophthalmic drug delivery **(Jain *et al*., 2002).**

1.4 Nanoparticles used in dentistry

Various applications of Nanoparticles (NPs) are used in the field of dentistry. Their chemical and physical properties are based on the metals or the compounds used to prepare the NPs **(Ma *et al*., 2003; Mcintyre, 2012)**

1.4.1 Applications of nanotechnology in dentistry

1. Dental diagnostics

In an attempt to improve the medical diagnostics, the concept of nano-biosensing was introduced. A biosensor is an analytical device which incorporates a biologically active element with an appropriate physical transducer to generate a measurable signal proportional to the concentration of chemical species in any type of sample. Biosensors were introduced in 1962 by Clark and Lyons followed by an ongoing extensive research and development leading to potential applications in public health, environmental monitoring, and food safety (Table 1) **(Touhami, 2014).**

Table 1: Detection principles in nano-biosensors

Detection Principle	Definition
Piezoelectric	Piezoelectric biosensors have the ability to generate an electrical charge in response to mechanical stress, and the translation of mechanical energy to electrical energy is called the piezoelectric effect (Kumar, 2000)
Electrochemical	This detection principle starts with the analyte (target) chemically binding to the highly specific bioreceptor (e.g. a fixed enzyme), affecting the electronic properties of the sensor, and ultimately generating a readable signal (Hasanzadeh and Shadjou, 2016)
Optical	Optical nanosensors give quantitative measurements on an intracellular level. It converts the biorecognition of the analyte into an optical signal (Clark et al., 1999)
Calorimetric	Thermal biosensors or calorimetric biosensors rely on the rate of enzymatic exothermic reaction to measure the concentration of the analyte

2. Preventive dentistry

Researchers developed a nano-toothbrush, by incorporating nanogold or nanosilver colloidal particles between toothbrush bristles **(Raval *et al*. 2016).** In addition to its ability to improve upon mechanical plaque removal, researchers reported an antibacterial effect of the added gold or silver which could ultimately lead to a significant reduction in periodontal disease. Oral hygiene products such as toothpastes and mouthwash solutions were also nano-modified according to recent reports. Nano-calcium fluoride, for instance, was added to mouthwash products to reduce caries activity, reduce dentine permeability, and increase labile fluoride concentration in oral fluid **(Sun and Chow 2008).** Toothpastes containing calcium carbonate nanoparticles and 3% nanosized sodium trimetaphosphate have been reported to promote remineralisation of early carious lesions in comparison to a conventional toothpaste with no nano-additives **(Danelon *et al*. 2015).** Additionally, toothpastes containing nano-hydroxyapatite crystals (nHA) significantly increased microhardness values in human enamel following an erosive challenge, in comparison to the same toothpaste without nHA **(Ebadifar *et al* 2017).**

3. Prosthodontics

Incorporating a 0.4% Titanium oxide (TiO_2) nanoparticles into a three dimensional (3D) printed poly-methylmethacrylate (PMMA) denture base was investigated in 2017, in an attempt to improve its antibacterial characteristics and mechanical properties **(Totu *et al*. 2017).** It was found that the PMMA containing nanomaterial improve the antimicrobial efficacy against Candid spp. Furthermore, the nano-zirconium not only improved physical properties of denture bases during the construction phase, they were reported to improve the transverse strength of a repaired denture base as well **(Gad *et al*. 2016)**.

4. Endodontics

Applications of nanotechnology in endodontics include the incorporation of bio-ceramic nanoparticles such as bioglass, zirconia, and glass ceramics in endodontic sealers. It has been found that the use of nano-particles enhances the adaptation of the adhesive to nano-irregularities, in addition to its fast setting time in comparison to conventional sealers, its dimensional stability, insolubility in tissue fluid, chemical bond to tooth tissue, and osseoconductivity **(Utneja *et al*. 2015)**. The sealer was a mix of dimethylaminohexadecyl methacrylate (DMAHDM), 2-methacryloyloxyethyl phosphorylcholine (MPC), and amorphous calcium phosphate nanoparticles (NACP). The sealer was able to inhibit the formation of endodontic strains, while the nano-particles were particularly useful in accelerating the remineralization process and in increasing bonding strength to dentine.

5. Conservative and aesthetic dentistry

The new development of a rechargeable nano-amorphous calcium phosphate (nACP) filled composite resin has been recently reported. The nanoparticles were able to not only improve composites' remineralising properties, it also maintained the same level of Ca and P release through recharge and release **(Wang *et al*. 2017).** Researchers described it as a ''smart" material through its constant ability to rapidly neutralise bacterial acids released along the restoration/tooth margins through the release of Ca and P, therefore was able to inhibit the initiation of secondary caries. This was corroborated by Wu et al., reporting a significant remineralising ability of nACP and its effectiveness in inhibiting the initiation of secondary caries **(Xie *et al*. 2016).** Researchers also reported that their results create a possibility for integrating nACP in other dental materials such as luting cements and bonding agents.

6. Periodontics, Implantology, and regenerative dentistry

Scientists were able to create a novel drug delivery system for the treatment of periodontal disease, through triclosan or tetracycline loaded nanoparticles. These nanoparticles are uniformly dispersed within a matrix, which gradually biodegrades, releasing loaded drugs in increments to provide a longer contact duration with the diseased site **(Sharma *et al*. 2016).** Niosomes, for instance, are chemically stable non-ionic vesicles, which offer a controlled and targeted drug delivery with enhanced penetration through biological tissue especially when the particles are less than 100 nm in size **(Pradeepkumar *et al*. 2012).**

Nanotechnology in Orthodontics

Introduction

Similar to other dental disciplines, nanomaterials have its clinical applications in orthodontics **(Sharan *et al*., 2017).** Nanotechnology is used in brackets, archwires, elastomeric ligatures, orthodontic adhesives.

3.1 Nanomaterials in Orthodontics

Nanomaterials versatility allows them to be used in many situations during orthodontic clinical treatment, as can be illustrated in Table 2.

Table 2: Applications of Nanomaterials in Orthodontics

Nanomaterial	Method of Use	Application
Silver NPs (AgNPs)	Applied as a coating agent on titanium	Implants
Zinc oxide NPs (ZnONPs)	Incorporated into dental resins	Resin composite adhesives
Chitosan NPs	Conjugated with silver nanoparticles	Resin composites adhesives
Copper (I) oxide NPs (Cu_2ONPs)	Antimicrobial effect in resin adhesives	Resin composites adhesives
Titanium (IV) oxide NPs (TiO_2NPs)	Nanotubes on titanium surfaces and incorporated with ZnONPs	Implants
Gold NPs (AuNPs)	Modified gold nanoparticles (AuDAPT) coated onto orthodontic aligners	Antimicrobial coated aligner
Carbonate hydroxyapatite nanocrystal	Antibacterial and antidemineralizing properties	Toothpastes, mouthwashes and composite resins
Amorphous Calcium Phosphate (ACP)	Antibacterial and antidemineralizing properties	Antibacterial and antidemineralizing properties
Novel Poly(l-lactic acid) (PLLA)/Multi-walled carbon nanotubes (MWNTs)/hydroxyapatite (HA) nanofibrous scaffolds	Polymer solution FOR entire-tooth regeneration	Dental Surface applications
Bioactive peptide—Amphiphile nanofibers	Branched peptide Amphiphile molecules containing the peptide motif Arg-Gly-Asp, or "RGD"	Dental surface applications

3.1.1 Silver Nanoparticles (AgNPs) Coating

Some studies have proposed silver nanoparticles as the most effective type of metal nanoparticles for preventing the growth of *Streptococcus mutans* **(Bapat *et al.* 2018)**. Recently, silver nanoparticles (AgNPs) have been shown to be materials with excellent anti-microbial properties in a wide variety of microorganisms. In the orthodontic field, studies have incorporated AgNPs (17 nm) into orthodontic elastomeric modules, orthodontic brackets, and wires, and others, against a wide variety of bacterial species concluding that these orthodontic appliances with AgNPs could potentially combat the dental biofilm decreasing the incidence of dental enamel demineralization during and after the orthodontic treatments **(Mhaske *et al.*, 2015, Hernández *et al.*, 2017)**. AgNPs can significantly inhibit the bacterial adherence of the *S. mutans* strain on the surfaces of the orthodontic bracket and wire appliances compared to NiTi (nickel–titanium) and SS (stainless steel wires) **(Espinosa *et al*. 2017).** Studies confirm, that AgNP-coated brackets can help to decrease the spot lesions appearance during orthodontic treatment, and may be useful in compromised patients with immune deficiency, diabetes, or high risk of endocarditis **(Kim and Shin, 2013).** .

3.1.2 Copper Oxide Nanoparticles

It was proved by **Yassaei *et al*.** , that no significant difference was found between silver and copper oxide (CuO) nanoparticles. The former is cheaper and additionally both physically and chemically more stable. CuO nanoparticles affect *S. mutans* bacteria in a similar way as silver particles do **(Bapat *et al*. 2018).** and is able to decrease biofilm formation from 70 up to 80% **(Eshed *et al.* 2012).** Moreover, a similar result was achieved when CuO particles were incorporated into adhesive materials .

3.1.3. Nitrogen-Doped Titanium Dioxide (N-Doped TiO_2) Brackets

The activation of N-doped TiO_2 leads to the formation of hydroxide (OH^-) free radicals, superoxide ions (O_2), hydrogen peroxide (H_2O_2), and peroxyl radicals (HO_2). These chemicals exert antimicrobial activity and reacting with lipids, enzymes, and proteins. According to **(Poosti *et al.*, 2013)** TiO_2 nanoparticles of size 21 ± 5 nm can be blended to light cure orthodontic composite paste in 1, 2, and 3% and all these concentrations have similar antibacterial effects. (**Salehi *et al*.,2018)** claimed that nitrogen-doped TiO_2 brackets have shown better antimicrobial activity when compared to the uncoated stainless steel brackets. Nitrogen-doped TiO_2 brackets were also reported to present antibacterial activity against normal oral pathogenic bacteria **(Cao B. *et al*., 2013).**

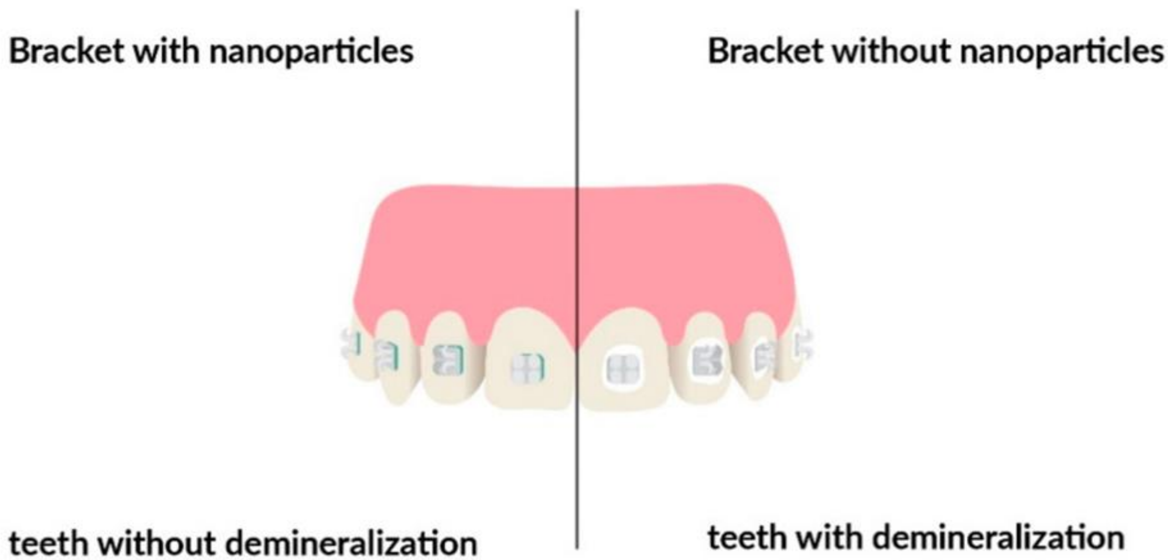

Figure. 7 Comparison of teeth demineralization development with and without nanoparticles' covered brackets.

3.1.4. Zinc Oxide (ZnO) Nanoparticles

It has been observed that as the concentration of ZnO increases, the antimicrobial activity also increases, followed by shear bond strength reduction. It is important to underline, that ZnO and CuO coated brackets have been observed with better antimicrobial characteristics on *S. mutans* than when the brackets were coated with CuO nanoparticles alone **(Kachoei et al 2013).** It was proposed that following ZnO nanoparticle coating, the frictional forces between archwires and brackets significantly decreased. Because of that effect, these nanoparticles offer new opportunities in overcoming the unwanted friction forces, better anchorage control, and reduced risk of resorption (**Kachoei *et al.***,2016; **Behroozian *et al***. ,**Goto *et al., 2013***).

3.2 Application of Nanotechnology in Orthodontic Materials

Orthodontic appliancs especially fixed appliances consists of attach,ent , wires and many axillaries(Figure.8) . Several studies incorporate nonotechnology in these components.

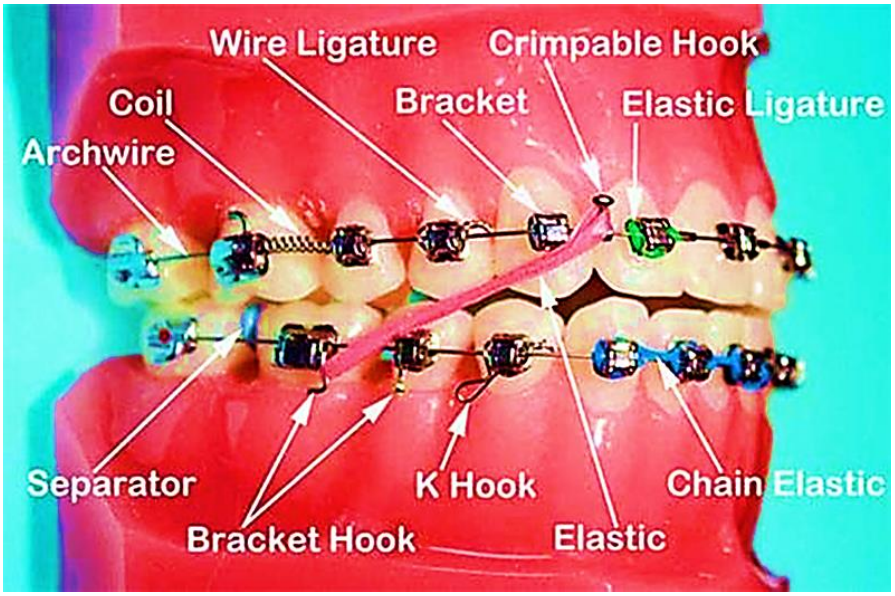

Figure. 8 Components of fixed orthodontic appliance

3.2.1 Orthodontic Elastomeric Ligatures

Orthodontic elastomeric ligatures (OEM) are synthetic elastic modules of polyurethane material, with advantages such as the quickness of application , patient's comfort and being inexpensive.

During orthodontic therapy, there is an inevitable increase in the accumulation of bacterial plaque, bacterial colonization and enamel decalcification, with a worsening of bleeding rates. The increase in bacterial plaque is partially related to the irregular surfaces of the orthodontic auxiliaries such as the brackets, adhesives and ligatures. For these reasons, maintaining correct oral hygiene and self-cleansing surfaces are indeed more difficult. It was found that the bacterial counts increase approximately thirty times at six weeks with an increase in *S. mutans*, *Staphylococcus aureus* and Lactobacilli.

It has been proposed that elastomeric ligatures can act as a support for the transport of nanoparticles, which can be molecules with anticariogenic or anti-inflammatory characteristics and/or antibiotic drugs, such as benzocaine, incorporated into the elastomeric matrix. Additionally, medicated wax applied to orthodontic brackets that reduces the pain associated with mucosal irritation caused by the brackets by slowly and continuously releasing benzocaine was shown to be significantly more effective **(Sharan *et al.* 2017).**

The most recent studies seem to evaluate the potentiality of the association of ligatures with silver nanoparticles, a material that appears to have the ability to counter dental biofilm and decrease the enamel demineralization caused by the accumulation of bacterial plaque, without affecting the mechanical characteristics of the material itself and, therefore, the effectiveness of orthodontic therapy **(Hernández *et al.* 2017)**.

3.2.2 Orthodontic Power Chains

Power chains have been used daily in every orthodontic practice since their development in the late nineteen sixties. They are generally composed of polymeric materials (polyesters or polyethers) formed through a process of polymerization. They present different clinical advantages: they are affordable, user-friendly and easy to adjust to every patient. They are characterized by high flexibility, and they enhance space closure in extraction cases. On the other hand, power chains have unfavorable characteristics: it is amply demonstrated that their mechanical effectiveness is limited in time, and, for this reason, they must be replaced periodically**(Leung *et al.* 2008).**

An attempt to improve the physical properties of power chains was done by performing a surface treatment called nanoimprinting. The treatment consists of creating nanostructures on the surface of the chains called nanopillars. The results seem encouraging, as this treatment converts the material from hydrophilic to hydrophobic and alleviates the shortcomings of these orthodontic auxiliaries **(Cheng *et al.* 2017).**

3.2.3 Orthodontic Bands

Fixed orthodontic treatment often requires the insertion of dental bands, which are often essential for orthodontic movements. However, these auxiliaries can cause the retention of bacterial plaque, especially in the posterior teeth, which are difficult to clean. Prolonged plaque accumulation around orthodontic brackets and bands has been demonstrated to determine a rapid shift in the bacterial flora, promoting acidogenic bacteria such as *S.mutans* and *Lactobacilli*, increasing the risk of enamel demineralization, white spot lesions and cavities **(Maxfield *et al.* 2012).** Different methods have been studied to prevent cariogenic events, in particular, the efficacy of fluoride-containing products. Their efficacy is indeed strongly related to patient compliance and accuracy in domiciliary hygiene procedures **(Robertson *et al*. 2011).**

Technology made it possible to add antimicrobial agents to dental resins and to cement to reduce the incidence of white spot lesions and cavities and, at the same time, maintain unchanged the adhesion properties. Companies tried to incorporate zinc oxide, chlorhexidine and fluorides to reduce the acid oral environment and decrease bacterial metabolism **(Prabha *et al.* 2016).**

Band cements with antimicrobial characteristics (antibacterial release materials such as silver nanoparticles) have been developed to counteract the onset of white spots. These resins have mechanical properties potentially comparable to controls, and in most cases, they were found to be biocompatible **(Moreira *et al.* 2015).**

3.2.4 Orthodontic Miniscrews

Managing the anchorage during tooth movement is a fundamental aspect of a successful orthodontic treatment. The principal aim of an orthodontic treatment is to control the anchorage and create a force system to provide the desired effect and avoid undesired movements.

In different years, temporary anchorage devices (TADs) have been integrated for orthodontic purposes including miniscrews, miniplates and implants **(Reynders *et al.* 2009).** They are inserted into the bone and aim to enhance orthodontic anchorage directly if they work as independent anchorage or indirectly if they support and reinforce the anchoring teeth (Figure. 8)

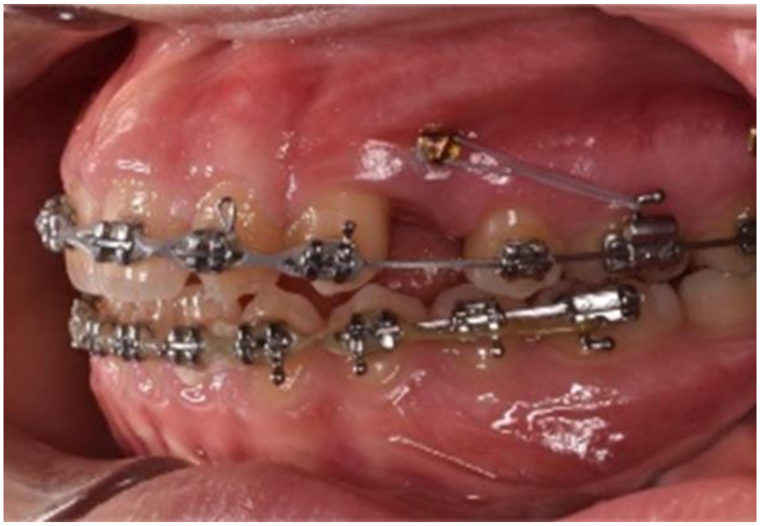

Figure. 9 Vestibular miniscrew to enhance molar mesialization

It is important to have a close intimacy between the bone and the surface of the miniscrew, as this allows better stability and greater resistance to orthodontic forces. Furthermore, inflammatory processes can affect the primary stability and determine a premature loss of the screw **(Jang et al. 2015).** The TiO_2 nanotube arrays were loaded with RhBMP-2 (recombinant human bone morphogenetic protein-2) and ibuprofen and were compared with a control group of standard miniscrews. These modified miniscrews can convey other drugs, such as antibiotic agents, aspirin and Vitamin C, to decrease inflammation at the insertion site and patient discomfort. This modification to the materials resulted in greater surface roughness and improving wettability compared to conventional products.

3.3 Prevention of Dental Caries and Control of Oral Biofilm

One of the goals of modern dentistry is to improve prevention and reduce the need for more invasive treatments. Nanotechnology can improve the management of these aspects; in particular, it seems to address the control of bacterial biofilms and remineralization following tooth decay. In this way, it would be easier for patients to maintain good oral hygiene, especially in those young patients at high risk of dental decay (Figure. 9)

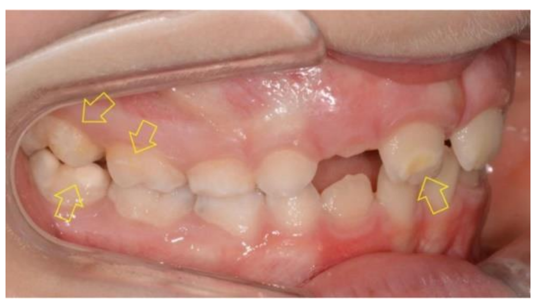

Figure 10: Molar incisor hypomineralization Orthodontic treatment can affect dental tissue and lead to cavities..

To overcome the problem of white spot lesion and caries around orthodontic brackets, antibacterial adhesives with different nanoparticles such as TiO_2 (titanium dioxide), SiO_2 (silicon dioxide) or SNPs (silver nanoparticles) have been tested and extensively discussed **(Pokrowiecki *et al.* 2018).** The incorporation of TiO_2 nanoparticles into an orthodontic adhesive has been shown to enhance its antibacterial effects for 30 days without compromising its physical properties **(Sodagar *et al.* 2017).** Furthermore, effective antibacterial properties have been described for silver nanoparticle primer (SNP) adhesives. However, these appear to be of limited use in orthodontics, as they can cause enamel discoloration and cosmetic treatment results. The other approach to reducing the failure rate due to dental caries has been to modify the arches or brackets with coatings such as TiO_2 nanoparticles doped with nitrogen **(Cao B et al. 2013)** or Ag–Zr nanocomposite coatings **(Pradhaban *et al.* 2014).**

The early lesions of enamel can be remineralized with dentifrices that contain nanosized calcium carbonate **(Solanke *et al.* 2014).** Inorganic materials such as hydroxyapatite (HA) or its derivates with zinc, fluoride, carbonate or organic compound materials present in food or beverages can be used as prophylaxis **(Gracco *et al.* 2016).**

3.4 Coated Orthodontic Archwires

Orthodontic treatment consists, essentially, of sliding brackets along an archwire; however, this implies that a friction force inevitably develops between the surfaces of the two auxiliaries (the archwire and the bracket), which opposes the therapeutic movement of the teeth. To perform the dental movement, 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 **(Kusy and Whitley 1997).**

Nanoparticles are Minimizing the frictional forces between the orthodontic wire and brackets has the potential to increase the desired tooth movement and thus shorten treatment time. In recent years, nanoparticles have been used as a component of dry lubricants, examples are Inorganic fullerene-like tungsten sulfide nanoparticles (IF-WS2) that are used as self-lubricating coatings for orthodontic stainless steel. Nanotechnology aims to reduce frictional forces, allowing the system to work more easily,it was suggested that the best solution is the coating of orthodontic archwires with a film incorporating nanoparticles. The best materials for achieving the goal of friction reduction are considered to be MoS2(molybdenum disulfide) and W2 (tungsten disulfide) **(Redlich M. *et al.* 2008).**

Chapter 2: Discussions/ comments

Nanotech hs many advantages not only in life science but also in dentistry and orthodontics. In orthodontis, several drawbacks have been encountered such as oral hygiene control , frictional resistance to sliding mechanics and biocompatibility and ionrelease characteristic

This review showed that incorporation of nanoparticles such as ZnO and AgO had antimicrobial and anti bacterial effects (Poosti et al., 2013) . this may play great role in reducing WSL and enhance oral hygiene. It was found that nanoparticles containing tooth pastes may reduce the prevelance of WSL (Cao B. et al., 2013) and promote enamel strength.

The use of nanocaoting may enhance the orthodontic treatemnet biocompatibility, it was found that the use of nonocoating to wires and brackets reduces frictional resistance (Kusy and Whitley 1997) and thus force level. Additionally it was reported that the coated surface was more resistance to ion release than in non-coated wires (Redlich M. et al. 2008).

Additionally, the incorporation of nanofilers to dhesive may improve the orthodontic welfare, it was found that the antimicrobial characteristics of nanoparticle containing adhesives has improved with out affecting bond strength,

Chapter 3: Conclusion and suggestions

Nowadays, nanotechnology plays an important role in dental field since it has the potential to bring significant benefits. The recent positive results are a stimulus for future research, especially regarding orthodontics. The range of research including orthodontic bonding materials, coating of brackets and wires, as well as their antimicrobial characteristics has a huge potential.

1. it is necessary to improve and search for new opportunities in overcoming the unwanted friction forces, better anchorage control, reducing the risk of resorption.
2. Despite the undoubted advantages of nanomaterials, knowledge about them is still incomplete and should be verified and carefully assessed, and the potential benefits should corresponded with the risk.
3. The application of nanomaterials in dentistry, especially in orthodontics is anticipated to grow further, and an interdisciplinary approach focusing on expertise in dentistry and nanomaterial science is required.

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