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Nanotechnology Application In Brackets And Archwires In Orthodontics

A Project Submitted to
The College of Dentistry, University of Baghdad, Department of Orthodontic, in Partial Fulfillment for the Bachelor of Dental Surgery

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Certification of the Supervisor

I certify that this project entitled “**Nanotechnology Application In Brackets And Archwires In Orthodontics** “prepared by the fifth-year student **Shams Ahmed Abd**, under my supervision at the College of Dentistry/University of Baghdad in partial fulfillment of the graduation requirements for the Bachelor Degree in Dentistry.

Prof. Abeer Bassim Mahmoud

Date: 26 April, 2023

(نَرْفَعُ دَرَجَاتٍ مَّن نَّشَاءُ وَفَوْقَ كُلِّ ذِي عِلْمٍ عَلِيمٌ)

صدق الله العظيم

DEDICATION

I dedicate my best effort, my knowledge and all that I have become today to the one who did his best so I can get here today, to the one who always believed in me and inspired me to keep working for the best,
my leader (my father).

To the one that always inspired me with wisdom and pure vision through hard times, my mother.

To my best friend who keeps supporting and inspiring me ever since I've known her.

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.

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List of abbreviation

IF-WS2	**Inorganic fullerene-like tungsten sulfide nanoparticles**
SEM	**Scanning electron microscopy**
EDS	**Energy dispersive X-ray spectroscopy**
AFM	**Atomic force microscopy**
SS	**Stainless steel**
β-Ti	**Beta-titanium**
NiTi	**Nickel-titanium**
USP	**Ultrasonic spray pyrolysis**
SMP	**Shape memory polymers**
RMGI	**Resin-modified glass ionomer**
ECA	**Experimental composite adhesive**
TMA	**Titanium–molybdenum**
TF	**Traction force**

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Introduction

Nanotechnology can be defined as the science and engineering involved in the design, synthesis, characterization, and application of materials and devices whose smallest functional organization, in at least one dimension, is on the nanometer scale or one billionth of a meter. At these scales, consideration of individual molecules and interacting groups of molecules in relation to the bulk macroscopic properties of the material or device becomes important, as it has a control over the fundamental molecular structure, which allows control over the macroscopic chemical and physical properties **(Silva Ga, 2004)**.

It's hard to imagine just how small nanotechnology is. One nanometer is a billionth of a meter, or 10-9 of a meter. Here are a few illustrative examples:

There are 25,400,000 nanometers in an inch.**(Littlewood et al.2006)**

A sheet of newspaper is about 100,000 nanometers thick. On a comparative scale, if a marble were a nanometer, then one meter would be the size of the Earth. Nanoscience and nanotechnology involve the ability to see and to control individual atoms and molecules. Everything on Earth is made up of atoms the food we eat, the clothes we wear, the buildings and houses we live in, and our own bodies.**(Closs et al.2010)**

But something as small as an atom is impossible to see with the naked eye. In fact, it's impossible to see with the microscopes typically used in a high school science classes. The microscopes needed to see things at the nanoscale were invented in the early 1980s.**(Seehra et al.2011)**

Once scientists had the right tools, such as the scanning tunneling microscope (STM) and the atomic force microscope (AFM), the age of nanotechnology was born. Nanomaterials are widely used in modern clinical dentistry. They improve various properties, such as antimicrobial properties, durability of materials. These particles do not exceed 100 nm, due to them obtaining a better ratio between the surface and mass. The larger the surface area of the material, the greater its reactivity. It is also easier to absorb them in the body, which can also result in high cytotoxicity **(Song W, 2019)**. Nanomaterials are used in many areas of dentistry, such as conservative dentistry, endodontics, oral, and maxillofacial surgery, periodontics, orthodontics, and prosthetics.**(Huang et al.2013)**

Orthodontics is a branch of dentistry dealing with the improvement of occlusal conditions and facial aesthetics in both children and adults. In cooperation with other specialists (such as dental surgeons, maxillofacial surgeons, periodontists), the orthodontist is able to significantly improve the patient's quality of life. Nanotechnology is used, among others, in brackets, archives, elastomeric ligatures, orthodontic adhesives (**Gkantidis,2010)**.

There are many advantages in medicine of using nanotechnology; however, it creates many doubts regarding the safety for humans and the environment. Nanoparticles can easily penetrate tissues and can affect biological behaviors at different levels. It is necessary to conduct detailed research on the environmental and toxicological properties in order to assess the risk and lead a sustainable application of nanomaterials.**(Fleming et al.2013)**

Aim of the study

The aim of this work is to describe and summarize the current use and application of nanoparticle activity in orthodontics field, spesifically including brackets, and archwires.

CHAPTER ONE: Review of literature

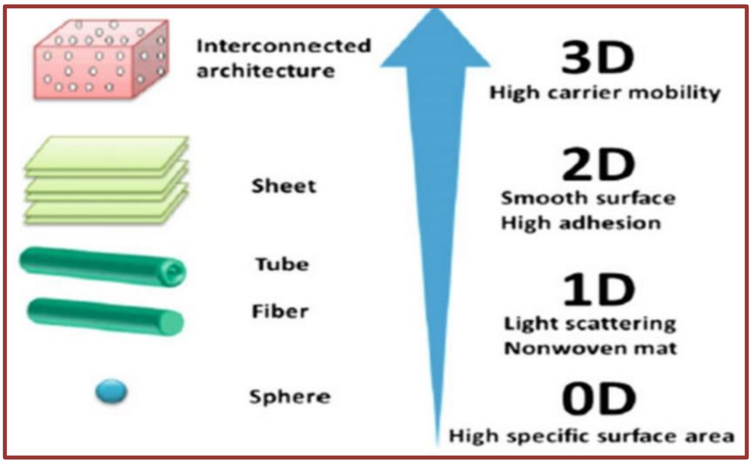
1.1. Shapes and Types of Nanoparticles

Different shapes of nanoparticles such as rod, rectangle, hexagon, cube, triangle, and star-shaped nanoparticles can be produced by variation of experimental parameters such as concentration of the metal precursor, reducing agents, and stabilizers and reaction conditions such as temperature, time. Bulk solution synthetic methods often produce nanoparticles of multiple sizes and shapes, and low yield of the desired size and shape. Colloidal solution can generally produce particles of desired shape and size. Controlling size, shape, and structural architecture of the nanocrystals requires manipulation of the kinetic and thermodynamic parameters as shown in**(Fig.1-1) (Ramesh S, 2018).**

1.2. Properties of Nanoparticles

The characteristics of nanoparticles like the size, shape, and surface characteristics determine the properties of the nanoparticles. Nanoparticles have properties different from microparticles due to their small size and relatively large surface area. When the size of a particle is close to or smaller than the de Broglie wavelength of the charge carrier (electrons and holes) or the wavelength of light, the periodic boundary conditions of the crystalline particle are destroyed, or the atomic density on the amorphous particle surface is changed. Due to these, a lot of the physical properties of nanoparticles are quite different from bulk materials, yielding a wide variety of new applications. Optical properties of nanoparticles are due to the excitation of surface plasmons in metallic nanoparticles, this property can be used in biomedicine, energy, and environment protection technologies. Magnetic properties of nanoparticles are by virtue of its external magnetic field and hence can be used for biomedical imaging and information storage technology **(Ramesh. S, 2018).**

The adhesion and the friction of nanoparticles play important roles in nanofab- rication, lubrication, the design of micro/nano devices, colloidal stabilization, and drug delivery. Controlling the size, shape, and surrounding media of metal nanoparticles are important as many of their intrinsic properties are determined by these parameters. Particular emphasis has recently been placed on the control of shape, because, in many cases it allows properties to be fine-tuned with a greater versatility that gives the particles a unique nature. It is only within the past decade that it has become possible to control the shape of particles synthesized in solution, and numerous methods have been developed for this. Stabilizing agent also plays a role in the size of nanoparticle. The key effect of the stabilizer on the nanoparticle size lies in the initial particle nucleation stage **(Ramesh. S, 2018)**. A thermodynamically stable and mature nanoparticle can only be formed when a nucleus grows into a cluster that is larger than a certain critical size. Therefore, a fast initial nucleation is critical to the production of stable nuclei and subsequently smaller nanoparticles. The higher the temperature, larger and more polydisperse nanoparticles are obtained. Similarly, change in pH or H+ activity can impact the reduction of ions. As the reduction of H+ proceeds, the solution pH goes up, which favors the reduction of metal ions **(Ramesh. S, 2018).**



(Figure 1-1) various kinds of nanomaterial and their specific properties (Ramesh S. ,2018)

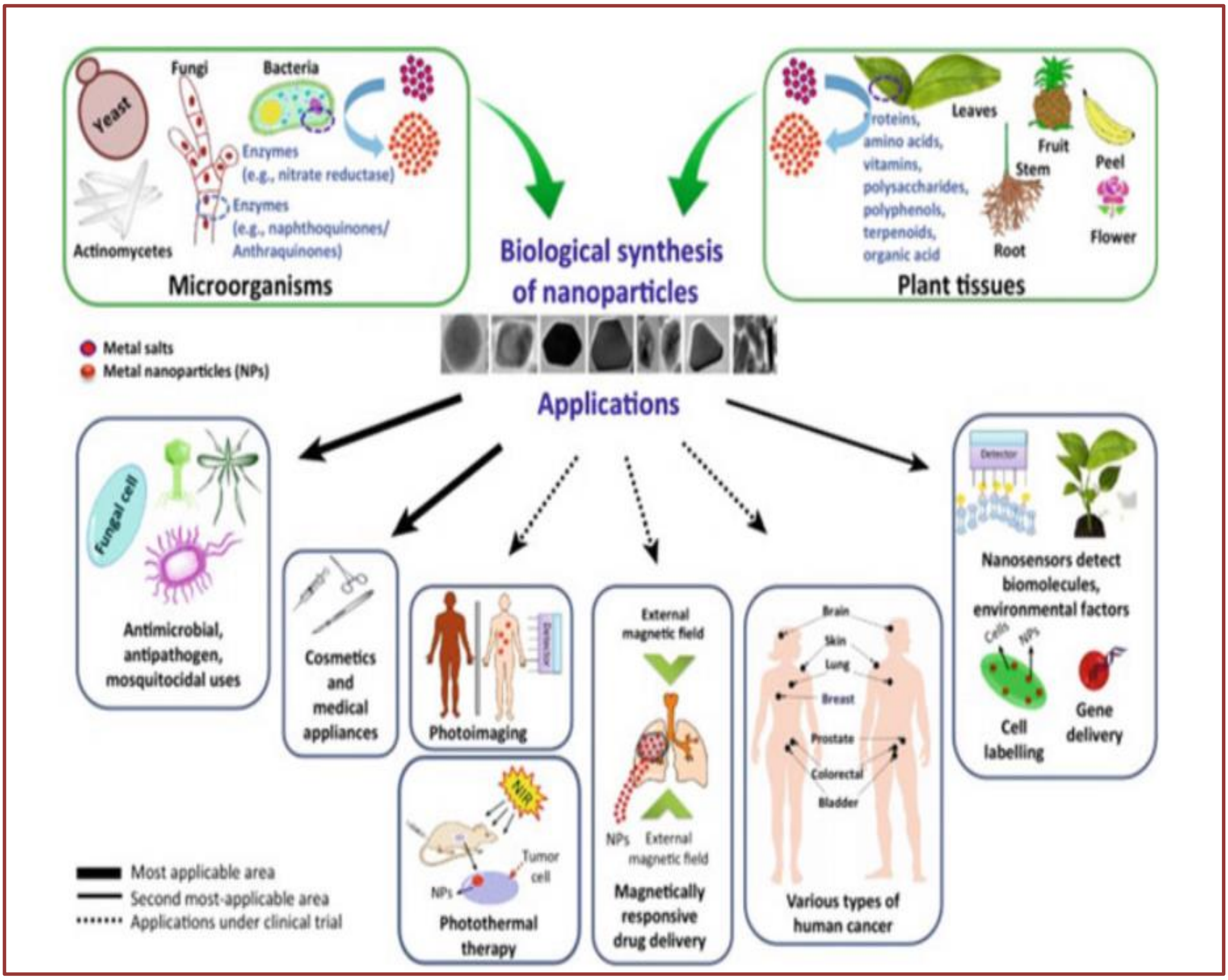
1.3. Synthesis of Nanoparticles

Nanoparticles may be synthesized by physical, chemical, or biological methods. Physical methods include evaporation, condensation, high gravity reactive precipitation, and laser ablation procedures. Chemical synthesis includes solvothermal methods, sol–gel conversions, chemical reduction, electrochemical techniques, photochemical reduction, and pyrolysis**(Keim et al.2014).**

Biosynthesis of nanoparticles may be done via microorganisms, enzymes, fungi, plants, and plant extracts as shown in **(Fig.1-2)**. Depending upon the location of nanoparticles, their synthesis via biological mode may be intracellular or extracellular. Intracellular method involves transport of ions into microbial cells to form nanoparticles in the presence of enzymes while extracellular synthesis is not within the cellular components of the organism. **(Otuyemi et al.2015)**

There are two alternative approaches for synthesis of metallic nanoparticles: the “bottom-up” approach and the “top-down” approach. In bottom-up approach, atoms or molecules are assembled to molecular structures in nanometer range. Bottom-up approach is commonly used for chemical and biological synthesis of nanoparticles. Advantage of the bottom-up approach is the enhanced possibility of obtaining metallic nanoparticles with comparatively lesser defects and more homogeneous chemical composition(s). In top-down approach, the bulk materials are gradually broken down to nanosized materials using physical (e.g., mechanical) or chemical means. A major drawback of the top-down approach is the imperfection of the surface structure. Such defects in the surface structure can have a significant impact on physical properties and surface chemistry of the metallic nanoparticles due to the high aspect ratio **(Ramesh. S, 2018).** Synthesis by various methods by top-down and bottom-up approach has been summarized as **(Table1-1)**:

Nanoparticles can be made from different materials composition with different physical and chemical properties. They can be attached with various ligands for biological targeting for different functions like contrasting agents, drug delivery vehicles, and therapeutics.**(Patcas et al.2015)**



(Figure 1-2) Biosynthesis of nanoparticles (Ramesh S. 2018)

Method	Process involved	
Physical method	Ball Milling	Top down approach
	Mechanochemical synthesis	
	Plasma vapor deposition	Bottom – up approach
	Laser pyrolysis	
	Flash spray pyrolysis	
	Inert gas condensation	
	Flame hydrolysis	
Chemical	Sol-gel or gel-sol conversions	
	Plasma/laser/flame enhanced chemical vapor deposition	
	Thermal decomposition	
	Solvo-thermal synthesis	
Biological	Fungi	Intracellular & Extracellular synthesis
	Bacteria	
	Yeast	
	Plant extracts	

(Table 1)Various methods of synthesis(Patcas et al.2015).

1.4. Nanotechnology Applications

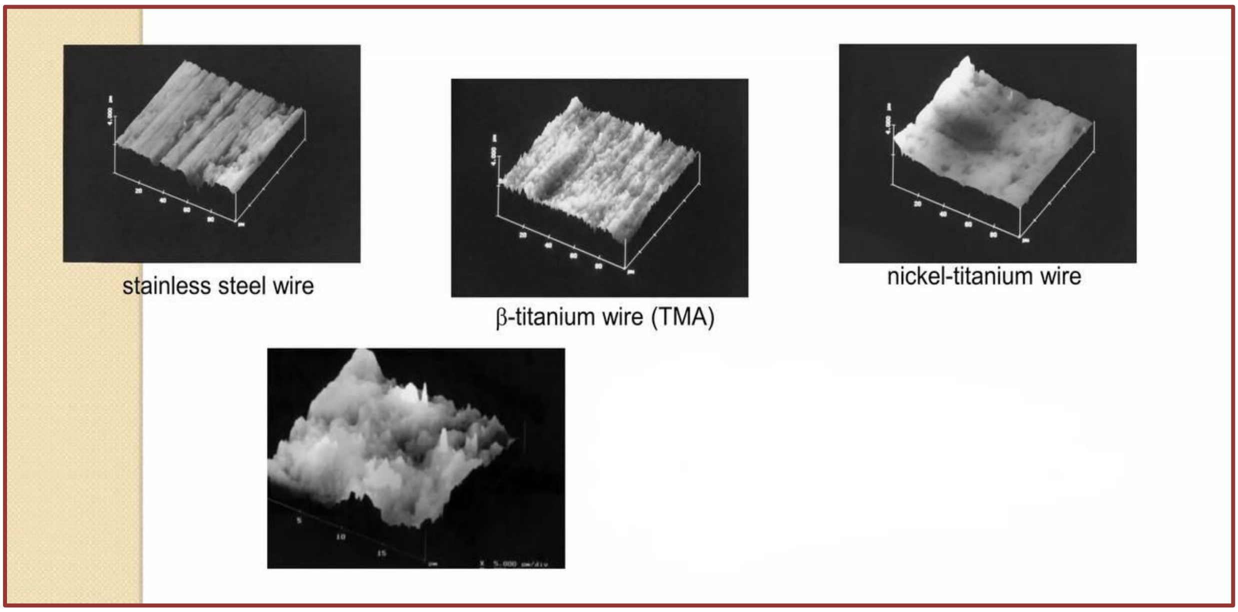
1.4.1. Nano-Coatings in Orthodontic Archwires and Brackets

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. These solid-phase materials are capable of reducing the friction between two sliding surfaces without the need for a liquid medium. One of the many examples are Inorganic fullerene-like tungsten sulfide nanoparticles (IF-WS2) that are used as self-lubricating coatings for orthodontic stainless steel wires **(Redlich M.,2008)**. Friction tests simulating the performance of coated and uncoated wires were carried out on an Instron machine, scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDS) analysis of the coated wires showed a clear impregnation of IF-WS2 nanoparticles in the Ni-P matrix**.(Subramanian et al.2019)**

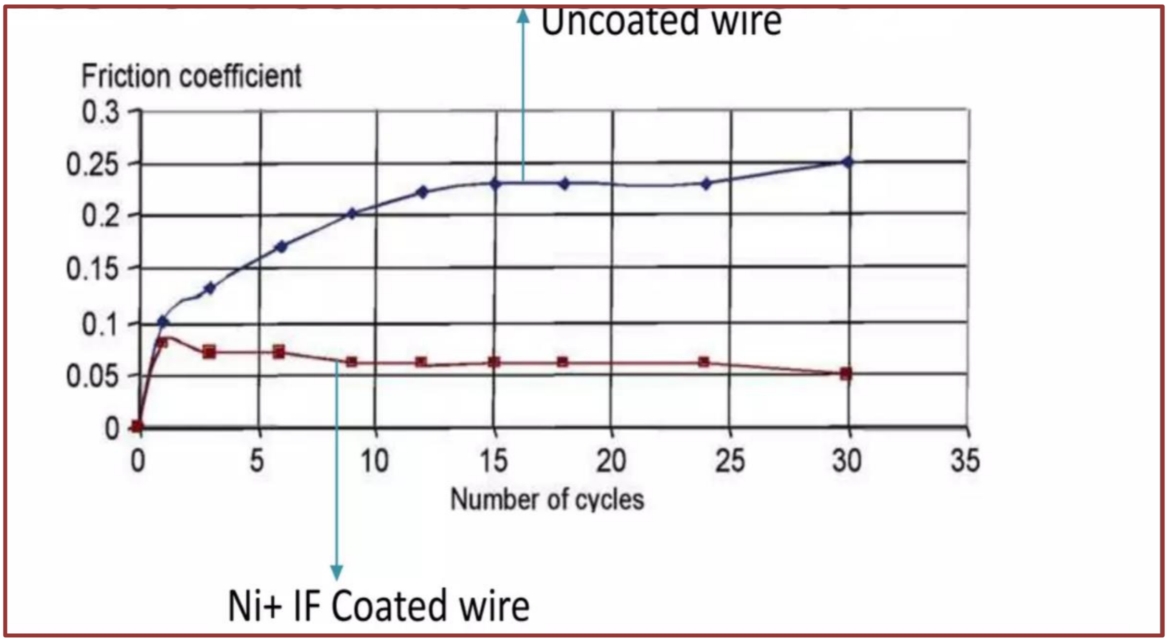
1.4.1.1 Nano Coatings Reducing Friction on Orthodontic Archwires and Brackets

Orthodontic arches are used to generate biomechanical forces that are transmitted through the brackets to move the teeth and correct malocclusion, spacing, or crowding. They are also used for retention purposes, i.e., to keep the teeth in their current position. Currently, orthodontic arches are made of non-precious metal alloys. The most common types of wire are SS, NiTi, and β-Ti alloy wires. In the case of sliding mechanics, friction between the wire and the lock is one of the major factors influencing tooth movement.When one moving object makes contact with another, friction occurs on the contact surface, which causes resistance to the movement of the teeth.**(Basdra et al.2008)** This frictional force is proportional to the force with which the contacting surfaces are pressed against each other and is governed by the interface surface characteristics (smooth/rough,chemically reactive/passive,or lubricant modified). Minimizing the frictional forces between the orthodontic wire and brackets will accelerate the desired tooth movement and thus shorten the treatment time.**(Lin et al.2009)**

NiTi substrates can be coated with cobalt and a layer of IF-WS2 nanoparticles using the electrodeposition method. The coated substrates showed friction reduction of up to 66% when compared to the uncoated ones. The results of such studies may have potential applications in reducing friction when using NiTi orthodontic wires. On the other hand, allergic reactions in patients with nickel sensitivity may be the disadvantage of introducing nickel into this type of coating. Therefore, the effect of such NiP coatings on stainless steel and NiTi wires should be assessed for biocompatibility in animal models and further human trials **(Ramesh. S 2018).** As shown in **(fig 1-3)**



(Figure 1-3) surface roughness of orthodontic wires via atomic force microscopy (A. Katz el., 2006)



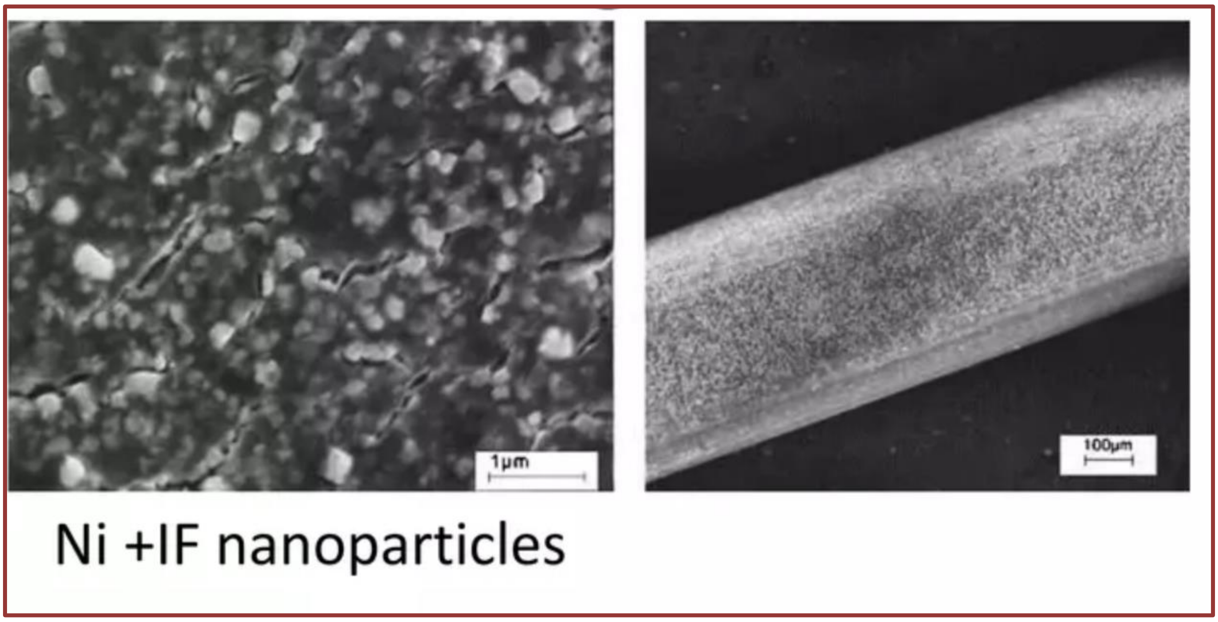
(Figure 1-4) Relation showing friction coefficient between coated and non-coated archwires (A. Katz el., 2006)

1.4.1.2. Nanoparticles Used in Coating

Various nanoparticles are being used as a coating in an effort to reduce friction**.** The nanoparticles used are as follows:

1. Nickel-phosphorus and tungsten disulfide (WS2)
2. Co + fullerene-like WS25
3. Carbon nitride (CNx)
4. ZnO
5. Molybdenum disulfide
6. Diamond-like carbon coating and nitrocarburizing
7. Polysulfone embedded with hard alumina nanoparticles for brackets.

As shown in **(fig 1-5)(Samorodnitzky-naveh GR, 2009)**



(Figure 1-5) micrograph of the composite coating on the orthodontic archwire (right) , the IF nanoparticles can be seen within the Ni-P matrix in the magnified image (left), (A. Katz el., 2006)

1.4.1.3. Mechanism of Action of Coating

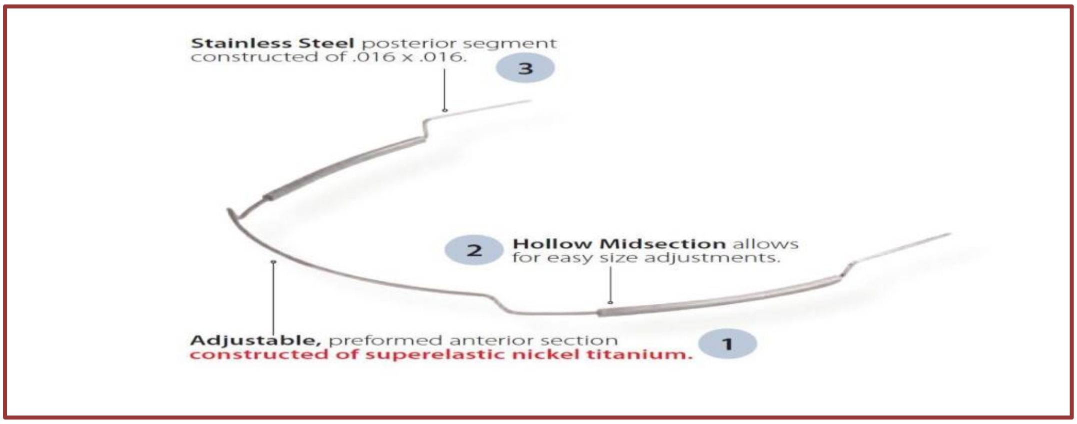
The mechanism by which the reduction in friction is achieved can be explained by the theories suggested by Rapoport et al. and Cizaire et al.At the first stage, when there is no angle between the slot and wire, the nanoparticles act as spacers and reduce the number of asperities that come in contact, resulting in a lower coefficient of friction. The friction at the wire increases as the angle increases**(Espinosa et al.2013)** .At this point on the coated wire, the nanoparticles from the coating are released into the tribological interface and their exfoliation occurs, resulting in the formation of a solid lubricant film on the sliding wire. The higher load at this point brings the asperities of the mating surfaces in straight contact causing the fluid (saliva in the mouth) to be squeezed out of the gap between the wire and slot, relying on the excellent tribological behavior of the solid lubricant film to allow the sliding of the archwire.**(Prime et al.2020)** When the two materials are SS, as is the case with the uncoated wire, the friction coefficient is high. The presence of nanosheets at the interface under high loads leads to a very facile sliding between these sheets, thereby reducing the coefficient of friction **(Ramesh. S, 2018)**

1.4.2. Fabrication of Hollow Wires

NiTi/Ni-TiO2 composite nanoparticles are being used for the fabrication of hollow wires. These wires are hollow from inside but retain the properties of NiTi wires. They are synthesized via the synthesis method called the ultrasonic spray pyrolysis (USP). The orthodontic wire is used to obtain the precursor solution for the synthesis of spherical NiTi particles. These spherical NiTi particles are then coated over a textile or a polymer fiber via electrospinning. Then, the fiber is removed from inside thus producing a hollow wire. Bending properties of these hollow NiTi wires were performed by the three-point bending test and compared with conventional NiTi wires. As shown in **(Fig. 1-6) (Ramesh. S, 2018).**

1.4.2.1. Advantages of hollow wires:

1. This wire could potentially have the shape-memory and superelasticity properties, while possibly reducing the material needed for the wire production.
2. They may deliver lighter and more continuous force.
3. The bending properties can be customized by inserting another wire into the hollow core **(Ramesh. S, 2018)**



(Figure 1-6) Adjustable Utility Archwires, Niti and Stainless Steel (Ramesh. S, 2018).

1.4.3. Fabrication of Orthodontic Brackets

Nanoparticles are being used for fabrication of brackets like the hard alumina nanoparticles embedded in polysulfone. These brackets have strength, reduced friction and biocompatibility while maintaining the transparency of the bracket. Brackets are also being coated with nanoparticles to improve their properties like:

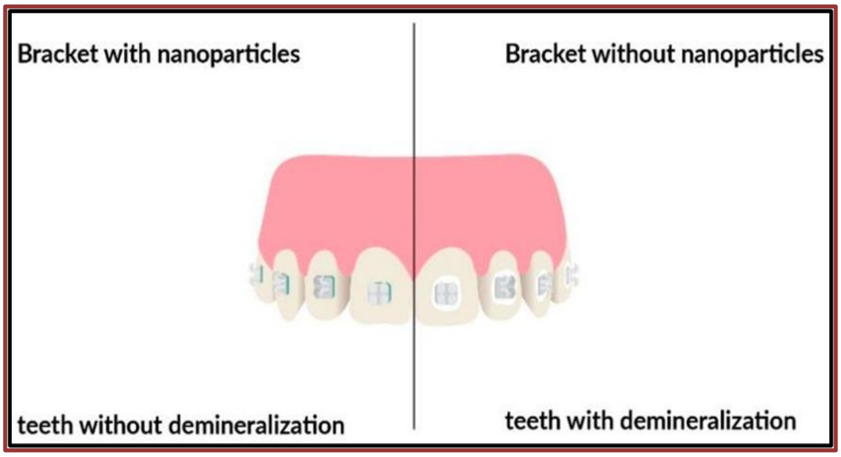
• Titanium dioxide because of its photocatalytic properties

• Nickel-phosphorous and tungsten disulfide (WS2) nanoparticles to reduce friction.

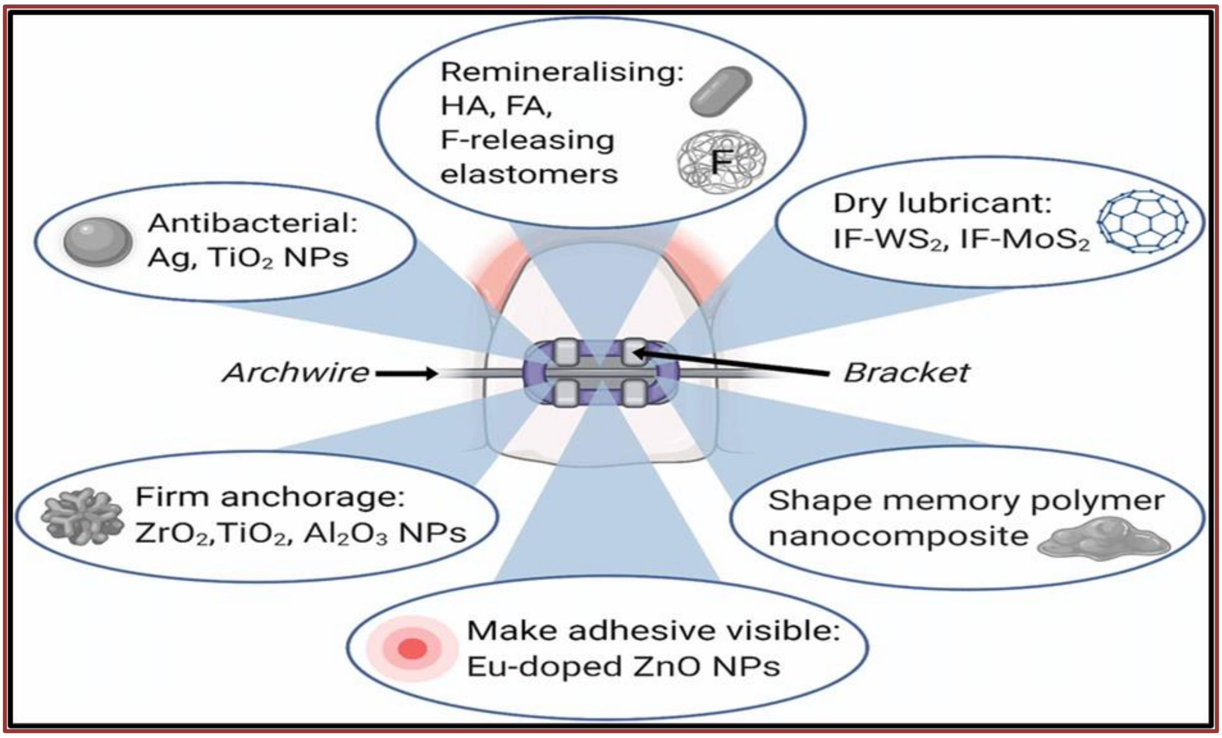
• ZnO and CuO nanoparticles for antibacterial properties **(Sato Y, 2009).**

1.4.3.1. Bracket Surface modification

Orthodontic brackets have been coated with nitrogen-doped titanium dioxide. The activation of nitrogen-doped titanium dioxide leads to the formation of OH free radicals, superoxide ions (O2), peroxyl radicals (HO2) and hydrogen peroxide (H2O2). These chemicals, through a series of oxidation reactions, react with biological molecules such as lipids, proteins, enzymes and nucleic acids, damage biological cell structures, and also exert antimicrobial activity **(Ramesh. S, 2018).** As shown in figure **(1-7),(1-8)**



***Figure(1-7)Comparison of teeth demineralization development with and without nanoparticles' covered brackets* (*Zi Hong Mok,* el , 2020).**



(Figure1-8) ***nano-particles used in brackets (Zi Hong Mok, el , 2020)***

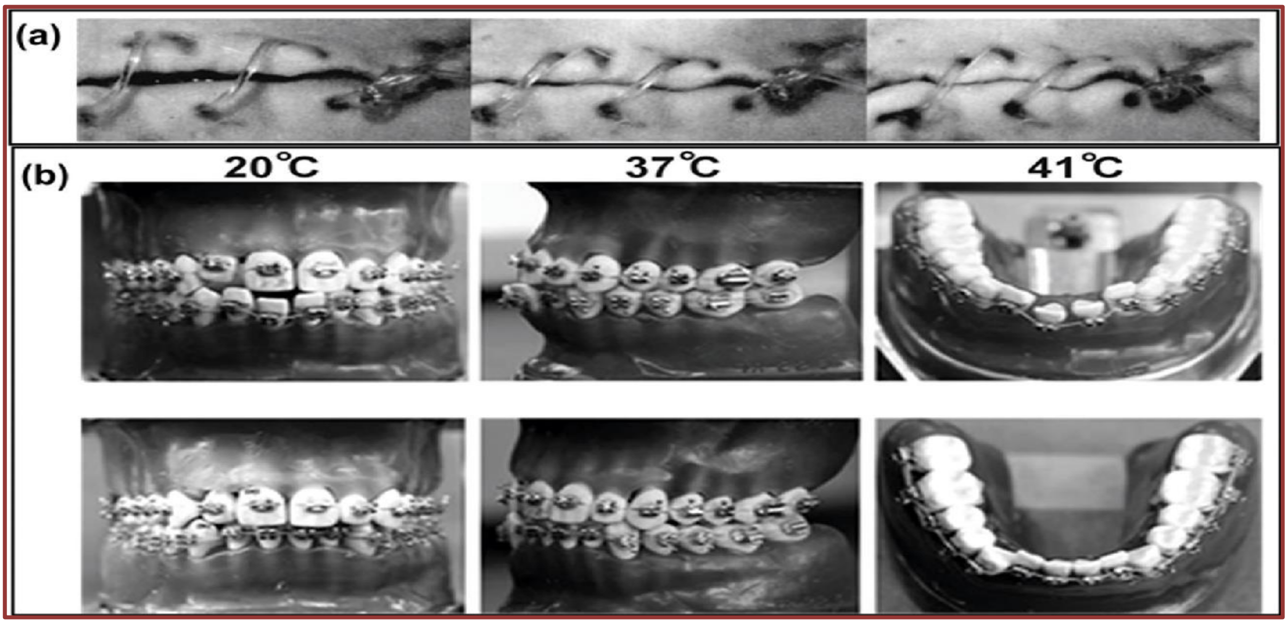
1.4.4. Delivering Nanoparticles from an Elastomeric Ligature

Elastomeric ligatures can serve as a support scaffold to deliver nanoparticles that can be anti-cariogenic or anti-inflammatory. They may also carry embedded antibiotic drug molecules. The release of anti-cariogenic fluoride from elastomeric ligatures has already been described in the literature **(Miura K.K, 2007)**. Research has shown that fluoride release is characterized by an initial burst of fluoride in the first few days followed by a logarithmic fall. The whole process is effective against common enamel demineralization around the orthodontic bracket during treatment **(Nalbantgil D.,2013).**

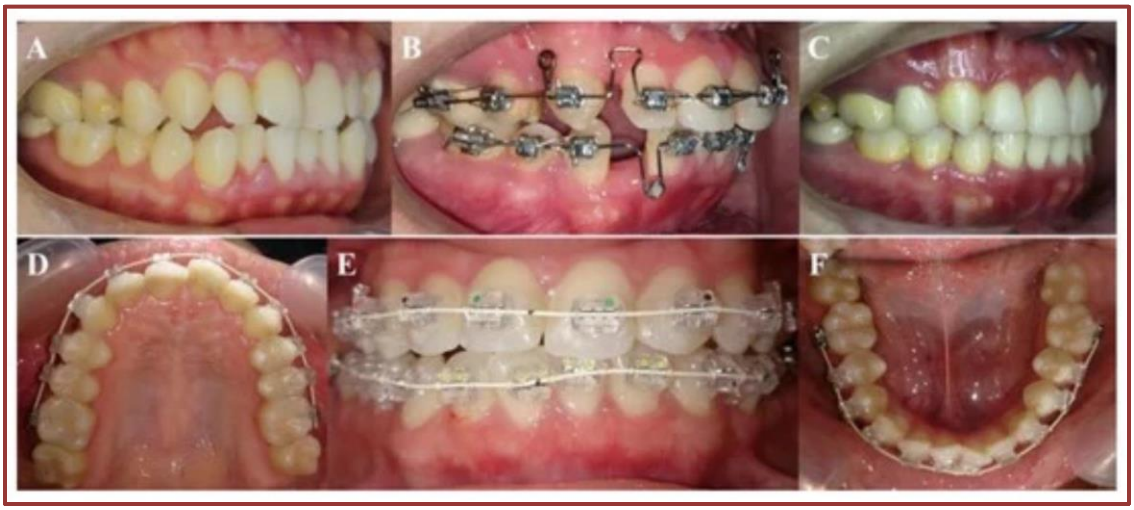
1.4.5. Shape Memory Polymers (SMP) in Orthodontics

In the last decade, there has been a growing interest in the production of aesthetic orthodontic wires to complement brackets in the color of the teeth. Shape memory polymers (SMPs) are materials that can remember equilibrium shapes and then manipulate and fix them into a temporary or dormant shape under certain temperature and stress conditions.**(Katsaros et al.2010)** They can later relax to their original, stress-free state under thermal, electrical, or environmental conditions. This relaxation is related to the elastic deformation stored in the previous manipulation. Recovery of SMP into equilibrium shape can be accompanied by an appropriate and prescribed force, useful for orthodontic tooth movement, or a macroscopic change in shape that is useful in ligation mechanisms. Due to the ability of SMP to have two shapes, these devices meet requirements unattainable by modern orthodontic materials, allowing the orthodontist to insert them into the patient's mouth more easily and comfortably As shown in **(Fig1-9) (Jung Y.C., 2010).**

When placed in the oral cavity, these polymers can be activated by body temperature or light-activated photoactive nanoparticles thereby causing tooth movement. SMP orthodontic wires can provide an improvement over traditional orthodontic materials as they provide lighter, more consistent forces which, in turn, can cause less pain to patients. Also, SMP materials are transparent, stainable, and stain-resistant, providing the patient with a more aesthetic apparatus during treatment. High percent elongation of the SMP apparatus (up to about 300%) allows for the application of continuous forces over a large range of tooth movement, and thus, fewer patient visits **(Leng J.,Cho J, 2011).**Future directions of research on shape nanocomposite polymers with memory for the production of aesthetic orthodontic wires may have interesting potential in the research of orthodontic biomaterials, SMPs are desirable in the orthodontics area for their shape memory effect. Jung and Cho in 2008 presented the use of SMPUs for archwires in a dental model. The melt spun PU, synthesized from 4,4_-methylene bis(phenylisocyanate) and polycaprolactone (PCL) diol was employed. The SMPU wires were stretched to the required length for realignment of the teeth before attaching to stainless steel brackets. **Figure (1-6)** shows the correction of misaligned teeth in orthodontics using shape memory NiTi wire and polymer-coated wire using Teflon-coated NiTi wire. Such wires are esthetics compared to the normal NiTi wire. As shown in **(Fig.1-10).(Jung,Cho,2008)**



(Figure 1- 9) Shape Memory Polymers (SMP)(*Schatzle et al.2011)*



(Figure1-10) Use of shape memory NiTi wire and Teflon-coated NiTi wire to close the space in orthodontic treatment: (A) before treatment; (B) during treatment; (C) after treatment for the NiTi alloy and (D) before treatment; (E) during treatment; and (F) after treatment for the Teflon-coated NiTi wire(Schatzle et al.2011)

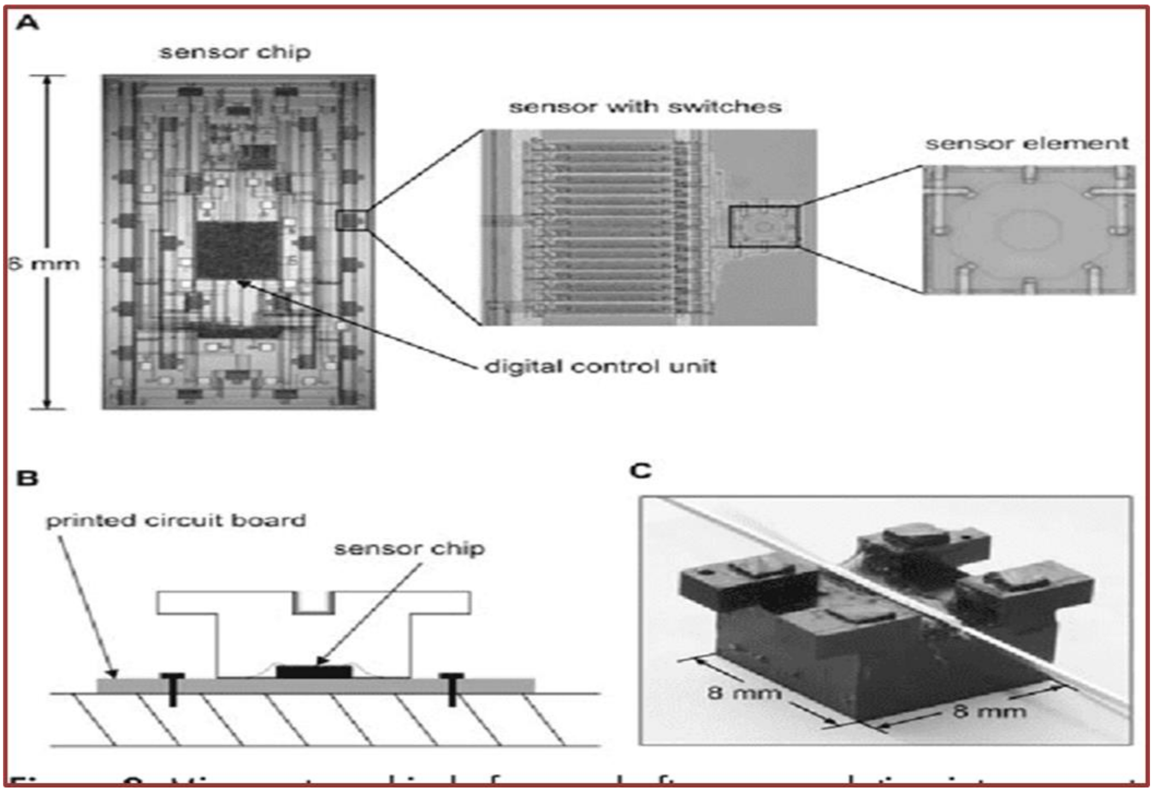
1.4.6. Control of Oral Biofilms during Orthodontic Treatment

Nanoparticles have a larger surface area to volume ratio (per unit mass) compared to non-nano scale particles, interacting more closely with microbial membranes and providing a much larger surface area for antimicrobial activity. In particular, metal nanoparticles with a size of 1–10 nm showed the highest biocidal effect on bacteria **(Allaker R.P, 2010).** Silver has a long history of use in medicine as an antibacterial agent. The antimicrobial properties of nanoparticles have been exploited through the mechanism of joining dental materials with nanoparticles or coating the surface with nanoparticles to prevent adhesion of microbes to reduce biofilm formation**.**It was found that resin composites containing fillers implanted with silver ions that release silver ions have an antibacterial effect on oral streptococci. **(Moolya N, 2014)**

compared an experimental composite adhesive (ECA) containing silica nanofillers and silver nanoparticles with two conventional composite adhesives and a resin-modified glass ionomer (RMGI) to investigate the surface characteristics, physical properties, and antimicrobial activity against cariogenic streptococci. The results suggest that the ECAs had rougher surfaces than conventional adhesives due to the addition of silver nanoparticles. Bacterial adhesion to ECA was lower than to traditional adhesives, which was not affected by saliva. Bacterial suspensions containing ECA show slower growth of bacteria than those containing conventional adhesives. There is no significant difference in the shear bond strength and fracture strength of the bond between ECA and conventional adhesives. **(Meng Q,2009)**

1.4.7. Smart brackets with nanomechanical sensors

Quantitative knowledge of the three-dimensional (3D) force moment systems applied for orthodontic tooth movement is of utmost importance for the predictability of the course of tooth movement as well as the reduction of traumatic side effects. The concept of a smart bracket with an integrated sensor system for 3D force and moment measurement has recently been published. Nanomechanical sensors can be fabricated and be incorporated into the base of orthodontic brackets in order to provide real-time feedback about the applied orthodontic forces. This real-time feedback allows the orthodontist to adjust the applied force to be within a biological range to efficiently move teeth with minimal side effects. **(Gupta J, el 2011)** Atraumatic, well-directed, and efficient tooth movement is interrelated with the therapeutic application of adequately dimensioned forces and moments in all three dimensions. The lack of appropriate monitoring tools inspired the development of an orthodontic bracket with an integrated microelectronic chip equipped with multiple piezoresistive stress sensors **(Mikami et al.2013).** As ashown in **(Fig.1-11)**



(Figure 1-11) smart bracket ((Gopinadh A, el 2015)

1.5. Nanomaterials in Orthodontics

- **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 R.A, 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 A.R, 2015).** AgNPs can significantly inhibit the bacterial adherence of the S. mutants' strain on the surfaces of the orthodontic bracket and wire appliances finding that the smaller AgNP samples demonstrated statistically to have the most important S. mutants anti adherence activities for orthodontic brackets and wires when compared to NiTi (nickel–titanium) and SS (stainless steel wires) **(espinosa-Cristobal, 2018**). It is also confirmed by several studies, that coverage of AgNPs in human dentin prevents biofilm formation on the surface of the dentin, together with bacterial growth inhibition **(Mhaske A.R, 2015)**. These studies confirm that AgNP coated brackets can help to decrease the spot lesions' appearance during orthodontic treatment, and may be even useful in compromised patients with immune deficiency, diabetes, or elevated risk of endocarditis (**Prime et al.2020**).

- **Chitosan**

Chitosan is a naturally acquired polysaccharide that is formed by the deacetylation of chitin. It is a non-toxic, biodegradable, biocompatible,and has antibacterial properties on Porphyromonas Gingivalis, and Streptococcus mutans.

Chitosan additionally inhibits action against fungi. This material's application as an antibacterial chemical agent in mouthwashes is limited due to its reduced solubility in water. **(Kim, 2013)** Nonetheless, its characteristics are highly desirable in dental materials. Chitosan could be maintained inside the materials in the oral cavity due to its insolubility in water. Chitosan, due to its low solubility and melting temperature, can be maintained in the oral cavity for a long period of time.**(Chen et al.2015)**

- **Copper Oxide**

It was proved by Yassaei et al. (**Eshed M., Lellouche J.,2012**), that no significant difference was found between silver and copper oxide (CuO) nanoparticles, but it was noted that a curing time increased with the use of copper material when compared to the silver one. The former is cheaper and additionally both physically and chemically more stable than the latter. CuO nanoparticles affect Streptococcus mutans bacteria in a similar way as silver particles do (**Bapat R.A.,2018**). It was confirmed in other studies **(Behnaz M.,2010)**, that copper and copper-zinc nanoparticles had a significant inhibitory effect on the studied microbes. According to other studies, CuO is able to decrease biofilm formation from 70 up to 80%(**Eshed M.,2012**). Moreover, the similar results were achieved when CuO particles were incorporated into adhesive materials. Additionally, nanoparticles like CuO can act as nano-fillers and enhance the shear bond strength of adhesive.**(Hernandez-Gomora, 2017)**

- **Nitrogen-Doped Titanium Dioxide (N-Doped TiO2) Brackets**

The activation of N-doped iO2 leads to the formation of OH. Free radicals, superoxide ions (O2), hydrogen peroxide (H2O2), and peroxyl radicals (HO2). These chemicals exert antimicrobial activity, also reacting with lipids, enzymes, and proteins. According to Poosti et al. (**Poosti M., Ramazanzadeh B.,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 P., Babanouri N.,2018)** proved, 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., Wang Y.,2013).**

- **Zinc Oxide (ZnO)**

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 Streptococcus muants than when the brackets were coated with CuO nanoparticles alone **(Kachoei M.,2013)**. Kachoei et al**.(Behroozian A.,2016)**, Behroozian et al.proved that following ZnO nanoparticle coating, the frictional forces be-tween 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.**(Goto M., Kasahara A.,2011)**

1.6. Summary of Studies on Nanoparticle Applications in Materials Used (Ramesh. S, 2018)

Material Studied	Nanoparticle/Nanoscale Material Studied Imaging Technique Used	Parameters Evaluated	Results
Orthodontic stainless steel wire	NiP film impregnated with IF-WS2 nanoparticles	1. Frictional forces measured on coated and uncoated wires2. Friction coefficient	1. Reduced to 54% on coated wires2. Friction coefficient reduced one-third from 0.25 to 0.08
Stainless steel, beta-titanium and NiTi archwires	AFM	surface roughness	Surface roughness influenced the effectiveness of sliding mechanics, corrosion behavior, and aesthetics
Conventional stainless steel, ceramic, self-ligating stainless steel and ceramic brackets	AFM	Surface roughness	Two-year orthodontic treatment regimen showed that self-ligating ceramic brackets had undergone less change in roughness parameters than self-ligating stainless steel brackets. Self-ligating ceramic brackets exhibited low friction and better biocompatibility than other brackets

1.7. Challenges faced by Nanotechnology

Biocompatibility: It is essential to develop biofriendly nanomaterials and ensure compatibility with all intricacies of the human body. Smaller particles are more bioactive and toxic. Their ability to interact with other living systems increases because they can easily cross the skin, lungs and in some cases the blood-brain barriers. Once inside the body, there may be further many biochemical reactions like the creation of free radicals that damage cells. While the body has built-defense for natural particles it encounters, the danger of nanotechnology is that it is introducing new types of particles. **(Knosel et al.2019)**

Ethics: The dominance of the drastic opposition of utopian dreams and apocalyptic nightmares in the debate on the future perspective of nanotechnology holds the risk of undesirable conflicts and unnecessary black lashes. Hence the present state of debate on nanotechnology calls for the development of more balanced ethical views. **(Gupta J, el 2011)**

Human safety: Nanotoxicity is still a new field but there is the possibility that some nanomaterials may present a health risk. The properties that allow nanomaterials to penetrate the body in new ways are not necessarily bad, but in fact may be beneficial, such as in the development of targeted cancer therapies. It is also crucial to bear in mind that not all nanomaterials are created equal; toxicity will likely vary depending not only on the material but also vary based on the particle size**(Gopinadh A, el 2015).**

CHAPTER TWO:

Dissection:

Nowadays, nanotechnology plays an important role in the dental field since it has the potential to bring significant innovations and benefits. The recent positive results are a stimulus for future research, especially regarding orthodontics.

This review has shown the nanomaterials application regarding mechanical and antibacterial properties in orthodontics.

This review marked that control and coordinated management of orthodontic treatment is crucial. Dental materials often present limitations during orthodontic treatment, but recently, nanotechnology and science have helped to partially solve some of the limitations. Nanomaterials can successfully reduce friction between the wire and the bracket, which may influence the orthodontic treatment. They are also useful in increasing the antimicrobial characteristics of materials used during treatment. This review provides several perspectives for the development of nanomaterials in orthodontics.

It is necessary to improve and search for new opportunities in overcoming the unwanted friction forces, antimicrobial activity and wires and brackets surfaces modifications all should be based on evidence-based medicine and research generating stronger evidence.

Also, it is necessary to monitor the treatment of patients who use orthodontic nanomaterials due to the specificity of the oral cavity environment, which is dynamically changing. Biocompatibility and cytotoxicity are important considerations when using new bioactive materials. In the available literature, the knowledge about adverse effects resulting from the use of nanomaterials in orthodontics is limited. The application of nanomaterials in dentistry, especially in orthodontics is anticipated to grow further.

CHAPTER THREE:

Conclusions

1. Application of nanotechnology is so beneficial in improving orthodontic treatment by reducing friction, reducing demineralization and producing new applications
2. Better control results in better, more predictable treatment, which reduces the stress of the orthodontist and increases patient satisfaction.
3. In the near future, adding nanoparticles to the materials of appliances will be the gold standard, improving the quality of orthodontic treatment. In addition to determining the basic components of the components of an orthodontic appliance, it will also be necessary to use appropriate proportions of nanoparticles in alloys.

Suggestions

1. Nanoparticles are increasingly involved in dentistry. where they become an integral part of treatment. Their dynamic development should also include other fields of somatology, such as orthodontics.
2. The improvement of the biomechanical value of the orthodontic locks and arches, as well as the interference with the bacterial flora by nanomaterials seem worth developing.
3. The level of compatibility remains a challenge for nanoparticles in the future. Further research is required to determine the safety of their use.

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