NANOTECHNOLOGY IN PERIODONTAL DISEASE TREATMENT: A COMPREHENSIVE REVIEW

Nivetha.S* [1], Kiruba. S [2], Nithya. L [3], Vikhash. T [4], Dr.Senthil Rajan [5]

[1,2,3,4,5] – **Department of Pharmaceutics, Swamy Vivekanandha college of pharmacy, Tiruchengode.**

ABSTRACT:

Globally, 538 million people were estimated to be affected in 2015, with 10-15% of the population generally affected. Periodontal disease is a chronic inflammatory condition affecting the periodontium, which includes the gums, periodontal ligaments, and alveolar bone. It's something that hurts public health big time and is affecting close to 90% of people on this planet. The disease is caused by the interaction between bacterial attack, environment, and host defence responses, leading to inflammation, tissue destruction, and tooth loss. Periodontics is the branch of dental science that aims exclusively on the tooth supporting structures such as gingival, periodontal ligament, cemented, alveolar bone and mucosa, as well as diseases that affect them. Periodontal disease is caused by bacteria in the mouth infecting the tissue around the teeth. Periodontal disease is multi factorial, and nutrition can have a big impact on how long it lasts. A healthy, well-balanced diet has been shown in studies to be essential for maintaining periodontal health. Drug molecules, which are naturally large macro particles and have difficulty penetrating periodontal pockets, are used in medical therapies. On the other hand, nanoparticles can more easily penetrate sub gingival regions due to their small diameters. Nanotechnology has a significant impact on medical and dental diagnostic and therapeutic sciences. Nano materials are highly advanced and essential for speedy detection and helpful in treating a variety of ailments in the health sector due to their distinctive and superior qualities, such as high surface area and nanoscale size. In comparison to their conventional equivalents, advanced nano materials can offer more hopeful outcomes in diagnosis and treatment operations.

KEYWORDS: Periodontal disease, Periodontum , Nano-technology, Nano-materials, Polymers

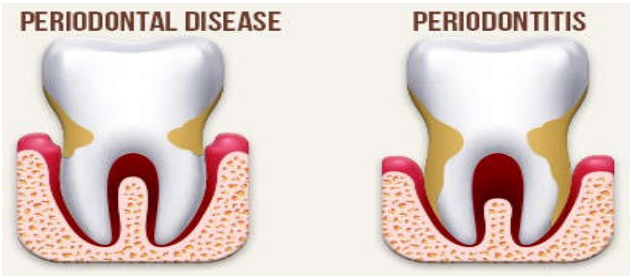
I. INTRODUCTION:

For at least 5000 years, periodontal diseases have been recognised and treated[1].From 1990 to 2010, periodontitis became a stable disease with no discernible decline worldwide[2].Periodontal disease, which affects up to 90% of the global population, is one of the most common chronic inflammatory diseases in humans[3].Periodontal disease is a major dental illness that affects millions of people worldwide[4].Periodontitis is a complex inflammatory disease that depends on the interaction between the bacterial attack, the environment, and the host defence responses to bacterial invasion, which predominantly consists of Gram-negative anaerobic bacteria[5].A chronic, mixed infection of Gram-negative and Gram-positive bacteria causes this condition. This disorder is caused by Gram-negative bacteria such as *Porphyromonasgingivalis, Prevotella intermedia, Tannerella* for synthesis, and *Aggregatibacter (Actinobacillus) actinomycetemcomitans*, as well as Gram-positive bacteria such as *Peptostreptococcus* micros and Streptococcus intermedius[6].The primary goals of

treatment for patients with chronic periodontitis are to slow disease progression and reduce inflammation[7]Periodontal cases are frequently associated with common systemic co-morbidities that necessitate pharmaceutical management, such as rheumatoid arthritis (RA) and dyslipidemia[8].Nanotechnology has been used in dentistry since the early 1970s, when micro fills were popular. Since then, various nano materials have been introduced in the field of dentistry, including periodontology, to aid in the maintenance of proper oral health. A nano material is an object with at least one dimension measured in nanometer (approximately 1 to 100 nm). One nanometer equals one billionth of a metre (10-9m) [9].

II. PERIODONTAL DISEASES:

Periodontal disease has been the most serious problem in our society for centuries, and its prevalence is increasing due to changes in eating habits and oral hygiene practises among the population[10].Periodontal treatment aims to remove bacterial deposits or dental plaque (biofilm) from the tooth's surface using a combination of mechanical treatment and adequate oral hygiene in order to prevent recurrence of infection in the subgingival area by periodontopathic microorganisms and, as a result, to preserve the tooth[11].Periodontal diseases are pathological processes caused by infections and inflammation in the periodontium, or the tissue that surrounds and supports the teeth[3].Periodontal disease is a disease, or more likely a group of diseases, of the periodontal tissues that causes attachment loss and alveolar bone destruction[1].It is distinguished by gum degeneration and inflammation, as well as degeneration and inflammation of periodontal ligaments, alveolar bone, and dental cementum. If left untreated, periodontal disease destroys the alveolar bone around the teeth, resulting in defects or tooth loss [6]. Periodontitis is a serious gum infection. It's caused by bacteria that have accumulated on your teeth and gums. Periodontitis can cause bone and tooth damage as it progresses. The damage, however, can be stopped if periodontitis is treated early and proper oral hygiene is maintained [12].Periodontal disease is a disease, or more likely a collection of diseases. Gingivitis and periodontitis are the most common types of periodontal disease[3]Periodontal disease is a disease, or more likely a numbing condition. Gingivitis is gingival inflammation that does not result in clinical attachment loss. Periodontitis is an inflammation of the gingival and adjacent attachment apparatus that causes loss of connective tissue attachment and alveolar bone.Periodontitis, a disease affecting the tooth's supporting structures, affects people of all races, ethnicities, and genders.[13]Periodontal disease can affect a single tooth or a whole row of teeth. As the disease progresses, the bacteria in plaque cause the pockets to deepen and more gum tissue and bone to be destroyed.[14]Periodontal disease has been the most concerning issue in our society for centuries, and its prevalence is increasing nowadays due to changes in dietary patterns and oral hygiene practises in the population.[15]Periodontal manifestations can occur in genetic, dermatological, haematological, granulomatous, immunosuppressive, and neoplastic disorders.[16]Periodontal disease has been linked to poor pregnancy outcomes, cardiovascular disease, stroke, pulmonary disease, and diabetes, but the causal relationships have yet to be established.[7]Infections and inflammation of the gums and bone that surround and support the teeth are the main causes of periodontitis.. In its early stages, known as gingivitis, the gums can become swollen, red, and bleed. Periodontitis is a more serious form of gum disease in which the gums pull away from the tooth, bone is lost, and teeth loosen or fall out.. Adults are more likely to develop periodontal disease. The term "electronic commerce" refers to the sale of electronic goods.[17]



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CLASSIFICATION:

In 2017, the American Academy of Periodontology and the European Federation of Periodontology collaborated to create a new classification of periodontal and peri-implant diseases. Periodontitis is divided into three categories under this new classification:

- Chronic periodontitis:
- Aggressive periodontitis:
- Necrotizing periodontitis:[18]

ETIOLOGY:

Normally, healthy people have hundreds of different types of bacteria in their mouth. The majority of them are completely safe. Bacteria grow and build up on your teeth if you don't clean them properly every day. [19]

Poor dental hygiene is the most common cause of periodontitis. When you don't brush your teeth or clean in hard-to-reach areas of your mouth, the following things happen:

1. Bacteria in your mouth multiply and combine to form dental plaque.

2. If the plaque is not removed by brushing, the bacteria deposit minerals within the plaque over time.

3. This mineral deposit is known as tartar, and it encourages bacterial growth toward the tooth's root.

4. Your body's immune response to this bacterial growth causes gum inflammation.

5.A periodontal pocket (gap) forms between the gum and the root of a tooth when the attachment of the gum to the root of a tooth is disrupted over time.

6. Dangerous anaerobic bacteria colonize and multiply in the pocket, releasing toxins that can harm the gums, teeth, and supporting bone structures. [20]

PATHOPHYSIOLOGY:

Through the process of dysbiosis, or microbial imbalance, commensal oral bacteria are responsible for the disease's initiation and propagation.As gingivitis progresses to periodontitis, a greater number of anaerobic organisms, such as *Aggregatibacteractinomycetem comitans* and *Porphyromonasgingivalis,* colonise deeper periodontal pockets, triggering the host inflammatory response.This response includes the production and spread of C-reactive protein (CRP), an inflammatory biomarker, as well as various neutrophil and macrophage compounds

such as tumour necrosis factor-alpha (TNF-a), matrix metalloproteinases (MMPs), and interleukins (IL-1 and IL-8)[17]

WARNING SIGNS:

Periodontal disease symptoms include the following:

• Persistent bad breath or taste

• Red or swollen gums

• Tender or bleeding gums

• Painful chewing

• Loose teeth

• Sensitive teeth

• Pulling gums from your teeth

• Any change in the way your teeth fit together when you bite.[17]

SYMPTOMS OF PERIODONTITIS:

The symptoms vary according to the stage of the disease, but they generally include:

• Gums that bleed when you brush your teeth or floss

• Bad breath

• Changes in the position of your teeth or loose teeth

• Receding gums

• Red, tender, or swollen gums

• Build up of plaque or tartar on your teeth

• Pain when chewing

• Tooth loss

• Foul taste in your mouth

• Inflammatory response throughout your body.[12]

DIAGNOSIS:

•Periodontal abscesses are localised purulent infections found in the periodontium surrounding the tooth.

• Endodontic lesions are localised infections originating in the tooth pulp that may seep out of the root tissue into the surrounding periodontium and appear to be periodontal in origin.

• Leukemia can cause gingival enlargement and bleeding gums, and it can mimic periodontal diseases such as gingivitis.

• Gingival hyperplasia, which can mimic gingivitis, is a side effect of certain medications, including calcium channel blockers, immune suppressants, and anticonvulsants.

• Squamous cell carcinoma can cause extensive bone loss and mimic periodontal disease that is resistant to mechanical and pharmacological treatments.

GRADING:

Grading is a term used to describe the rate of disease progression based on evidence for risk factors such as smoking and diabetes mellitus.

• Grade A: slow rate of progression

• Grade B: anticipated progression

• Grade C: high progression risk [21]

PERIODONTITIS STAGES:

Staging is determined by factors such as clinical attachment loss, radiographic bone loss, and tooth loss and is based on the severity and extent of the management required.

• Stage I: Early periodontitis

Periodontitis causes your gums to recede, or pull away from your teeth, and small pockets to form between your gums and teeth. The pockets are a breeding ground for harmful bacteria. As your immune system battles the infection, your gum tissue begins to recede. You will almost certainly experience bleeding while brushing and flossing, as well as bone loss.

• Stage II: Moderate periodontitis

If mild periodontal disease is allowed to progress, you may experience bleeding, pain, and gum recession. Your teeth will loosen and lose bone support. In addition, the infection may trigger an inflammatory response throughout your body.

• Stage III: Severe periodontitis with the possibility of tooth loss

• Stage IV: Severe periodontitis with the possibility of tooth loss.[22]

PERIODONTAL DISEASE RISK FACTORS:

***Modifiable Risk Factors**:*

• Microorganisms and Periodontal Disease

• Tobacco Use

• Diabetes Mellitus

• Cardiovascular Disease

• Drug-Induced Disorders

• Stress

Nonmodifiable Risk Factors:

• Osteoporosis

• Hematological Disorders

• Host Reaction

• Female Hormonal Changes

• Pregnancy

Periodontal disease is made more likely by the following factors:

• Smoking

• Diabetes

• Poor oral hygiene

• Stress

• Heredity

• Crooked teeth

• Underlying immuno-deficiencies—e.g., AIDS

• Defective fillings

• Taking medications that cause dry mouth

• Bridges that no longer fit properly

• Female hormonal changes, such as pregnancy or oral contraceptive use.[17]

PREVENTION:

It is treatable and controllable with good oral hygiene and regular professional cleaning.More severe forms of periodontal disease can also be successfully treated, but may necessitate more extensive treatment.Such treatment may include deep cleaning of the tooth root surfaces beneath the gums, medications taken orally or placed directly under the gums, and, in some cases, corrective surgery.To help prevent or control periodontal diseases, it is critical to do the following:

1. Brush and floss daily to remove the bacteria that cause gum disease.

2.See a dentist at least once a year for routine checkups, or more frequently if you have any of the warning signs or risk factors listed above.[22]

TREATMENT AND MANAGEMENT:

The various advancements made in the diagnosis and treatment of periodontal disease:

1. A newer generation of probing systems

2. Disease biomarkers

3. Disease vaccine

4. Probiotics in the treatment of periodontal disease

5. Lasers in the treatment of periodontal disease.[20]

III. NANOTECHNOLOGY IN THE TREATMENT OF PERIODONTAL DISEASE:

Tanaguchi coined the term "nanotechnology". Nanotechnology is the study of phenomena and materials at the nanoscale through research and development at the

atomic, molecular, or macromolecular level on a length scale of approximately 1-100 nm. Nanotechnology research is being carried out in order to develop better and even modified products for periodontal regeneration, with the goal of reducing side effects and increasing product biocompatibility.[9]

NANORODS:

The advantage of recent advances in nanotechnology is that they can mimic the natural bio-mineralization process used to create the hardest tissue in the human body, dental enamel, by employing highly organised micro architectural units of nano rod-like calcium hydroxyl apatite crystals arranged roughly parallel to each other.One of the most widely used techniques in nanotechnology is the use of surfactants as reverse micelles or micro emulsions for the synthesis and self-assembly of nanoscale structures.[23]This structure spans the entire thickness of the enamel and is most likely responsible for the unique physicochemical properties.[24]Drug delivery, enzyme immobilisation, and DNA transfection are just a few of the biomedical and biotechnological applications for nano rods that are being developed.[25]Spherical nanoparticles are commonly used for the applications discussed above, but this is only because spheres are easier to make than other shapes.[26]Nanofibers less than 100 nm in diameter, such as nano rods, nano platelets, nanotubes, nano fibrils, and quantum wires, are other major nano materials being studied for a variety of applications, including periodontal disease management.[27]

NANO TUBES:

Organosilicon polymer nanotubes, self-assembling lipid micro tubes, fullerene carbon nanotubes, template synthesised nanotubes, and peptide nanotubes are examples of nanotubes. For biotechnological applications, they have some intriguing advantages over spherical nanoparticles.[28]

Furthermore, the distinct inner and outer surfaces can be chemically or biochemically functionalized differentially. [29]

• In-pore polymerization to make polymeric nanotubes

• Electro-less deposition to make metal nanotubes

• Sol-gel chemistry to make nano tubes composed of silica and other inorganic materials are some of the approaches used to make micro and nano tubes.[30]

Large inner volumes (relative to the tube's dimensions) can be filled with any chemical or biochemical species ranging in size from proteins to small molecules.[31]Drugs can be incorporated into biodegradable polymer nanospheres, allowing for controlled drug release as the nanospheres degrade. This also allows for drug delivery at specific locations.[32]

NANO MATERIALS:

Fundamentally, nano materials are of interest because the properties of a material (e.g., melting point, electronic properties, and optical properties) change when the size of the particles that make up the material becomes nanoscopic[33]At the moment, tissue engineering concepts for periodontal regeneration are centred on the use of synthetic scaffolds for cell delivery.[34]The recent development of Arestin, in which tetracycline is incorporated into microspheres for drug delivery by local means to a periodontal pocket, is an excellent example of how this technology could be developed.[35]

NANO PARTICULATE MATERIAL FOR DRUG ADMINISTRATION SYSTEMS:

Polymeric nano particles, nano fibres, liposomes, quantum dots, and nano composites/nano gels are some of the nano particulate systems available for local drug delivery in periodontal diseases.A nano particle is a small, rigid material with dimensions ranging from 1 nm to 100 nm.[36]Nano structured macromolecules have demonstrated their potential for entrapping and/or conjugating high molecular weight hydrophilic/hydrophobic entities through host guest interactions and covalent bonding (pro drug approach). [37]Dendrimers are emerging polymeric constructs known for their defined structures, versatility in drug delivery, and high functionality, which are similar to bio molecules. [38]Nanoparticle drug delivery systems can be directly endocytosed as opposed to larger drug-delivery particles that release high local drug concentrations. [39]As a result, it can release drugs on the exterior or interior of target cells, allowing for smaller amounts of drug delivery to achieve the desired effect. Because of their small size, nanoparticles can reach areas that other devices cannot, such as the periodontal pocket regions below the gum line. [40]Materials used to create a nano particle can be biodegradable, such as albumin, ethyl cellulose, gelatin polyesters, or non-biodegradable. These materials have been sterilised and are non-toxic.[41]

POLYMERIC NANOPARTICLES:

Polymeric nanoparticles (PNPs) are the most important class of nanoparticles used in drug delivery due to their easily customizable bio-degradability properties. These PNPs come in two varieties: nanospheres and nanocapsules (polymerosomes). [42]A nano particle matrix is used to disperse, trap, envelope, or couple the drug. They are easily dispersed in water and have a controlled release rate. PNPs have higher biological fluid stability. They have a high solubility capacity, are transparent, have a high stability, and are easy to manufacture. These biodegradable PNPs can enter the junctional epithelium and cause damage. [43]The surface hydrophilicity/charge, molecular mass (MM), and free functional groups of PNPs can be easily tuned to improve drug loading and release.They are particulate dispersion or rigid particles with sizes ranging from 1 nm to 1000 nm. [44]Nanoparticles are cytotoxic and have a long shelf life. They demonstrate better clinical outcomes in terms of probing depth reduction and clinical attachment gain. These benefits imply that PNPs have the potential to be used as intrapocket drug delivery systems in the future.[45]A nano particle matrix is used to disperse, trap, envelope, or couple the drug. They are highly dispersible in water, have a controlled release rate, and are more stable. These benefits imply that PNPs have the potential to be used as intrapocket drug delivery systems in the future.[46]

NANO GELS/NANO COMPOSITES:

The synthesis of nano composite hydrogels begins with the mixing of nanoparticles, monomers, and the drug in an aqueous solution, followed by cross linking via photo polymerization. These nanoparticles can be combined with a hydrogel matrix to create new drug delivery devices for the treatment of periodontal diseases.[47]Matrix-based nano composites have received a lot of attention in the current data polymer world. The architecture of polymers or micro particle-based hydrogels influences the rate of release, allowing them to be used in periodontics[48].In the treatment of periodontal diseases, nano composite hydrogels are combined as replica systems for in situ cured local drug delivery devices. The nano composite is made up of several components, including nanoparticles, a matrix gel, and the appropriate antibacterial drug[49].The nanoparticles are formed through the process of free radical initiated copolymerization of monomers, 2-hydroxyethyl methacrylate (HEMA), and

polyethylene glycol methacrylate in aqueous solution. By photopolymerization, the same monomers are used to create cross-linked matrices[50]Nano gels have demonstrated good flow properties and syringealability, which are critical characteristics for an intrapocket drug delivery system. They have the benefits of both emulsions and liposomes, such as controlled drug release, no drug leakage, low toxicity, and good biocompatibility and bioavailability.[51]

HYDROGELS:

A functional polymer substance known as hydrogel has emerged as a viable option for periodontal disease therapy. With its excellent biocompatibility, water retention, and gradual release, it has the ability to imitate the extracellular matrix and provide ideal attachment sites and growth conditions for periodontal cells. The creation of intelligent and multifunctional hydrogels for periodontal tissue regeneration is critical for future study.[52]

THE ESSENTIAL HYDROGEL COMPONENTS IN PERIODONTAL TISSUE REGENERATION:

NATURAL POLYMER:

Gels can be made using natural polymers. These gels are not naturally resistant to *Actinomycetem comitans* and *S. mutans*. They can, however, be used as a vehicle for transporting and dispensing antimicrobial drugs. [53]Hydrogels derived from natural sources have important properties such as biocompatibility and promising cell-material interactions, which pave the way for the development of a native ECM (extracellular matrix) analogue structure.[54]

CHITOSAN:

Chitosan is a chitin derivative, which is the second most common natural polymer after cellulose. The term "chitosan" refers to a family of chitin-derived polymers with varying degrees of deacetylation, beginning with 50%.[55]Chitosan with a molecular weight of 1,080 kDa and a deacetylation degree of 75.6% was synthesised in our laboratory using an acidic-degradation method.[56]Chitosan (CTS), a natural cationic polysaccharide, is thought to be the most promising biomaterial for tissue engineering and tissue repair. CTS has been shown to have a number of excellent properties, including non toxicity, stability, biodegradability, and biocompatibility, as well as being less expensive than other biomaterials.[57]Chitosan hydrogels without cell loading can improve periodontal regeneration in terms of functional ligament length, indicating this hydrogels great clinical potential. More research into the use of chitosan hydrogels as cell carriers is needed.[58]

SODIUM ALGINATE:

Alginate-based hydrogels have received a lot of attention in the biomaterials community because of their ease of chemical modification, non-toxicity to encapsulated cells, and ability to elicit a minimal immune response after implantation.[59]

ALGINATE FILMS FABRICATION:

A 4% (w/v) solution of sodium alginate was air-dried to form thin films (1mm), which were then immersed in a 10% (w/v) solution of calcium nitrate

[ca(no3)2](ca2+ concentration 0.15M),zinc sulphate [znso4](zn2+ concentration 0.25M),or strontium nitrate [Sr(NO3)2](Sr2+ concentration 0.20M). The crossed alginate films were then washed twice with deionized water and air-dried at room temperature before being oven-dried for 24 hours at 40 degrees Celsius.[60]

SYNTHETIC POLYMERS:

Chemical reactions are used to make synthetic polymers. Polyethylene glycol, PVA, and poly (lactic-co-glycolic acid) (PLGA) are common synthetic compounds that can be tailored to achieve excellent mechanical properties and hydrogel stability, but they lack inherent bioactivity.

PEG:

Hydrogels were created by combining equimolar amounts of star-PEG-BCN and star-PEG-N3, or by substituting star-PEG-MMPCP-N3 for the azide functionalized star polymer component.[61]The biological behaviour of the PEG hydrogel is influenced by its physical and chemical properties. PEG can be used in the network as a barrier membrane (with a slow degradation time and a dense network) for GBR in implant dentistry or as a matrix (with a faster degradation time and a loose network) for tissue engineering.[62]

GELATIN METHACRYLOL:

Gelatin methacryloyl (GelMA) is a versatile material that can be used in a variety of bio applications. There is a great deal of interest in developing efficient chemical strategies for producing GelMA with high batch-to-batch consistency and controllability in terms of methacryloyl functionalization and physiochemical properties.[63]GelMA hydrogels' macrostructure and microstructure are formed during the formation process. The pore size of the GelMA hydrogels was 46.43 12.65 m, as shown.[64]

HYDROGELS' MULTIPLE COMPONENTS IN PERIODONTAL TISSUE REGENERATION:

ANTI-BACTERIAL AGENTS:

The antibacterial activity of the Cts-Se-NPs solution against gram positive bacteria was outstanding. This product can be researched further for various antibacterial applications in medicine and dentistry, such as medical device disinfection and sterilisation, as well as periodontal disease mouthwash and anti-caries agents.[65]

ADJUNCTS OF ANTIBACTERIAL AGENTS IN THE TREATMENT OF PERIODONTAL LESIONS:

PEROXIDES:

For many years, peroxides have been used to treat periodontal lesions. They have four important properties: antibacterial action, mechanical cleansing, tissue oxygenation, and deodorization.[66]

CYTOKINES:

Cytokines are in charge of maintaining a complex communication network between homotypes. Thus, cytokines play an important role in a variety of biological activities including differentiation.[67]As the immune response progresses, the released cytokines and chemokines can cause damage to the periodontal ligaments,

gingival, and alveolar bone. Periodontitis produce a wide range of cytokines and chemokines.[68]

INORGANIC NANOPARTICLES:

Inorganic NPs play numerous roles in periodontology, particularly in the prevention and treatment of peri-implantitis.The clinical success of titanium implants is dependent on their surface properties, which can influence cell adhesion, proliferation, differentiation, and integration with surrounding tissues.[69]

CERAMIC NANOPARTICLES:

Ceramic materials are of "synthetic crystalline, inorganic non-metallic materials"."Bioactive glass, bioactive glass-ceramic, calcium phosphate groups, and alumina" are all examples of bio ceramics.[70]

HYDROGEL STRATEGIES IN PERIODONTAL DISEASE:

Hydrogels act as a survival space for cells, allowing them to exchange nutrients and gases while also regulating cell morphology and function. While hydrogels have numerous advantages, due to their poor mechanical properties, modifications to the hydrogel components, network structure, gelation process, and cross linking are frequently required to achieve hydrogels with adequate mechanical strength to improve tissue regeneration.

BIOMIMETIC HYDROGELS:

Hydrogels can be formed through both physical and chemical cross-linking. The incorporation of ECM-derived bioactive molecules, particularly short peptides, into synthetic hydrogels via chemical bonding or physical interactions is a general strategy for the fabrication of bio mimetic hydrogel.[71]Different approaches to the use of bio mimetic hydrogels for soft tissue repair are discussed, with a focus on synthetic, non-biodegradable polymers. We include both traditional polymers and bio mimetic polymers. The chapter concludes by outlining possible future trends and recommending additional reading materials.[72]Currently, bio mimetic hydrogels with adequate biological and physicochemical properties, such as mechanical properties capable of supporting load bearing capability, have yet to be developed. The benefits and drawbacks of biomaterials for the production of biomimetic hydrogels for cartilage regeneration are discussed in this review.[73]

INTELLIGENT HYDROGELS:

Hydrogels are water-enriched polymeric biomaterials used as scaffolds that mimic the extracellular matrix and are used in a variety of tissue engineering applications. Intelligent hydrogels respond to environmental factors such as temperature, pH, hypoxia, ischemia, and the presence of reactive oxygen species by changing their physiochemical structure.[74]

IV. DRUG DELIVERY DEVICE:

FIBERS:

Fibers are thread-like and reservoir-type drug delivery systems that are placed circumferentially into pockets with an applicator and sealed in place with cyanoacrylate adhesive.[75]Fiber placement within a pocket takes time and requires trained personnel. In the case of a non-biodegradable polymer system, it

must be removed after treatment, necessitating another visit to a therapist, and the fibres must be secured with Cyano Acryate glue.[76]

STRIPS:

Strips are thin, elongated, and made of flexible material using the solvent casting method. Because of changes in the physical properties of acrylic strips in serum, the strip's surface dissolves. [75]

FILMS:

Films are the most commonly used intrapocket delivery medium. These are matrix drug delivery devices with drugs dispersed throughout the polymer matrix.The films were made using a simple solvent casting technique that did not involve the use of any hazardous organic solvents. The physical parameters and stability of the prepared films were evaluated.[77]

GELS:

Gels are semisolid systems composed of a dispersion of either small inorganic particles or large organic molecules. These are hydrophilic polymeric networks with 3D cross-linked structures of ionic interaction and hydrogen bonding.[78]The purpose of this study is to evaluate the efficacy of 2% ibuprofen gel as an adjunct to non-surgical periodontal therapy in the treatment of chronic periodontitis patients.[79]Controlled discharge Local delivery of antimicrobial agents results in higher drug concentrations in the periodontal site for longer periods of time than systemically delivered methods.[80]

MICRO PARTICLES:

Microspheres are solid polymeric spherical (1-1000 m) particles with the drug dispersed throughout the polymeric matrix. Microspheres are free-flowing powders made of biodegradable proteins or synthetic polymers that are used to deliver therapeutic substances to the target site in a sustained and controlled manner.[79]The use of a mucoadhesive microparticulated drug delivery system increases residence time and thus bioavailability.[76]Particle size analysis, mucoadhesion, in vitro drug release, process yield, and drug content were used to characterise microspheres. The current study's goal was to create spray dried mucoadhesive micro particles.[81]

NANO PARTICLES:

Nano particles: Because of their small size, nano particles can reach areas that other delivery systems cannot, such as periodontal pockets beneath the gum line.[76]Nanoparticles have been studied using a variety of methods to determine their size, crystal structure, elemental content, and a variety of other physical properties. In many cases, physical characteristics can be examined using more than one method. [82]

LIPOSOMES:

Liposomes: These are microscopic particles. Unilamellar lipid vesicles can be produced using cholesterol, non-toxic surfactants, glycol lipids, and even membrane proteins.[75]The charge and size of liposomes vary depending on the method of preparation and the lipids used, such as the multi lamellar vesicle (size range is 0.1-5.0 m), the small unilamellar vesicle (size range is 0.02-0.05 m), and the large unilamellar vesicle (size range is 0.06 m and greater). For the treatment of

periodontal disease, drug-containing liposomes can be administered via a variety of routes (intravenous, oral inhalation, local application, and ocular.[79]

NANO FIBERS:

Nano fibres are biomaterials that mimic the natural extracellular matrix and have a high drug loading efficiency. Electro spinning was used to create Poly Capro Lactone (PCL) nanofibers containing two antibacterial agents, oxy tetracycline (OTC) and zinc oxide.[76]Among these, electro spinning has been recognised as a viable method for producing continuous nanofibers from a variety of polymers.[75]

V. LOCAL DRUG DELIVERY:

They can function as drug delivery systems (DDS) or cell carriers in tissue engineering. Only studies on the preparation of drug-loaded electro spun fibres made from biopolymers for the treatment of periodontitis were considered in this section. Typically, these fibres are placed in the periodontal pocket around the tooth using an applicator and are sometimes fixed with cyanoacrylate adhesive.[83]Goodson and colleagues created a local drug delivery device for the treatment of periodontal disease that consisted of a hollow cellulose acetate fibre filled with tetracycline that released 95% of the entrapped drug within 2 hours. [76]For a long time, hollow-fiber delivery systems failed to provide an effective drug concentration when placed circumferentially into the target lesion. Because hollow fibres have a high rate of drug evacuation, drug-impregnated monolithic fibres have been developed to slow drug release.[84]

FILMS:

Periodontal films are made using a solvent casting method. [77]The films are matrix systems, similar to nanofibers and bands, with the drug dispersed throughout their mass and release accomplished primarily through diffusion but also through matrix erosion or dissolution.[83]

STRIPS:

Strips are thin matrix bands that contain drugs that are dispersed throughout the polymer.The benefit of Strips is that it can be shaped and sized to fit the shape and size of the periodontal pocket, making it simple to insert with minimal discomfort for patients. The inability of such delivery systems to degrade is a major issue.[84]

INJECTABLES:

Injectables: An in-situ gel formulation is designed to be injected directly into the periodontal pocket, where it immediately converts to gel form at body temperature, extending the active substance's residence time.[76]

MICRO PARTICLES:

Microspheres are polymer structures with a diameter ranging from 1 to 1000 m. The active therapeutic agent is distributed uniformly across the polymer matrix. For the development of microspheres, two classes of materials have been investigated: non-biodegradable and biodegradable materials.[83]Micro particulate systems can control drug release while maintaining stability. Natural polymers, modified natural substances, and synthetic polymers are among these materials.[84]

NANO PARTICLES:

The antibacterial properties of single nanoparticles and combinations of nPLGA and nCS, as well as their effects on the proliferation and mineralization of

periodontal membrane cells, were investigated.[76]Because of their small diameter (between 10 and 1000 nm), nanoparticles are the most promising strategy in the treatment of periodontal disease because they can penetrate regions that other drug delivery systems cannot reach.[83]Micelles, metallic and polymeric nanoparticles, and liposomes are examples of nano systems that have been widely used in dentistry.[84]

NANO FIBERS:

Nanofibers are biomaterials that mimic the natural extracellular matrix and have a high drug loading efficiency.[76]To overcome this limitation, as LDDs systems delivery drug local use is required, treatment outcomes periodontitis. Nano particles are designed to reach areas where other drug delivery methods cannot.[84] Electro spinning has emerged as a promising technique for the fabrication of delivery carriers to treat a variety of oral diseases, including periodontitis, by creating a favourable microenvironment for limiting bacterial and bio film adhesion and promoting bone and tissue regeneration.[85]

VI. CONCLUSION:

Periodontal disease remains a significant global health issue, affecting a large portion of the population and necessitating effective management strategies to prevent progression and associated systemic complications. Advances in treatment, including the application of nanotechnology, offer promising avenues for enhancing periodontal care and improving patient outcomes. Nanotechnology has the potential to revolutionize periodontal disease treatment by providing targeted, controlled, and sustained delivery of therapeutic agents, as well as improving diagnostic capabilities. Further research is needed to fully explore the potential of nanotechnology in this field.

VII. REFERENCE:

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