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NANOTECHNOLOGY IN ORTHODONTICS – A REVIEW

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ABSTRACT Nanotechnology which concerns structures at a microscopic and atomic level is being utilized by not only dentistry but other fields as well and will soon become an integrated part of our daily life. This review highlights the various applications of nanotechnology in Orthodontics.

KEYWORDS : Nanotechnology, Nanodentistry, Orthodontics.

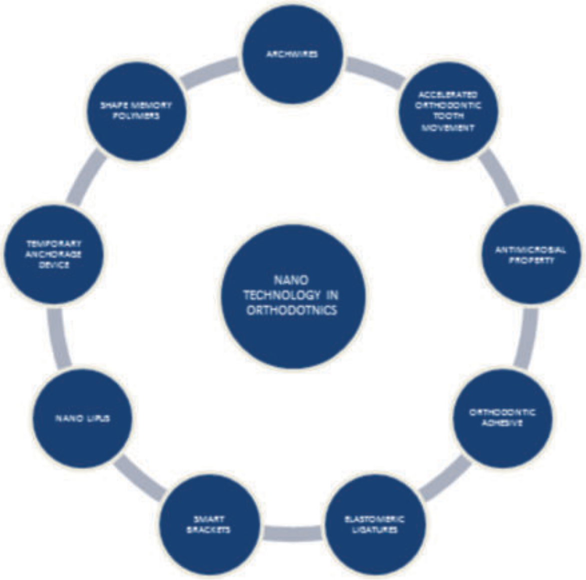
INTRODUCTION:

Nanotechnology is the science of manipulating matter, measured in the billionths of a nanometer, roughly the size of two or three atoms.

The term "Nano" is derived from Greek word meaning "dwarf". Nanotechnology is the science of manipulating matter, measured in the billionths of a nanometer, roughly the size of two or three atoms [1]. Nano dentistry is the science and technology of maintaining near-perfect oral health through the use of nanomaterials including tissue engineering and nanorobotics [2]. Dentistry compromises of many interdisciplinary branches and nanotechnology has different applications for each like local drug & anaesthesia delivery in oral surgery & periodontics, advanced diagnosis in oral medicine and biomechanics in orthdodontics [3].

Nanotechnology In Orthodontics:

Nanotechonology has a wide array of applications in orthodontics.



In Archwires:

It is known that less frictional forces between the orthodontic wire and the bracket slot produces more desirable forces and better results and hence dry lubricants are used to coat the surface of archwires to reduce the friction. Inorganic fullerene-like nanoparticles of tungsten sulfide (IF-WS_2) have been used as self-lubricating coatings for orthodontic stainless steel wires and a study done by Redlich et al has found 54% reduction in frictional forces when the wires were coated [4].

Hollow wires are wires coated with NiTi/Ni-TiO_2 composite nanoparticles via the synthesis method called ultrasonic spray pyrolysis (USP). The precursor solution for the synthesis of spherical NiTi particles is prepared from an orthodontic wire with a chemical composition of Ni (amount fraction x = 51.46 %) and Ti (x = 48.54 %). A textile or polymer fiber is coated with NiTi nanoparticles via electrospinning and then the fiber is removed to produce a hollow wire for orthodontic purposes. This wire could potentially have the shape-memory and superelasticity properties, while possibly reducing the material needed for the wire production [5].

In Shape Memory Polymers:

Shape memory polymers (SMP) are materials that most commonly used in aesthetic archwires. They have the ability to memorize a macroscopic or equilibrium shape and then be manipulated and fixed to a temporary or dormant shape under specific conditions of temperature and stress. They can later relax to the original, stress-free condition under thermal, electrical, or environmental condition. This relaxation is associated with elastic deformation stored during prior manipulation. The return of polymers toward its equilibrium shape can be accompanied by an adequate and prescribed force, useful for an orthodontic tooth movement, or macroscopic shape change, which is useful for ligation mechanisms. Due to it's ability to have two shapes, these devices meet needs unattainable with current orthodontic materials allowing for easier and more comfortable procedure for the orthodontist to insert into the mouth of the patient [6,7]. Once placed in the mouth, these polymers can be activated by the body temperature or photoactive nanoparticles activated by light and thus bring about tooth movement. The orthodontic wires can provide improvements over traditional orthodontic materials as they will provide lighter, more constant forces which in turn may cause less pain for the patients. In addition, the SMP materials are clear, colourable, and stain resistant, providing the patient a more aesthetically appealing appliance during treatment. The high percent elongation of the SMP appliance (up to about 300%) allows for the application of continuous forces over a long range of tooth movement and hence, results in fewer visits for the patient [8,9].

In Orthodontic Adhesive:

Nanoparticles which are very minute in size are found in nanofiller composites. Due to the reduced dimension of the particles there is a wide size distribution the filler load can be increased and that increases the mechanical properties such as tensile and compressive strength [10]. Hence resistance to fracture is increased and polymerization shrinkage is reduced [11]. Geraldeli and Perdigao reported that nano-composites had a good marginal seal to enamel and dentine compared with total-etch adhesives [12]. Few of the advantages of nanocomposite materials include their excellent optical properties, easy handling characteristics and superior polishiability due to the filler size [13]. Due to its highly polished surface, bacterial adhesion is quite less [14,15].

Resin modified GIC has been improved by incorporating nano-sized fluoroapatite (NFA) or fluorohydroxyapatite (NFHA) particles at 25% concentration; however, this was at the cost of significant reduction in shear bond strength. The fluoride release nearly tripled after 70 days [44]. Nano-hydroxyapatite (Nano-HA) has also been added to orthodontic banding cement to prevent microleakage. This study assessed the microleakage under orthodontic bands by the methylene blue dye penetration method after 60 days [16]. Copper (Cu/CuO) and ZnO nanoparticles have been coated on either brackets or added to cements and bonding agents to reduce the demineralization produced as a result of orthodontic treatment [5]. Silver NPs have been added to composite adhesive containing silica nanofillers. Addition of silver nanoparticles significantly reduced the adhesion of cariogenic streptococci to orthodontic adhesive relative to conventional adhesives, without compromising physical properties [17].

In Elastomeric Ligatures:

Elastomeric ligatures can serve as a carrier base for delivery of nanoparticles which can render anticariogenic, antiinflammatory and antibiotic properties. Studies have supported the release of anticariogenic fluoride from elastomeric ligatures and they conclude that the fluoride particles could be dispensed from elastomeric ligature which is characterized by an initial burst of fluoride during the first few days followed by a logarithmic decrease [18,19].

BIO MEMS/NEMS For Orthodontic Tooth Movement:

Biomedical Microclectromechanical systems (Bio MEMS) can be defined as the science and technology of operating at the microscale for biological and biomedical applications, which may or may not include any electronic or mechanical functions. They are made up of micromachined elements usually made of sillicon, including gears, motors with linear and rotary motion for applications to biological systems. Implantable bioMEMS have been used as biosensors for in vivo diagnosis of diseases and drug delivery microchips [20,21,22]. Nanoelectromechanical systems (NEMS) are devices which combines electrical and mechanical functionality on the nanoscale level. According to the evidence orthodontic tooth movement can be enhanced by supplementing the mechanical forces with electricity. Animal studies have shown increased tooth movement on giving the electric stimulation which enhances cellular enzymatic phosphorylation activities, and leads to accelerated tooth movement [23,24]. These findings suggest that electric stimulation enhanced cellular enzymatic phosphorylation activities, leading to synthetic and secretory processes associated with accelerated bone remodelling [10].

Nano LIPUS Devices:

Low–intensity pulsed ultrasound (LIPUS) has been reported to be effective in liberating preformed fibroblast growth factors from a macrophage-like cell line (U937), and it enhances angiogenesis during wound healing [25]. LIPUS has been reported to enhance bone growth into titanium porous–coated implants and also bone healing after fracture and after mandibular distraction osteogenesis. The specific mechanisms by which ultrasound stimulation works on bone cell activities are still unknown [26]. El-Bialy et al in their study applied LIPUS on the temporomandibular joint (TMJ) region of growing rabbits and baboon monkeys for 20 minutes daily [27]. Their results show a significant increase in mandibular cartilaginous growth, especially under chronic mandibular advancement [28]. In another study by Oyonartea et al experimental rats were stimulated with LIPUS in the TMJ region unilaterally, for 10 or 20 minutes for 20 days. The results showed that LIPUS application may affect mandibular growth pattern in rat [29].

Another application of this technique is to reduce root resorption during orthodontic treatment. Based on their observation that LIPUS can promote dental tissue formation in rabbits, el-Bialy et al [30] concluded that it may be used to treat root resorption and similar results were found by Liu et al [31]. The initial devices were bulkier but with nanotechnology the LIPUS device can be made more compact with a chip design.

Temporary Anchorage Device (TAD):

Biocompatible coatings like Titanium nanotubes can be applied to evaluate if this can enhance initial osseointegration and can serve as an interfacial layer between the newly formed bone and the mini screw which could prevent failure of TAD [32].

Smart Brackets:

Lapaki et al reported on the introduction of a 'smart" bracket for multidimensional force and moment control. Nanomechanical sensors can be fabricated and be incorporated into the base of orthodontic brackets to provide a clear assessment and real time feedback of the applied orthodontic forces, which allows precise application of force within the biological limits [33].

CONCLUSION:

The future in orthodontic treatment will benefit enormously through nanotechnology should all the current attempts succeed to its clinical application which would be beneficial to both the orthodontist and the patient The toxicity of the nanoparticles/materials should not be neglected and must be properly evaluated prior usage as they come in direct contact with the oral cavity which could be biohazardous.

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