IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Nano-Enhanced Periodontics: A Future Of Precision Dentistry.

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Abstract-

Nanotechnology is an expanding scientific domain which deals with the manipulation and application of materials at a level of precision smaller than 100 nanometers (nm). The versatility in characteristics and functions has driven profound developments in various fields such as electronics, medicine, and energy production. More significantly within dentistry, particularly within periodontics, nanotechnology has become promising. Its integration has revolutionized the landscape of how periodontal diseases are managed, ultimately enhancing treatment effectiveness and patients' satisfaction. This review elucidates this rising trend in current application for periodontics; encompassing its roles in diagnosis, therapeutic interventions as well as regenerative.

Keywords- Nanotechnology, periodontics, diagnosis, therapeutic, regenerative.

1. INTRODUCTION- Even twenty years ago, the traditional treatment approaches of mechanical periodontal debridement and maintenance oral hygiene procedures have been accompanied by antibiotics/antiseptics/probiotics to enhance the outcome of therapy.[1] However, efficient delivery to the site poses a challenge.[2] The use of systemic antibiotics in periodontal management is often discouraged due to high chances of harmful side-effects and difficulty achieving mini-mum inhibitory concentrations at the target site because of tissue bound or encapsulated bacteria. Other problems such as prompt decrease in plasma concentration after administration; gastrointestinal intolerance; resistance developed by microbes

leading to inadequate plaque suppression; and hypersensitivity reactions are added barriers against their systemic usage. [3]

These side effects have given rise to the development of new local drug delivery systems, ensuring improved drug concentration at the target site with minimum systemic side effects or toxicity. [4] These systems aim to locally deliver therapeutic levels of prescribed pharmacological agents to the periodontium by means of novel approaches and technologies. [5]

1.1 Nanotechnology: Advancing Diagnosis of Periodontal Disease

Traditional diagnostic aids like probing and radiographs often do not suffice to detect the disease in an early stage. [6] Nanotechnology is a novel technology to increase precision as well as sensitivity of diagnosis of periodontal diseases. One such development includes the use of nanosensors for detection of periodontal diseases. These nanosensors can be used to detect specific biomarkers, e.g.metalloproteinases, present in the (GCF).[7] By showing high sensitivity and specificity, these sensors represent a promising way to detect periodontal diseases at early stage.

Nanotechnology is employed in periodontal diagnosis for nanoscale imaging techniques such as atomic force microscopy (AFM). AFM helps in producing high-resolution images of periodontal tissues, outlining the structures like the periodontal ligament, cementum and alveolar bone. [8] This imaging modality is essential in identification of initial structural changes found within the periodontal tissues which further allows early recognition and management of a disease process.

Nanotechnology has a potential for the treatment of periodontal diseases, as it involves the use of nanomaterials, particularly in relation to drug delivery. A noteworthy development is accomplished by using nanoparticles for effective delivery of drugs to periodontal tissues, thus reducing systemic side effects and increasing drug availability. [9] Furthermore, these nanoparticles have an ability to penetrate tooth surface biofilm which leads to better drug-delivery in targeting the periodontal pocket.

Dentifrobots is a kind of nanorobots that you introduce them to the mouth through mouthwash or toothpaste thus, uses it to remove natural material left on teeth's surface. These nanorobots have the ability to function well over supragingival and subgingival surfaces hence they keep away from hard deposits developing over your teeth. These robots are 1-10 µm in size and they move at 1-10 µm per second. Properly programmed dentifrobots could recognize and destroy pathogenic bacteria in dental plaque. [7]

Nanotechnology has been Advantage taken in the development of new periodontal materials, which include nanofibres and nanocomposites. These materials have enhanced mechanical properties and biocompatibility, making them fairly appropriate for application during periodontal surgical procedures, including GTR and root coverage. [10] Moreover, incorporation of antimicrobial agents into such materials aids in preventing bacterial adhesion and promoting regeneration of tissues related to periodontium.

1.2 Application of Nanotechnology in Regenerative Therapies

Keeping in view the problems encountered during regeneration of lost periodontal tissues is one of the greater challenges to the treatment of periodontal diseases. Nanotechnology has provided new ways to modulate new strategies in facilitating periodontal tissue regeneration. Good outcomes in periodontal structure regeneration were shown by employing nanofibers and nanocomposites, and growth factor-loaded nanomaterials like platelet-derived growth factor and bone morphogenetic protein. All these nanomaterials provide cell attachment and proliferation by acting as a scaffold, thereby promoting the formation of new periodontal tissues.[11]

1.3 Engineering of Ligament Tissue:

Tissue engineering strategies using nanofibers have been investigated to overcome the issue of incomplete or inappropriate healing of the ligament after injury. [6] In this regard, aligned nanofibers revealed a better cellular response to remain under investigation for application as scaffolds for tissue engineering of the ligaments.

1.4 Tissue Engineering and Graft Material:

A graft with nano-structured polylactic-co-glycolic acid on its external surface to promote smooth muscle cell function and conventional PLGA on the inside to promote endothelial cell function has been investigated.[6] This design shall improve integration to vascular tissue, increasing the efficiency of the implant.

Moreover, it has also been explored that nanotechnology has been used in developing nanoscale tissue engineering scaffolds, which have the potential for emulating natural extracellular matrix, thus enables periodontal tissue regeneration. [12] These scaffolds can also be functionalized and loaded with growth factors and antimicrobial agents to enhance their regenerative potential.

1.5 Dental Hypersensitivity:

Dental hypersensitivity is another such condition where nanodental treatment can yield promising results. Most of the therapeutic agents for Dental hypersensitivity are short-term relieving. But dental nanorobots can close selectively some of the tubules using natural biomaterials in just minutes and provide immediate relief and recovery from this disorder. [13] Tian et al. suggested that due to the high dispersion of nanomaterials, they easily enter dentinal tubules which are normally of the diameter of 2-3 micrometers to block sensation, hence alleviating dental hypersensitivity. [14]

1.6 Nano Anesthesia:

Anesthesia forms one of the most important parts of periodontal surgery, traditionally involving injections, and for long procedures, this can also include a long wait and the need for multiple injections. Nanotechnology offers a new avenue by encapsulating various anesthetic drugs in liposomes, with high clinical acceptance rates. [16] In other words, these spherical nanovesicles, composed of only a phospholipid bilayer and a hydrophilic core, allow for different drugs to be encapsulated without any distortion. [15, 16]

Nanorobotic local anesthetics are a colloidal solution with suspended, activated nanosized local anesthetic molecules. After being applied to the gingival or oral mucosa and then activated, the anesthetic diffuses through the epithelium and connective tissue, transmitting the anesthetic effect to the pulp, thereby producing dentist-controlled selective anesthesia. [17] This eventually offers greater comfort to the patient, reduced apprehension, absolute selectivity, and analgesic controllability, while the merit of being fully reversible is retained. [18]

1.7 Nanotechnology Applications on Dental Implants:

Several studies have underlined the high impact of nanometrically rough surfaces on early events, including protein adsorption, blood clotting, and cellular behaviors that take place subsequent to the implantation of dental implants. These early events affect migration, adhesion, and differentiation of MSCs. Nanostructured surfaces might modulate differential activities into particular lineages and therefore affect the makeup of the tissue developed around the implant. Although much research is continuously being done on dental implants, the ideal surface for predictable tissue integration remains unknown. [19]

2 Challenges and Future Directions:

Although nanotechnology holds immense potential for being assimilated into periodontics, a few difficulties need resolution before universal approval. The research work is not yet enough to comment on the long-term actions and possible toxicity of nanomaterials in periodontal tissues. Nanoscale imaging techniques and nanosensors call for standardization for their application in clinical practice. The cost assessment for treatments using nanotechnology is also necessary as it can be more expensive.

2.1 Nanotechnology defects

Engineering: Mass production techniques, their workability

– Precise positioning and assembling molecular-scale parts

– Manipulation and coordination of several microrobots

Biological:

– Biocompatible nanomaterial development

– Compatibility with all the intricacies of the human body

Social:

– Issues related to ethics

– Social acceptance

– Regulation measures and human safety

3. Conclusion:

With the advancement regarding this particular field, nanotechnology has become a mighty tool in periodontics and offers immense promise for periodontal diagnosis, treatment, and regenerative strategies. The use of nanosensors, nanoscale imaging modalities, and nanomaterials in periodontal diseases management has unraveled promising results. However, the obstacles for clinically translating nanotechnology into periodontics must be surpassed. It is therefore envisaged that further innovative and more effective methods for the diagnosis and intervention of periodontal diseases will emerge on the horizon with continuous improvements in nanotechnology.

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