Nanotechnology in Orthodontics: A Detailed Review

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ABSTRACT-
Nanotechnology is the science of manipulating matter at the molecular and atomic levels, as well as studying matter at the nanoscale level to detect and exploit the useful properties that result from these dimensions; materials with components smaller than 100 nm in at least one dimension are referred to as nanomaterials. Nanotechnology is used in many fields, including medicine (nanomedicine) and dentistry (nano-dentistry). The goal of these innovations and research in this field is to improve human life and health. This article aims to summarise and describe the most recent and well-known nanotechnology innovations in the field of orthodontics and the use of new nanomaterials in the fabrication.
KEYWORDS - Nanotechtnology, nanodentistry, nanomaterials, nanomedicine, orthodontics

INTRODUCTION-

Nanotechnology is the science of manipulating matter at the molecular and atomic level. Researchers have explored a variety of application areas to recognize and exploit the beneficial properties available from nanoscale components. The term was coined by N. Taniguchi in 1974 (Solanke et al., 2014).

Nanomaterials are materials containing components smaller than 100 nm in at least one dimension. Sheets are defined in one dimension, nanowires and nanotubes in two dimensions, and quantum dots in three dimensions. The fact that these new particles have more surface area per unit mass than larger particles changes the physical and chemical properties of the material significantly (Bhardwaj et al., 2014).

Nanotechnology is used in a variety of fields, including medicine (nanomedicine) and dentistry (nano-dentistry). Nanomedicine is the science of using nanosized particles to prevent, diagnose, and treat disease, as well as to preserve and improve human health. The goal of these advancements and research in this area is to improve human life and health (Kumar and Vijaylakhshmi., 2006).

Although nanotechnology has the potential to make the clinic more efficient and convenient, some authors point out that there are currently limitations in terms of safety (Aeran et al., 2015).

Nanoparticles are intentionally incorporated into dental products to improve their qualities (Schmalz et al, 2015).

In recent years, a new field known as nano-dentistry has grown in popularity, involving the efforts of various researchers and clinicians in the development of new materials. The science of using nanostructured materials and technologies to diagnose, treat, and prevent oral and dental disease is known as nano-dentistry (Bhardwaj et al., 2014). Common goal is to improve patients' oral health while reducing invasiveness of treatments and increasing doctor compliance (Mantri and Mantri., 2013).

This article will summarise and describe the most recent nanotechnology innovations in orthodontics.

DISCUSSION-

Nanotechnology has been expanding its territory in healthcare field. With constant evolution, the utility of Nanotechnology in the field of Orthodontics is widely increasing.

Orthodontic Bands-

Fixed orthodontic treatment frequently necessitates the insertion of dental bands, which are frequently required for orthodontic movements. However, these auxiliaries can cause bacterial plaque to be retained, particularly in the posterior dentition, which are difficult to clean. Prolonged plaque accumulation around orthodontic brackets and bands has been shown to cause a rapid shift in bacterial flora, favouring acidogenic bacteria like Streptococcus mutans and Lactobacilli and increasing the risk of enamel demineralization, white spot lesions, and cavities (Maxfield et al., 2012). Various methods for preventing cariogenic events have been investigated, particularly the efficacy of fluoride-containing products. Their effectiveness is linked to patient compliance and accuracy in domiciliary hygiene procedures (Robertson et al., 2011).

Antimicrobial agents can now be added to dental resins and cement to reduce the incidence of white spot lesions and cavities while keeping the adhesion properties unchanged. Companies attempted to reduce the acidic oral environment and bacterial metabolism by incorporating zinc oxide, chlorhexidine, and fluorides. Furthermore, it is hypothesised in this case that the use of antibacterial release materials such as silver nanoparticles aids in the maintenance of good oral hygiene during orthodontic treatment (Prabha et al., 2016).

To combat the onset of white spots, band cements with antimicrobial properties (antibacterial release materials such as silver nanoparticles) have been developed. These resins have mechanical properties that are potentially comparable to controls, and they have been found to be biocompatible in the majority of cases. However, more research is needed to validate the efficacy of these materials in the oral environment, especially given the length of an orthodontic treatment (Moriera et al., 2015).

Orthodontic Miniscrews-

Two studies examined the stability and osseointegration of nanotechnology-modified miniscrew surfaces: the studied surface was characterised by TiO_2 (titanium dioxide) nanotube arrays (Jang et al., 2015; Jang et al., 2017).

The TiO_2 nanotube arrays were loaded with RhBMP-2 (recombinant human bone morphogenetic protein-2) and ibuprofen and compared to a standard miniscrew control group. The drugs' effects were evaluated in vivo: the study looked at how drug-modified miniscrews improved tissue health. Other drugs, such as antibiotics, aspirin, and vitamin C, can be delivered through these modified miniscrews to reduce inflammation at the insertion site and patient discomfort. This material modification has also proven important in increasing the surface roughness of the aids and improving wettability when compared to conventional products.

Orthodontic Elastomeric Ligatures-

Several studies have attempted to highlight the associations based on the chemical properties of different elastic ligatures and the requirements for modifications to mitigate the effects of microbiological biofilms on oral health. Some studies have evaluated fluoride-releasing ligatures, but the results have been mixed and controversial: some emphasise how, in particular, there is long-term ineffectiveness linked to the ligatures' inability to guarantee a prolonged release over time; they also appear to be ineffective even against decalcification (Hernández-Gómora et al., 2017; Sawhney et al., 2018; Sharma et al., 2018).

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

Recent studies appear to evaluate the potentiality of ligature association with silver nanoparticles, a material that appears to have the ability to counter dental biofilm and decrease enamel demineralization caused by bacterial plaque accumulation, without affecting the mechanical properties of the material itself and thus the effectiveness of orthodontic therapy. Nanotechnology in dentistry applied to materials is novel in the concept of improving anticariogenic properties; silver particles have been incorporated into various materials and can be obtained with minimally invasive methods from elements such as flowers and mushrooms. Silver is known to have superior antibacterial properties when compared to other metals; it has a strong cytotoxic effect on a wide range of microorganisms; the mechanism is unclear; it most likely acts by denaturing respiratory cycle and DNA synthesis enzymes. Silver is also non-toxic and has a high compatibility with human cells. However, additional research is required to determine their actual biocompatibility (Hernández-Gómora et al., 2017).

Orthodontic Power Chains-

Since their introduction in the late 1960s, power chains have been used on a daily basis in every orthodontic practise. They are typically made of polymeric materials (polyesters or polyethers) formed through the polymerization process. They have several clinical advantages: they are inexpensive, user-friendly, and simple to adjust to each patient's needs, and they provide light and continuous forces. They have a high degree of flexibility and improve space closure in extraction cases. Power chains also have disadvantages: it has been amply demonstrated that their mechanical effectiveness is limited in time, necessitating their replacement on a regular basis. The strength of orthodontic power chains is affected by both intrinsic and external factors, which determine permanent deformation. Material composition, manufacturing methods, and external morphology are examples of intrinsic factors. The external factors are the temperature of the oral cavity, pH, and moisture absorption. They also have hydrophilic properties and discolour over time; they absorb fluids from the oral cavity and are thus unsuitable for maintaining oral health (Cheng et al., 2017).

Cheng et al. conducted a study in Taiwan to improve the physical properties of power chains using a surface treatment called nanoimprinting. The treatment entails forming nanostructures called nanopillars on the surface of the chains. The results appear promising, as this treatment converts the material from hydrophilic to hydrophobic, thereby addressing the shortcomings of these orthodontic auxiliaries (Cheng et al., 2017).

Coated Orthodontic Archwires-

Orthodontic treatment is essentially comprised of sliding brackets along an archwire; however, this implies that a friction force develops inevitably between the surfaces of the two auxiliaries (the archwire and the bracket), which opposes the therapeutic movement of the teeth. The force applied by the orthodontic appliance must overcome this resistance in order to perform the dental movement. More than 60% of the orthodontic force used to achieve dental movement is expected to be lost due to frictional forces (Kusy and Whitley., 1997). The design of the bracket (torque), the section of the slot, the types of ligations, the section of the archwire, the inter-bracket distance, and the oral functions are the most important factors in determining friction forces (Chimenti et al. ,2005; Suhani et al., 2018; Syed et al., 2015)

It is easy to see how reducing friction force would benefit treatment times and the risk of root resorption by allowing greater control of movement and anchorage (Gracco et al.,2019; Kusy and Whitley., 1997; Reznikov et al., 2010).

For many years, various strategies have been pursued in order to find solutions to reduce friction. First and foremost, research focused on various bracket designs. Second, various archwire alloys and surface treatments were investigated.

Today, nanotechnology aims to reduce frictional forces, allowing the system to function more easily: it has been proposed that coating orthodontic archwires with a film containing nanoparticles is the best solution. MoS2 (molybdenum disulfide) and W2 (tungsten disulfide) are thought to be the best materials for reducing friction (Gracco et al., 2016; Gracco et al., 2019).

Prevention of Dental Caries and Control of Oral Biofilm-

Antibacterial adhesives containing nanoparticles such as TiO2 (titanium dioxide), SiO2 (silicon dioxide), or SNPs (silver nanoparticles) have been tested and extensively discussed to combat caries around orthodontic brackets (Borzabadi-Farahani et al., 2013; Pokrowiecki et al., 2018). TiO2 nanoparticles added to an orthodontic adhesive have been shown to improve its antibacterial properties for 30 days without compromising its physical properties (Pokrowiecki et al., 2018; Sodagar et al.,2017). SNP adhesives have also been shown to have effective antibacterial properties (Borzabadi-Farahani et al., 2013; Pokrowiecki et al., 2018). These, however, appear to be of limited use in orthodontics because they can cause enamel discoloration and cosmetic treatment outcomes. Another strategy for lowering the failure rate due to dental caries has been to coat the arches or brackets with coatings such as TiO2 nanoparticles doped with nitrogen (Cao et al., 2013; Pokrowiecki et al., 2018) or Ag-Zr nanocomposite coatings (Pokrowiecki et al., 2018; Pradhaban et al., 2014).

Early enamel lesions can be remineralized with dentifrices containing nanosized calcium carbonate (Gracco et al., 2016; Solanke et al., 2014). Prophylactic use of inorganic materials such as hydroxyapatite (HA) or its derivatives with zinc, fluoride, carbonate, or organic compound materials found in food or beverages (Gracco et al., 2016).

New research on dental robots (also known as dentifrobots), nanorobots that are incorporated in mouthwash or toothpaste to clean the surfaces above and below the gingival margin and that counteract calculus formation by metabolising trapped organic matter into harmless and odourless vapours; they are safely inactivated when ingested(Cheng et al., 2017; Gracco et al., 2016; Hernández-Gómora et al., 2017; Jang et al., 2015; Jang et al., 2017; Kanaparthy., 2011; Kumar and Vijaylakhshmi., 2006; Moreira et al., 2015; Prabha et al., 2016; Suhani et al., 2018).

However, some studies have found that the presence of nanofillers in fluoride-releasing materials does not provide additional protection against the development of carious lesions (Melo et al., 2013). More research is needed to assess the degradation and behaviour of these new particles to ensure that they pose no special risks because they are not normally in contact with the organism (Gracco et al., 2016).

CONCLUSION -

Nanotechnology now plays a larger and more consistent role in the dental field due to the potential for significant innovations and benefits. The recent positive results must serve as a catalyst for future research, particularly in the field of orthodontics. We've discussed how nanomaterials have provided numerous benefits in this field, particularly in terms of mechanical and antibacterial properties. The coordination and safety of orthodontic treatment are critical; the limitations of dental materials and technical procedures frequently refer to this goal, but science and nanotechnology have helped to partially solve some limitations, improving patient management in the clinical pathway. However, because production technical difficulties and engineering problems have not yet been completely overcome, nanotechnology must evolve in order to realise its full potential.

REFERENCES-

1. Aeran H, Kumar V, Uniyal S, Tanwer P. Nanodentistry: Is just a fiction or future. J Oral Biol Craniofacial Res, 2015; 5:207–211.
2. Bhardwaj A, Bhardwaj A , Misuriya A, Maroli S, Manjula S, Singh AK . Nanotechnology in dentistry: Present and future. J Int Oral Health, 2014; 6:121–126.

3. Borzabadi-Farahani A, Borzabadi E, Lynch E. Nanoparticles in orthodontics, a review of antimicrobial and anti-caries applications. Acta Odontol Scand, 2013; 72:413–417.
4. Cao B, Wang Y, Li N, Liu B, Zhang Y. Preparation of an orthodontic bracket coated with an nitrogen-doped TiO2-xNy thin film and examination of its antimicrobial performance. Dent Mater J, 2013; 32:311–316.
5. Cheng HC, Chen MS, Peng BY, Lin WT, Shen YK, Wang YH. Surface Treatment on Physical Properties and Biocompatibility of Orthodontic Power Chains. BioMed Res Int, 2017; 2017: 6343724.
6. Chimenti C, Franchi L, Di Giuseppe MG, Lucci M. Friction of orthodontic elastomeric ligatures with different dimensions. Angle Orthod, 2005; 75:421–425.
7. Gracco A, Siviero L, Dandrea M, Crivellin G. Use of nanotechnology for the superlubrication of orthodontic wires. In Nanobiomaterials in Dentistry: Applications of Nanobiomaterials, Elsevier Inc Amsterdam, The Netherlands, 2016;11:241–267.
8. Gracco ALT, Dandrea M, Deflorian F, Zanella C, De Stefani A, Bruno G, Stellini E. Application of a Molybdenum and Tungsten Disulfide Coating to Improve Tribological Properties of Orthodontic Archwires. Nanomaterirls, 2019; 9: 753.
9. Hernández-Gómora AE, Lara-Carrillo E, Robles-Navarro JB, Scougall-Vilchis RJ, Hernández-López S, Medina-Solís CE, Morales Luckie RA. Biosynthesis of Silver Nanoparticles on Orthodontic Elastomeric Modules: Evaluation of Mechanical and Antibacterial Properties. Molecules, 2017; 22: 1407.
10. Jang I, Shim SC, Choi DS, Cha BK, Lee JK, Choe BH, Choi WY. Effect of TiO2 nanotubes arrays on osseointegration of orthodontic miniscrew. Biomed Microdevices, 2015; 17: 76.
11. Jang I, Choi DS, Lee JK, Kim WT, Cha BK, Choi WY. Effect of drug-loaded TiO2 nanotube arrays on osseointegration in an orthodontic miniscrew: An in-vivo pilot study. Biomed Microdevices ,2017; 19: 94.
12. Kanaparthy R. The changing face of dentistry: Nanotechnology. Int J Nanomed, 2011; 6: 2799–2804.
13. Kumar SR, Vijayalakshmi R. Nanotechnology in dentistry. Indian J Dent Res, 2006; 17: 62.
14. Kusy RP, Whitley JQ. Friction between different wire-bracket configurations and materials. Semin Orthod, 1997; 3:166–177.
15. Mantri SS, Mantri S. The nano era in dentistry. J Nat Sci Biol Med, 2013; 4:39–44
16. Maxfield BJ, Hamdan AM, Tüfekçi E, Shroff B, Best AM, Lindauer SJ. Development of white spot lesions during orthodontic treatment: Perceptions of patients, parents, orthodontists, and general dentists. Am J Orthod Dentofac Orthop, 2012; 141:337–344.
17. Melo MAS, Morais WA, Passos VF, Lima JPM, Rodrigues LKA. Fluoride releasing and enamel demineralization around orthodontic brackets by fluoride-releasing composite containing nanoparticles. Clin Oral Investig, 2013; 18:1343–1350.
18. Moreira DM, Oei J, Rawls HR, Wagner J, Chu L, Li Y, Zhang W, Whang K. A novel antimicrobial orthodontic band cement with in situ–generated silver nanoparticles. Angle Orthod, 2015; 85:175–183.
19. Pokrowiecki R, Pałka K, Mielczarek A. Nanomaterials in dentistry: A cornerstone or a black box? Nanomedicine, 2018; 13: 639–667.
20. Prabha RD, Kandasamy R, Sivaraman US, Nandkumar MA, Nair PD. Antibacterial nanosilver coated orthodontic bands with potential implications in dentistry. Indian J Med Res, 2016; 144: 580–586.
21. Pradhaban G, Kaliara GS, Vishwakarma V. Antibacterial effects of silver-zirconia composite coatings using pulsed laser

deposition onto 316L SS for bio implants. Prog Biomater, 2014; 3: 123–130.
22. Reznikov N, Har-Zion G, Barkana I, Abed Y, Redlich M. Influence of Friction Resistance on Expression of Superelastic Properties of Initial NiTi Wires in "Reduced Friction" and Conventional Bracket Systems. J Dent Biomech, 2010; 2010: 613142.
23. Robertson MA, Kau CH, English JD, Lee RP, Powers J, Nguyen JT.MI Paste Plus to prevent demineralization in orthodontic patients: A prospective randomized controlled trial. Am J Orthod Dentofac Orthop, 2011; 140: 660–668.
24. Sawhney R, Sharma R, Sharma K. Microbial Colonization on Elastomeric Ligatures during Orthodontic Therapeutics: An Overview. Turk J Orthod, 2018; 31: 21–25.
25. Schmalz G, Hickel R, Van Landuyt KL, Reichl FX. Scientific update on nanoparticles in dentistry. Int Dent J, 2018; 68: 299–305.
26. Sharan J, Singh S, Lale S, Mishra M, Koul V, Kharbanda OP. Applications of Nanomaterials in Dental Science: A Review. J Nanosci Nanotechnol, 2017; 17: 2235–2255.
27. Sharma R, Sharma K, Sawhney R. Evidence of variable bacterial colonization on coloured elastomeric ligatures during orthodontic treatment: An intermodular comparative study. J Clin Exp Dent, 2018; 10: e271–e278.
28. Sodagar A, Akhundi MSA, Bahador A, Jalali YF, Behzadi Z, Elhaminejad F, Mirhashemi A. Effect of TiO2 nanoparticles incorporation on antibacterial properties and shear bond strength of dental composite used in Orthodontics. Dent Press J Orthod, 2017; 22:67–74.
29. Solanke IA, Ajayi D, Arigbede A. Nanotechnology and its application in dentistry. Ann Med Health Sci Res, 2014; 4:171–177.
30. Suhani MF, Băciu t G, Băciu t M, Suhani R, Bran S. Current perspectives regarding the application and incorporation of silver nanoparticles into dental biomaterials. Med Pharm Rep, 2018; 91:274–279.
31. Syed SS, Kulkarni D, Todkar R, Bagul RS, Parekh K, Bhujbal N. A Novel Method of Coating Orthodontic Archwires with Nanoparticles. J Int Oral Health, 2015; 7:30–33.