Journal of Pharmaceutical Research International

Volume 35, Issue 27, Page 30-40, 2023; Article no.JPRI.108307
ISSN: 2456-9119
(Past name: British Journal of Pharmaceutical Research, Past ISSN: 2231-2919, NLM ID: 101631759)

Knowing the Unknown: A Review on Nanotechnology in Orthodontics

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JPRI/2023/v35i277443

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/108307

Review Article

Received: 15/08/2023
Accepted: 20/10/2023
Published: 27/10/2023

ABSTRACT

Nanotechnology is the structuring and manipulation of matter at nanoscale for the creation of new particles and devices. The applications of nanotechnology are being explored in various arenas including health care. The use of this technology aims to improvise the quality of health care being rendered to the patients. Nanotechnology has paved its way into various specialties of dentistry including orthodontics. The goal of these innovations and research in this field is to improve human life and health. The merging of nanotechnology with orthodontics helps the clinicians to a great extent in improving the quality of patient care and its applications. This article aims to summarize and describe the most recent advancements and well-known nanotechnological innovations in the field of orthodontics and the use of new nanomaterials, nano devices, nano LIPUS, nano particles and nano sensors incorporation of the same to the arsenal of Orthodontics.

Keywords: Nano materials; nano orthodontics; nano robots; nano technology; nano dentistry.

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1. INTRODUCTION

Conventional orthodontic treatment has seen a giant leap in technological advancement in the last decades. Nanotechnology describes the technique of creating and utilizing devices and components comparable in size to molecules and intracellular architecture at the size scale of less than 100 nm.

Nano technology bundles up an array of rapidly emerging technologies based on the scaling down of existing technologies to the next level of precision and miniaturization and it has found its magnificent entrance to the field of dentistry and re-emerging as nano dentistry. An arsenal of nano technological advancements has been directly shot on to the diagnostic and treatment methodologies in the field of orthodontics and thus escalating the overall quality of treatments granted [1].

As it goes with the saying "there is plenty of room at the bottom" ,there is more to be added to the name nanotechnology which was initially coined by Norio Taniguchi in 1974 at Tokyo science University [2]. "The term nanotechnology has its origin from the Greek word "nannos" meaning dwarf. Nanotechnology involves a vast arena of design characterization, production and applications of structures, devices and systems by controlling shape and size at nanometer scale along with the direct manipulation of materials at the nanoscale" [3].

"Nanomaterials are now used widely in the dentistry they target in modifying various properties, such as antimicrobial properties and durability of materials. As these nanoparticles do not exceed 100 nm, they obtain a better ratio between the surface and mass. Nanotechnology is currently employed in improvising brackets, arch wires, elastomeric ligatures and orthodontic adhesives. It improves the microbicidal properties thus reducing friction thus facilitating better treatment outcome" [4].

2. METHODOLOGY

A review of literature was carried out by following the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines. The study protocol was developed to address the main research question and the study's eligibility criteria. The scoping review was performed on MEDLINE, Cochrane Library, EMBASE, PubMed, Google Scholar, Web of Science, and Science Direct to collate the studies on nanotechnology in orthodontics. The literature search was dated back to fifteen years from the time of this review and was limited to English language only. First-level screening was done to select articles for the review on the basis of title and abstract. Then, full texts of selected articles were studied, and relevant articles were selected to be included in this review. A total of 125 articles were collected, out of which 108 were retained. Articles selected were critically appraised to evaluate their quality.

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3. REVIEW

3.1 Application of Nanotechnology in Orthodontics

3.1.1 Nano coated Arch wires

Kusy et al. done a study and showed that effective reduction in treatment time and risk of root resorption could be brought out by the decreased frictional force between arch wire and brackets [5]. Reduction of friction between the bracket slot and arch wire when a tooth slides along the arch wire can be attained by coating nanoparticles on the surface of wire. Khatria et al. reported that self-lubricating coating containing fullerene-like tungsten disulfide (IF-WS_2) nanoparticles are productively used as a dry lubricant on the orthodontic wires [6].

"A new type of composite metal–NP coating that significantly reduces the friction force of various surfaces, particularly arch wires in orthodontic applications, is developed. The coating is based on electrodeposited Ni film impregnated with IF like nanospheres of tungsten disulfide" [7]. The best materials that aids in reduction of friction by coating the arch wire areMoS_2 (molybdenum disulfide) and W2 (tungsten disulfide) [8].

The development of dry lubricants has emerged as part of the use of nano-particles to reduce friction. These solid phase materials are highly capable of reducing friction between two surfaces without the need for a liquid media in between two sliding surfaces. Nanoparticles which are biocompatible in nature are coated on surface of orthodontic stainless steel wires for the friction reduction. Redlich et al. reported that materials coated on to nickel titanium (NiTi) wires and a reduction of frictional force by about 21% and efficient antibacterial activity against Streptococcus mutans was observed [9]. Venkatesan et al. did a study and observed that stable and well-adhered cobalt combined with IF-WS2 coating of the NiTi substrates under friction tests gave out up to 66% reduction of the friction coefficient [10]. "NiTi orthodontic wires when coated with Zn O nanoparticles using the chemical deposition method has shown up to 21% reduction in the frictional forces and antibacterial activity against Streptococcus mutans. surface quality of NiTi wires were also improved after Zn O nanocoating" [11].

3.1.2 Orthodontic brackets

"In fixed orthodontics, brackets and archwires are used to correct the irregularity of teeth. For effective tooth movement to occur , the wire should be able to move inside the bracket, and friction between bracket and wire surfaces opposes this ability" [12] .Ameli et al. stated that coating the bracket using different nanoparticles, especially metal nanoparticles like silver hydroxyapatite (S-HAP), copper oxide (CuO), and titanium oxide (TiO) nanoparticles which were used as solid lubricants since the 1990s, were successful in reducing wire bracket friction [13].

Cao et al. in 2013 used "brackets coated with a thin film of nitrogen-doped titanium oxide (TiO_2) NPs and reported on the antimicrobial and bacterial adhesive properties against normal oral pathogenic bacteria through visible-light. The nitrogen doping and modification enable TiO_2 to exhibit catalytic activity within the visible-light region. The activation leads to the formation of OH, free radicals, superoxide ions, peroxyl radicals, and hydrogen peroxide. These chemicals, through a series of oxidation reactions, react with biological molecules such as lipids, proteins, enzymes and nucleic acids, damage biological cell structures, but also exert antimicrobial activity. Good anti-adhesive properties against *Streptococcus mutans* were observed in this study".

"The rate of antimicrobial activity of the coated bracket against streptococcus mutans, lactobacillus acidophilus, Actinomyces viscous and Candida albicans were 95%, 91%, 69% and 99%, respectively. These findings have implications on the prevention of enamel demineralization and gingivitis during orthodontic treatment" [9].

3.1.3 Orthodontic power chains

Generally made from polymeric materials (polyesters or polyethers), power chains form an inevitable entity in everyday orthodontic practice. Offering a wide array of clinical advantages like being affordable, easy to use and able to be adjusted to every patient, power chains can offer light and continuous forces as and when required. But it has to be mentioned that power chains demonstrate their disadvantages as well like being effective for a limited period of time and also exhibiting hydrophilic characteristics. Thus, power chains eventually undergo dis colouration and absorb oral fluids, making it very difficult to maintain hygiene [14].

Inorder to improve the properties of power chains, several studies have been carried out and one among them is a study by Cheng et al, wherein they performed a surface treatment called nanoimprinting [15]. The treatment consists of creating nanostructures on the surface of the chains called nanopillars. This treatment converts the material from hydrophilic to hydrophobic and thereby solves some disadvantages of power chains.

3.1.4 Orthodontic bands

Orthodontic bands have been incorporated in fixed mechanotherapy to facilitate certain tooth movements. But, the use of bands has been often associated with plaque accumulation and cause a imbalance in the oral flora. With the help of nanotechnology, dental resins and cement have been incorporated with antibacterial particle like nano silver particles [16]. These cements are found to be biocompatible, though further future studies have to be carried out to validate the efficiency [17].

“Orthodontic bands are seated in supra- and subgingival areas, that eventually compromises the health of the surrounding periodontal tissues and leads to the occurrence of periodonto pathogenic bacteria” [18]. “Coated orthodontic bands with silver nanoparticles were biocompatible, had distinct antimicrobial activity, and could be developed into antimicrobial dental bands for future clinical use” [16].

3.1.5 Control of oral biofilm

Orthodontic appliances could diminish the self-cleansing ability of teeth, alter the oral microflora and increase the levels of acidogenic plaque bacteria, i.e., mutans streptococci and lactobacilli in saliva and dental biofilm during active wear of the appliance. Many metals in nano particle form were employed as antimicrobial agents including Silver, copper, gold, titanium, and zinc with different properties and wide range of actions [19]. Most of the toothpastes and mouth washes, by incorporating powdered zinc citrate or acetate controls the formation of dental plaque. Titanium dioxide in powder form is also used as a whitening agent in toothpastes [20].

Pabha et al. conducted a study to “evaluate the anti-biofilm activity of chlorhexidine-releasing elastomerics against dental microcosm biofilms and concluded that Chlorhexidine-releasing elastomerics showed an increased in the anti-biofilm and demineralization-inhibiting effect compared to 0.1% chlorhexidine mouthwash. Therefore, it is possible to prevent biofilm-related diseases effectively by applying chlorhexidine-releasing elastomerics to orthodontic patients” [16].

3.1.6 Nano particles in orthodontic adhesives

Calcium hydroxyapatite nanoparticles are commercially made available or synthesized from natural sources. Several techniques for hydroxyl apatite synthesis have been proposed such as sol-gel, wet chemical precipitation, sono chemical and microwave [21].

New class of material called polymer nano composites contains nano fillers that are 0.005 - 0.01 microns in size. The common nanoparticles used in orthodontic adhesives are Curcumin (Cur), Curcumin-Zinc oxide (Cur-ZnO), Copper (Cu), Copper oxide (CuO), Quaternary ammonium polyethyleneimine (QPEI), Silver (Ag), Silver-Hydroxyapatite (Ag-HA), Titanium dioxide (TiO2), and Zirconium Oxide-Titanium dioxide (ZrO2-TiO2). Ahn et al reported that “there was no significant difference in the shear bond strength of different percentage of Ag nanoparticle was used” [22].

Different percentage of Cu (0.01 wt%) and CuO (0.01, 0.5, and 1 wt%) in studies showed increased shear bond strength with no negative effect [23]. Evaluation of the shear bond strength of different percentage of TiO2 nanoparticles were compared and the mean value of shear bond strength of the experimental groups with 0.1, 1, and 5 wt% TiO2 were significantly high, while the lowest value was seen in 10 wt% TiO2 nanoparticles group [24]. Al Thomali etal. did a comparison of shear bond strength of Nano-Bond adhesive system with AgNPs and reported significantly highest mean SBS (20.25 MPa) than Nano-Bond adhesive system without additives (15.64 MPa,p =0.001) [25].

3.1.7 Nanotechnology in elastomeric ligatures

Elastomeric ligatures are made of polyurethane material which are widely used to secure arch wires to the brackets. Orthodontic therapy can increase the plaque accumulation and microbial colonization due to increased retentive areas with difficulty in maintaining meticulous oral hygiene measures. Bacterial counts increase approximately thirty times at six weeks with an increase in Streptococcus mutans, Staphylococcus aureus and Lactobacilli.

Nanoparticles can be influxed to the elastomeric ligatures to achieve anticariogenic and anti inflammatory properties. Newer elastomeric ligatures (Orthoshield Safe-T-tie) that incorporates silver-zeolite which releases silver ions to decrease microbial colonization around brackets have been introduced widely. Kim et al. did a study and found no significant differences in the antimicrobial property among nano coated silver elastomers and conventional elastomers [26].

Caccianiga et al. did a study and stated that Orthoshield Safe-T-Tie ligatures effectively reduced gingival inflammation and periodontal pathogens in orthodontic patients. Orthodontic elastic modules decorated with AgNPs demonstrated higher physical properties such as maximum strength, tension and displacement compared to conventional modules [27].

"Polymeric coating utilizing the Metafasix Technology and the OrthoShield Technology have been introduced in the Super Slick™ and Safe-T-Ties™ by TP Orthodontics, Ortho Organizers, respectively, to reduce bacterial adhesion. The unmodified elastomeric modules Mini Stix™, Hand-EE-Lasts™ was associated with higher mean values of colony-forming units/millimeter than the surface modified Super Slick™ and Safe-T-Ties™ ligatures" [1].

3.1.8 Enamel remineralization

Application of nanotechnology is successfully rendered nowadays for remineralization of incipient caries lesions as well as biomimetic strategies for enamel synthesis. Bencze et al. did an analysis of *in vitro* data and has revealed that apatite nanoparticles might be effective in reversing lesion progression in the outer part rather than in the deeper part of early caries lesions [28]. "The development of calcium and phosphate or fluoride ion-releasing nanofillers, enabling resin composites to release ions, if the pH decreases under *in vitro* conditions to control caries-induced demineralization is the new feat in dentistry. Strategies for formation of highly organized biomineralized structures that aids in remineralization include oriented aggregation of nano crystallites or the assembly of apatite nanoparticles mediated by organic scaffolds" [29].

"Nanotechnology is promising to inhibit caries by controlling biofilm acids and enhancing remineralization. In order to combat biofilms and the acids, nanoparticles of silver were incorporated into composites/adhesives, along with quaternary ammonium methacrylates(QAM). Nano particles of amorphous calcium phosphate (NACP) released calcium/phosphate ions has been found to re mineralize tooth-lesions and neutralize acids. By combining nanoparticles of silver/QAM/NACP, a new class of composites and adhesives with antibacterial and remineralization benefits were developed. Cheng et al. reported that metal and oxide nanoparticles such as Zn O and TiO_2, as well as poly ethylenimine nanoparticles exhibited excellent antibacterial capabilities in dental resins. These nanoparticles when incorporated into dental composites/ cements /sealants/ bases/ liners/adhesives proved to be promising" [30].

"Nano characterization is the technique that utilizes the unique capabilities and resolution of nanotechnology that enables nanoscale probing of surfaces using forces, displacement resolutions, and concentrations on the pico newton, nanometer, and picomolar scales, respectively. Using atomic force microscopy techniques diseases like dental caries, tooth hypersensitivity, periodontitis, and oral cancer, could be quantified. Using nano characterization tools for oral fluids like saliva, a variety of oral diseases could be understood at the molecular and cellular levels, and thereby prevented effectively" [31].

3.2 Recent Advances in Nanotechnology in Orthodontics

3.2.1 Nano LIPUS in orthodontics

Low-intensity pulsed ultrasound (LIPUS) has been shown to enhance cell metabolism. Its efficacy for bone regeneration and healing of fractures has long been proven for which it is approved by the US Food and Drug Administration and the UK National Institute for Health and Care Excellence. Ultrasound in combination with functionalized microbubbles has been shown to induce local shear forces and controllable mechanical stress in cells, amplifying the mechanical effects of LIPUS. Nanoscale lipid bubbles (nanobubbles) have high stability and good biosafety. However, the effect of LIPUS combined with functionalized nanobubbles on osteogenesis has rarely been studied.

Yao et al. reported that the nanomechanical force generators cyclic arginine-glycine-aspartic acid-modified nanobubbles [cRGD-NBs] with a particle size of ~ 500 nm could promote the osteogenesis of bone marrow mesenchymal stem cells (BMSCs) and bone formation induced by LIPUS, through integrin receptors, actin cytoskeleton, and intracellular calcium oscillations [32].

El Bialy et al stated that "applying LIPUS decreased the treatment time to 49% and the patient compliance increased to about 66% by comparing patients using LIPUS and Invisalign SmartTrack® clear aligners with those only using the aligners" [33].

El Bialy et al. reported that "the effect of low intensity pulsed ultrasound (lipus) on tooth movement and root resorption is evaluated and it is elucidated that LIPUS increased the rate of tooth movement by an average of 29%. For orthodontic root resorption, the LIPUS side (0.0092 ± 0.022 mm/week) showed a statistically significant decrease as compared to control side (0.0223 ± 0.022 mm/week). The LIPUS application accelerated tooth movement and minimized orthodontically induced tooth root resorption at the same time" [34].

3.2.2 Nano robots

"Nanorobotics is defined as the discipline of designing and constructing nanorobots whose components are at or near the scale of a nanometer. Nanorobots have been used for acceleration of tooth movement through the use of nanoelectromechanical systems (NEMS) and nano LIPUS ultrasound device" [35].

Verma et al. stated that "nanorobots are 0.5–3 mu in diameter and they are constructed with parts of dimensions in the range of 1–100 nm. The element mostly used is carbon in the form of diamond/fullerene nanocomposite owing to its increased strength and chemical inertness. Other light elements such as oxygen, nitrogen can also be used for special purposes. An external passive diamond coating is found to provide a smooth, flawless coating" [36].

Orthodontic robots facilitates painless tooth up righting, rotating, and vertical repositioning, as well as rapid tissue repair in a lesser time as compared to the conventional methods [37]. "Nanorobots are found to induce oral analgesia, desensitize the tooth and they manipulate the tissue to level and align the irregularities of teeth and to improve the life and also the durability of teeth" [38].

Nanorobots can directly manipulate periodontal tissues that makes them a pertinent orthodontic treatment tool [39]. "Nanorobots are also used in preventive, restorative & curative procedures. An important application of the nanorobots is in implant placement in orthodontics and maxillofacial surgeries , cleft palate surgeries, and aids in improving surgical efficiency and precision" [40].

The practice of "whole tooth renaturalization" might gain popularity and displace more common operational dental treatments. With the regeneration of tissues, the patient may benefit from replacing the missing tooth. The dentinal tubules can be selectively occluded by biological materials created using nanotechnology, which can treat the patient quickly and effectively. Nanorobots can directly alter the periodontium, including the alveolar bone and periodontal ligament, causing the teeth to move quickly and painlessly in a few hours. Once a day, nano robotic toothpastes move across the supra as well as subgingival surfaces of the tooth and eliminates any debris and associated organic matter, while detecting cariogenic bacteria in the bio film [41].

"Dental robots (also called dentifrobots), kinds of nanorobot that are incorporated in mouthwash or toothpaste to cleanse the surfaces above and below the gingival margin, and that inhibit the formation of calculus, later breaks down these into organic matter into harmless and odorless vapors; they are safely inactivated when ingested" [42].

"Robots can be used in to aid in mini implant placement, for calibrating forces and stresses on the implant and between implant and bone. It can also be utilized for measuring the torque and stability of the implant site, as well as to enhance accuracy of implant placement. Different systems that incorporates nano robots include, surgical robotic arms, stress sensors, coordinate measuring machines, and optical navigators" [43].

3.2.3 Smart brackets

"Smart orthodontic brackets are a significant technological advancement in orthodontics. Smart orthodontic brackets are incorporated with sensors and digital capabilities that aids in the monitoring and management of orthodontic treatments" [44]. "They primarily regulate and control tooth movement more effectively than conventional brackets. They are constructed based on advanced nanoelectronics technology, that gives control over the direction, amount, and speed of tooth movement. Real-time monitoring, wireless connectivity (communication between the brackets and external devices, such as computers or smartphones), data collection, and patient engagement and compliance are the prime features of this bracket" [45].

Lapatki et al. in 2007 introduced a novel "smart" bracket for multidimensional force and moment measurement .They developed a nano system chip that can be encapsulated into small low-profile contemporary bracket systems with reduced mesio-distal and occluso gingival dimensions that enabled the clinical testing of the utilization of this technology [33].

In 2013, M. Kuhlet al came up with a prototype bracket with a wireless stress mapping chip that achieves a maximum stress resolution of 11 kPa with a power consumption of 1.75 Mw for the stress evaluation. The stress mapping chip was fabricated in a 0.35µ m process and a micro coil produced by gold electroplating in a photoresist mask.

They worked on the concept of developing a smart bracket with an integrated sensor system for 3D force and moment measurement, using finite-element (FE) simulation and came up with promising results. It was proposed that quantification of real time forces exerted by the orthodontic mechanisms would aid in optimization of the applied mechanical stimulus to predict the course of tooth movement as well as reduction of traumatic side effects such as orthodontic pain and external apical root resorption.

Nanomechanical sensors incorporated into the base of orthodontic brackets could make a clear assessment of the applied orthodontic forces, that allows precise force application by orthodontist [46]. These smart brackets rely on an innovative clip system to hold the wires in place and are manufactured in both metal and a translucent ceramic material designed to blend in with the teeth for a less noticeable and more esthetic presentation [47].

3.2.4 Shape memory polymers

Shape memory polymers (SMPs),also called Actively Moving Polymers(AMPs),are a class of polymeric materials that demonstrates Shape Memory Effect(SME).Different types of polymers, such as polyacrylate copolymers, polynorbornene, segmented poly urethanes, segmented polyurethane ionomers, epoxy - based polymers, thiolene -based polymers, cross linked poly cyclo octene, crosslinked ethylene – vinyl acetate copolymer and styrene -based polymers could exhibit SME [48].

“An increased interest in producing esthetic orthodontic wires to complement tooth colored brackets are emerging these days .Shape-memory esthetic polymer is an area of potential research” [49]. Shape memory polymers (SMPs) are materials that have the ability to “memorize” a macroscopic shape, be manipulated and fixed to a temporary or dormant shape under specific conditions of temperature and stress, and then later relax to the original, stress-free condition under several external stimuli such as temperature, magnetism, electricity, specific wavelength, moisture, pH and some specific chemicals [48]. Intraorally these polymers are activated by the body’s temperature and photoactive nanoparticles are activated by light [50].

Akihiko et al. reported that nowadays shape memory polymers holds more patents on SMPs registered in the field of orthodontics (51%) compared to other fields of dentistry, ranging from arch wires, clear aligners to elastic modules and orthodontic bands [51].

3.2.5 Bio MEMS

Biological micro electromechanical system are microcircuits that include electric motors and generators for the application of linear or rotational movement to a biological substrate [52]. BioMEMS can be reproduced at a nano level and these electrical circuits can be used to aid in orthodontic tooth movement. It has been found that these electrical stimulation has a positive effect on acceleration of bone remodeling [53].

Biological MEMS (BioMEMS) or biomedical microelectromechanical systems are rapidly emerging field and they are developed as a subset of MEMS devices which were used in biomedical research and medical micro devices [54].

BioMEMS, if placed in the gingiva in close proximity to the alveolar bone, could provide enzymatic movement with the use of a micro battery. This mechanism mainly uses organic sources such as glucose. Nano structures particularly those with high electrical conductivity are used to construct these type of devices .Due to the large surface area, nanostructures can optimize the enzymatic processes [8]. By using electricity to complement the mechanical forces these devices could accelerate orthodontic tooth movement [55].

Kolahi et al. did a study and reported that on optimal improvisation of soft tissue biocompatibility and the influence of food with varying temperatures and pH on the performance of a microfabricated protein battery MEMS/NEMS based system can be used to enhance orthodontic tooth movement [56].

The other main areas of applications of BioMEMS in the clinical field are diagnostic (using implantable sensors) and therapeutics (drug delivery microchips). Implantable bio MEMS are used as biosensors for in vivo diagnosis of diseases and drug delivery microchip.

Nanoelectromechanical systems (NEMS) are devices integrating electrical and mechanical functionality on the nanoscale level. Orthodontic tooth movement can be enhanced by supplementing the mechanical forces with electricity. Animal experiments indicated that when 15— 20 micro- amperes of low direct current (dc) when applied to the alveolar bone by modifying the bioelectric potential, osteoblasts and periodontal ligament cells showed an increased concentrations of the second messengers cAMP and cGMP. These findings proves that electric stimulation will enhance cellular enzymatic phosphorylation activities, and will lead to synthetic and secretory processes associated with accelerated bone remodeling to aid orthodontic tooth movement.

Govindankutty et al. stated that many nanostructured materials, such as mesoporous media, nanoparticles, nanofibers, and nanotubes, are efficient hosts of enzyme immobilization. Over the next few years the MEMS/NEMs based system develop biocompatible powerful biofuel cells, which can be safely implanted in the alveolus of the maxilla or mandible to enhance orthodontic tooth movement [57].

3.2.6 Nanotechnology in mini implants

Temporary anchorage devices procure their stability mechanically (cortical or bi cortical stabilization) and do not require biomechanical osseointegration. Mini screws had proved to be versatile: they are available in favorable sizes, can be easily inserted and removed, are affordable, and the procedure can be easily performed by a qualified orthodontist [58]. It is necessary to have close intimacy between the bone and the surface of the mini screw, as this will provide improved stability and increased resistance to orthodontic forces. Inflammatory response might affect the primary stability of mini implant and may lead to premature loss of the screw.

Studies were done to evaluate the stability and osseointegration of mini screw post modification of the surface of implant by nano technology. The studied surfaces were characterised by TiO_2 (titanium dioxide) nanotube arrays. These TiO_2 nanotube arrays were then loaded with RhBMP-2 (recombinant human bone morphogenetic protein-2) and ibuprofen and these two groups were then compared with a control group of standard mini screws. The effects of the drugs were evaluated in vivo: the study was aimed to assess the positive effects of drug-modified mini screws on tissue health.

These modified mini screws can deliver other drugs, such as antibiotic agents, aspirin and Vitamin C, and thus decrease inflammation at the insertion site and reduce patient discomfort. The modifications on implant surface were successful in ensuring greater surface roughness and improving wettability compared to the conventional mini screws [2]. Padmanabhan et al. stated that the small sized nanoparticles when incorporated into surface of mini implants provides a greater surface area and leading to improvised reactivity and changes their physicochemical, mechanical and antibacterial properties rendering it more biocompatible intraorally [59].

4. CONCLUSION

The scenario of nanotechnology is evolving in a rapid pace and plays a significant role in development of dental materials and improvisation of armamentarium in orthodontics thus ameliorating patient care. The amalgamation of nanotechnology, nano robotics and nano medicine into orthodontics has overhauled many shortcomings in diagnosis and treatment methods and has incurred significant benefits. It is for sure that advancements in nano technology will fetch more power in the recent future and would emerge and evolve to its full potential and strength benefitting the entire field of dentistry. The dynamic field of nanotechnology has expedited panoramic changes in the orthodontic realm and is promising and propitious for the man kind.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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