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NANO-BIOPOLYMERS IN DENTISTRY

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Abstract: Biopolymers at nanoscale are of immense value for its medical and dental applications. Chitosan is abundant in nature and chitosan nanoparticles have been widely used for biomedical applications because of its antibacterial and antimicrobial properties. Similarly there are other bio polymers widely used in the medical and health care sector.This review attempts to provide a comprehensive insight on the applications of Nanobiopolymers in orthodontics, its significance and uses.

Keywords: *Biopolymers, Nanoparticles, antimicrobial properties, Orthodontics.*

INTRODUCTION

Biopolymers are complex molecular structures unlike normal synthetic polymers in that they have a 3 D structural arrangement which makes them active substances when used in invivo conditions. They comprise of several monomeric units arranged in precise order to form polymeric units. Biopolymers have been broadly utilized in biomedical applications such as tissue engineering, wound dressing, dentistry etc. Biopolymers and nanoparticles in a combined form provide a plethora of uses, one of which is fabrication of membranes for regeneration in periodontics [1].

Biopolymers due to their appropriate mechanical and aesthetic properties are widely utilized in orthodontic materials. The biopolymers can be incorporated into adhesives, brackets, elastomeric modules and chains. Some of the polymers which are commercially available are polycarbonate, polyamides, polymethyl-methacrylate etc. The primary quality of an orthodontic material is biocompatibility in the oral environment. They should be non-toxic and have sufficient mechanical properties in the oral cavity during the treatment process [2]. Bio polymer coatings on orthodontics materials helps in improving the surface characteristics as well as the biocompatibility. This review attempts to discuss some of the Nano biopolymers that have been used in the field of orthodontics concerning its sources, synthesis, surface characterization, and its biological applications

Types of biopolymers:

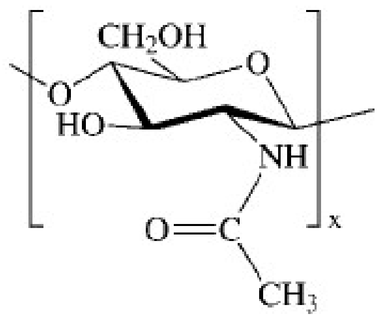
Biopolymers are broadly classified into 4 categories namely sugar based, starch based, cellulose based and synthetic biopolymers. Sugar based polymers include the polylactides which are basically lactic acid polymers. These are derived from milk sugar or lactose. Some of the sources from which these are extracted are maize, potatoes, wheat, sugar etc. Vacuum forming, injection moulding are the methods through which these are manufactured. These polymers are resistant to water [3]. Starch based Biopolymers act as natural polymers and are obtained from vegetables like tapioca, potatoes etc [1]. cellulose based polymers are composed of glucose. They are obtained from natural resources such as cotton, wood etc. Synthetic biopolymers are sometimes used for making biodegradable polymers such as aliphatic aromatic polyesters and are usually sourced from petroleum. Biopolymers can be further classified as hydrolytically degradable polymers and enzymatically degradable polymers. Polyesters, polyanhydrides, polycarbonates & polyurethanes are hydrolytically degradable polymers. Synthetic polymers, Proteins and Poly (Amino Acids) and Polysaccharides are enzymatically degradable polymers. The polyester group consists of poly-glycolic acid (PGA) and polylactide (PLA). Polylactide is widely used in ridge along with socket preservation and can be used as space fillers which promotes regeneration and maintenance of the original socket size. It also facilitates in preventing resorption of alveolar bone [4]. Poly(lactide-co-glycolide (PLGA) used for alveolar ridge augmentation with bone allograft and osteo inductive proteins. Polycaprolactone (PCL) is utilized as 3D- polycaprolactone/hydroxyapatite scaffold which is used for various mesenchymal stem cells. In reinforced dicalcium phosphate dihydrate cement composites, Poly (propylene fumarate) are used [5]. Polyanhydrides (PAN) are used widely in devices around the dental implants as well as extraction sockets. The polymer is also used in drug delivery system. Polycarbonates (PC) are tyrosine- derived polycarbonate polymer and are utilized in scaffolds in order to support alveolar jaw , regenerations along with bone repair. Polyurethanes (PUR) possess ester bonds along with amide bonds. They are biocompatible and mouldable. They have a wide variety of uses in orthodontics.

Synthetic polymers are enzymatically degradable polymers, and are used for coating the titanium dental implants. They are also used as coating on maghemite nanoparticles which helps in treating hypersensitivity. Polyethylene glycol hydrogel along with hydroxyapatite/tricalcium phosphate can be used for bone regeneration. Proteins and Poly (Amino Acids) include collagen, elastin and fibrin which are used for scaffolds which are loaded with various growth factors for regenerating dental pulp-like tissue. It is also used as scaffolds used in case of osteogenic differentiation. Polysaccharides such as hyaluronic acid which includes hyaluronan gel is used for local application during surgical procedures and also in chronic periodontitis. Restylane are used for endodontic treatment and for regenerative procedures hyaluronan scaffolds are used. Chitosan (CS) in the form of Chitosan nanoparticles are used as drug carriers in order to enhance the antibacterial effect

Chitosan and its structure: Chitosan is an amino-polysaccharide derived from chitin with a skeletal framework based on repetitive acetylated and deacetylated units distributed randomly. Its regenerative potential, increased accessibility, convenience in chemical treatment, and biocompatibility has made its use often in dentistry and medicine including all the fields of specialization. This paper emphasizes on the use of chitosan in the field of orthodontics.

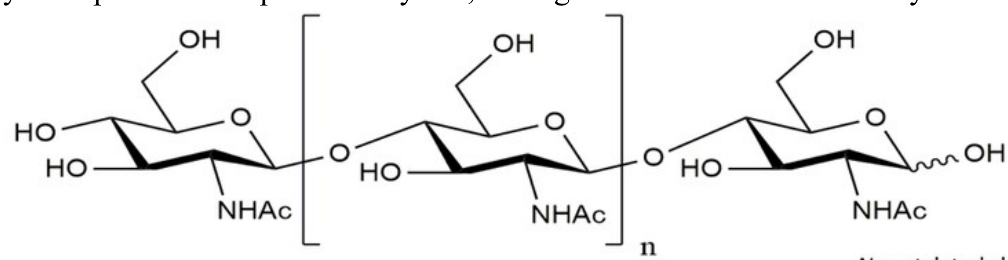
Chitosan, an amino-polysaccharide has a molecular weight between 300-1000 kDa depending on the origin of chitin. Following cellulose, chitin is the second most abundant natural polymer on the planet. It is found in crustacean like shrimps as well as crabs. The primary sources of chitosan and chitin are: Fungi, Insects, centric diatoms, squid and crustaceans.

Structural chemistry of chitin consists of 1-4 linked 2-acetamido-2-deoxy-β-D-glucopyranose.

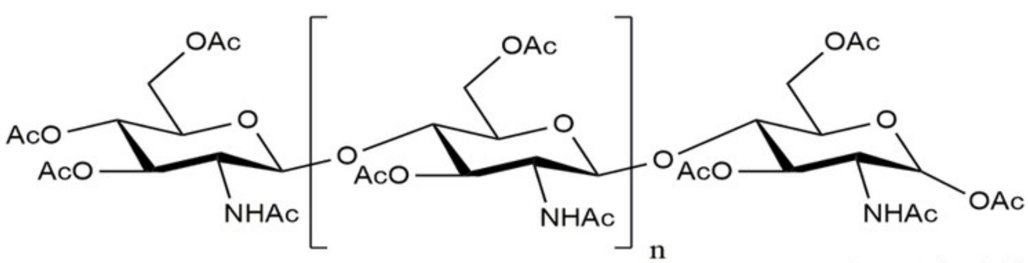


Chemical Structure of Chitin

Chitosan is a copolymer of N-acetyl-D-glucose amine and D-glucose amine. The deacetylation process of chitin is carried by chemical hydrolysis in severe alkaline state or by enzymatic hydrolysis in presence of specific enzymes, among which one is chitin deacetylase.



N-acetylated chitosan



Peracetylated chitosan

Chitosan and its uses:

Use in Dentifrices: Chitosan is used in dentifrices to prevent demineralization around brackets. Oral hygiene is difficult to maintain with orthodontic attachments placed inside the oral cavity and aggregation of plaque and debris is comparatively easy around these attachments. Chitosan has a slight acidic pH of 6.3, and is appropriate for buffering the oral cavity. The pH is high enough to fend off the harmful and deleterious effects of organic acids on surface of teeth. Studies have illustrated the beneficial effects of materials containing chitosan on the changes in the pH in bacterial dental plaque and also has a satisfactory antimicrobial activity [6]. It has a positive charge which enables it to attach to the bacterial cell membrane and cell wall, and has bactericidal effects. Water-soluble and chemically reduced chitosan has been used as a mouthwash. Studies have depicted that chewing gum which contains chitosan can effectively prevent the proliferation of cariogenic bacteria present in saliva [6].

Use as an Anti-bacterial agent:

Chitosan is used for its antibacterial properties as a coating material for orthodontic mini-implants. Orthodontics mini-implants have been a revolutionary addition to orthodontics due to various advantages including resistance to opposing force which are generated by the opposite teeth. They provide good patient compliance and have comparatively low cost. They can be placed as well removed with ease according to the biomechanics. Nevertheless, mini-implants can cause infections such as peri mucositis as well as peri-implantitis. This usually occurs when there is inflammation in tissues around neck of mini-implant which is in close contact with oral mucosa because of increased bacterial growth. The bacteria which is present around the mini-implant are similar to bacteria present in gingival crevicular fluid which includes red complex which is responsible for inflammation and infection which ultimately leads failure of the mini-implant [7].

The surfaces of titanium alloy (Ti6Al4V) implants can be covalently bonded with chitosan. This bonding can be done by 3 step process which includes amino-functionalization with APTES followed by grafting of either polyacrylic acid or succinic acid spacer and finally attachment of chitosan to the Titanium-alloy surface of the implant [8,9.]

Use as an anti-microbial agent:

As the demand for orthodontic treatment increases, the requirement for better orthodontic acrylic resins is also greatly surges. One of the few problems with acrylic resins is the agglomeration of microorganisms. Two factors that influences the agglomeration of microorganisms are porosities on the surface and poor oral hygiene of the patient. Nevertheless, the addition of antibacterial substances enhances the antibacterial properties but at the expense of its mechanical properties [10]. Chitosan being a cationic material, contains one primary amine group which enables it to adhere to the bacterial cell wall and degenerate the bacterial cell wall and the cell membrane of bacteria. Nanosized chitosan also exhibits superior antimicrobial activities [11]. Addition of chitosan Nanoparticles up to 1% (w/w) gives exceptional antibacterial power and has no deleterious effects of significance on the cold-cure acrylic resin's mechanical properties which encompasses impact strength, flexural strength, microhardness and compressive strength These negative effects are not visible in the mechanical properties till chitosan nanoparticles are added up to 4%(w/w).

In Summary, Chitosan as a material present in nature, has immense potential as an antibacterial and anti-microbial agent in Orthodontics. The use of Chitosan nanoparticles as protective coatings for materials used in Orthodontics and dentistry at large, is very much warranted, as it is a non-toxic and biocompatible **Polydopamine and its applications :**

Polydopamine is an insoluble dark brown biopolymer which is a synthetic analog of melanin, produced by the monomer dopamine (DA) by autoxidation and hence termed as Polydopamine (PDA). [12,13] This biopolymer was put forward by Lee et al in 2007[14], which consists of neurotransmitter, a major catechol in the brain i.e., Dopamine. PDA has unique properties of adhesive proteins which can be attached to almost all kind of structures and this adhesive versatility was found to be associated with secretions in muscles which may be associated with amino acids as well as 3,4-dihydroxy-L-phenylalanine (DOPA) [15]. The major application of the Dopamine-based drugs is to treat central nervous system disorders such as schizophrenia and Parkinson's disease. Nowadays, dopamine has gained lot of attention since the development of polydopamine biopolymer, which is a powerful coating. Polymerization of dopamine leads to formation of polydopamine. Polydopamine is manufactured by three common methods solution oxidation, enzymatic oxidation and electro polymerization methods [13]

Polydopamine nanostructures application and synthesis has been rapidly growing in biomedical fields which includes bone and tissue engineering, drug delivery, cell adhesion and patterning, photothermal therapy and antimicrobial applications. PDA is an excellent biopolymer for modifying surfaces and function of nanoparticles because of its non-specific adhesiveness. There are many nanoparticles which are coated with PDA for cancer diagnosis and therapy including iron oxide, graphene oxide, silica particles, etc. [16] Polydopamine has another feature other than modifying surfaces, it plays vital role in nanocomposite industry because of its inherent stability which is useful for photo preservation activities

Polydopamine nanoparticles consists of factors like good biocompatibility, easy preparation, and high-water dispersal all of these constitute for special features of polydopamine which aids in effective identification of cell structures such nucleic acid, these features can be used as an adaptive stimulus to evaluate and identify many procedures including human immunodeficiency virus (HIV), which is of great value in medical and dental fields

Role of Polydopamine in modifying nanoparticles:

1. Biocompatibility- PDA surface modifications enhance the biocompatibility of a material which can be used for various biomedical applications.
2. Biodegradation- PDA helps in regulating the degradation rate of nanoparticles during drug delivery which can be used to prevent accumulation of nanoparticles in normal tissues. [17]
3. Bioactive molecules-PDA has ability to modify surfaces by achieving physical or chemical bonds between the anchor drugs, proteins or peptides. [18]
4. Hydrophilicity-PDA modified surfaces provide with great amount of hydrophilicity with no functional alteration required in further. [19]
5. Photo-thermal conversion-PDA has ability to perform thermal reaction shift of materials with phase transformation which aims at drug delivery in a near-infrared light-controlled manner [20,21]

6. Scavenging reactive oxygen species (ROS)- PDA shows the excellent proficiency in scavenging of radical species like Reactive Oxygen Species and also aids in reducing inflammation induced by ROS [22]

Applications of PDA-modified nanoparticle:

1. Cancer therapy- with the development of PDA coated nanoparticles it offers great loading efficiency of drugs and improved permeability and retention which is essential for cancer therapy for multifunctional tumour destruction. [23]
2. Monotherapy- To enhance oxygen deficiency in tumour site PDA plays a vital role as it has drug loading ability and antioxdative property. Man-made red blood cells are created which consists of encapsulating PDA-hemoglobin hybrid nanoparticles to deal with the oxygen in tumour site.[13]
3. Antibacterial-PDA is a novel bactericide which enhances both physical and chemical antibacterial effects [24].PDA antibacterial mechanism is based on the superior absorbability and positive charge acidic conditions in infection site. PDA communicates with surface of bacteria and impedes with the metabolism of bacteria.
4. Prevention of oxidative stress and inflammation- as PDA show's excellent proficiency in scavenging different radical species it contributes in reduction of inflammation, trauma or bacterial infections.[25]
5. Theranostics- for treatment and diagnosis, PDA offers the modified surface for various imaging agents anchored by physical or chemical bonds, which include metal ions, photosensitizer, radionuclide, fluorochrome for efficient imaging to monitor the tissues. It is used for various imaging tools for diagnosis, such as computed tomography imaging (CT), magnetic resonance imaging (MRI), photoacoustic imaging (PA), optical imaging and nuclear imaging [26].

Dental applications

Polydopamine nanoparticles exhibits strong evidence in scavenging reactive oxygen species(ROS) and reducing ROS-induced inflammation reactions. These are useful antioxidants to treat and decrease periodontal inflammation or orthodontically induced gingival inflammation[27]

Dentin remineralisation-as PDA promotes intrafibrillar mineralization by concentrating the interfacial energy of collagen and calcium phosphate resulting repair of dentin which exhibits similar mechanical properties of natural dentin[28]

The remarkable features of Polydopamine and its association with nanoparticles have shown tremendous improvement in biomedical applications, with its different roles and applications this biopolymer can be useful in the field of Orthodontics where patient presents with gingival inflammation(Periodontal inflammation) and white spot lesions (demineralized dentin), further Polydopamine can also be used to improve the biocompatibility of various metals used in Orthodontics as PDA can be easily functionalized with nanoparticles by surface modifications.

Gold nanoparticles :

Gold nanoparticles are considered to be of stupendous interests due to their outstanding features: physicochemical properties, electronic properties, high X-ray absorption coefficient, control over the particle's, ease of manipulation with strong binding affinity to different chemical groups [29,30] Plasmon absorption of gold nanoparticles in the visible and near infrared (NIR) region, has given rise to various biomedical applications including diagnostics and therapy [31]. Unique features of gold nanoparticles consist optical properties which harmonizes with their shape, leading to imaging and sensing[32].

The properties of gold nanoparticles including optoelectronic properties, biocompatibility, large surface-to-volume ratio and low toxicity, make them an essential tool in health care sector [33,34]. Synthesis of Gold Nanoparticles is based on three methods-Physical method (thermolytic process), Chemical method(Turkevitch procedure) and Biological method(biosynthesis-green chemistry). The efforts have been made to manage approaches consisting of shape, size, solubility, functionality and stability.[35]

Applications of Gold nanoparticles(AuNPs)

1. Photodynamic therapy(PDT)-AuNPs shows effective plasmon resonance absorption and fluorescence quenching which are associated with Photodynamic therapy (PDT) to treat skin and oncological diseases.
2. Photothermal therapy (PTT) – also known as optical hyperthermia or thermal ablation therapy used in cancer therapy. AuNPs–antibody conjugates are used for diagnosis and treatment as AuNPs play an important role in binding and intercellular transfer in tissues.[36]
3. Drug delivery – remarkable properties of AuNPs with high surface area for drug loading, nontoxicity and stability make AuNPs an efficacious nano-carrier in drug delivery. [37]
4. Sensing- AuNPs have one of the major application of sensors detection by utilising internal properties of AuNP for different chemical and biological sensing substances which includes metal ions, molecules, anions,protiens,nucleotides,etc.[38]

Dental applications of gold nanoparticles:

1. Dental caries –caries is caused by acidogenic microorganism such as Streptococcus mutans and Lactobacillus, whereas, AuNPs are used as anticaries agent as they possess antibacterial and antifungal properties.[39]
2. Dental implants –due to good biocompatibility of AuNPs and surface properties it is used in the field of implantology as bone regenerating and coating material.[40]
3. Periodontology- the unique optical properties of AuNPs helps in the diagnosis and detection of different microorganism in dental plaque for diagnosing periodontal pathology.[41]
4. Stem cell technology –AuNPs have special properties through which these nanoparticles can enter the cells to affect their function, this has been studied further to evaluate the application of AuNPs on cell matrix and its effect on morphology of cells.[42]
5. Dental adhesives and composite resins- studies have shown the effect of AuNPs on MMPs (Matrix metalloproteases) inhibition and its cytotoxicity, which showed that nanoparticles inhibit MMP activity and its process at lower concentrations.[43]
6. Acrylic resins- Addition of AuNPs in acrylic resins markedly improves the mechanical properties such as flexure and fracture strength.[44]

Various interventions have been carried out in dentistry and orthodontics as gold nanoparticles are known for high surface volume and biocompatibility, they also acquire antibacterial and antifungal properties along with mechanical properties of materials. Hence gold nanoparticles can be used in the field of dentistry or orthodontics to improve the treatment outcomes.

Silver particles :

Silver nanoparticles(AgNPs) have received special attention over the past decade as it consists of antibacterial and anticancer characteristics for therapeutic applications. There are other properties of silver nanoparticles(AgNPs) which includes wound repair and bone healing, improving efficacy of immunogenic vaccines, anti-diabetic effects and many more.[45,46]

There are three methods for synthesis of AgNPs, which includes chemical, physical and biological synthesis methods out of which, chemical synthesis is widely used method for obtaining AgNPs[47], which involves nucleation and growth or size and shape controlled silver nanoparticles[48,49]

Medical Applications of silver nanoparticles(AgNPs)

Antimicrobial Application: Silver nanoparticles have antimicrobial properties with factors affecting this property consists of shape, size and dose of AgNPs. Ultimately this helps in damaging various pathogens (bacteria and parasites). Silver Nanoparticle are coated around Orthodontic micro implants to inhibit bacterial growth around the micro implant, traditionally the implant failure occurs as a result of microbial growth around the implant with addition of AgNPs coating it has restricted the growth of microbes.[50,51]

Antifungal and Antiviral Activities of AgNPs: Some recent studies have shown that AgNPs also exhibit antifungal properties against various pathogenic fungi. Besides antifungal properties they also show good antiretroviral activity against human parainfluenza virus (HPIV), hepatitis B virus (HBV)and herpes simplex virus (HSV)[52,53]

Anticancer and DNA damage Application: AgNPs can restrict bacterial growth or may kill them by membrane destruction, Reactive Oxygen Species(ROS), enzyme inactivation, DNA damage and protein denaturation[54], which account for Anticancer activity of AgNPs. Silver nanoparticles also play a vital role in gene regulation of cells. AgNPs induces Reactive oxygen species production to interfere with the DNA structure, basically to cause DNA mutations[55].

Shfiei et al., evaluated the antibacterial activity of titanium dioxide (TiO2) and silver(Ag) nanoparticles which they coalesce into a dentin bonding agent. Integration of dental adhesives and these nanoparticles were found to be an effective way to reduce the chances of secondary caries [56]

Incorporation of Silver nanoparticles into the acrylic plate of orthodontic retainers was shown to have an effective antimicrobial action against Streptococcus mutans [57]. Silver coated orthodontic materials or incorporation of nanoparticles in adhesives maintained the same shear strength and provide resistance to pathogens associated with oral cavity.

Wound Repair: The wound healing is associated with surgical treatment where silver nanoparticles increase the rate of wound healing with minimal scarring in the thermal injury. It was observed that silver nanoparticles have shown shorter period of healing with excellent cosmetic appearance. In this process of healing, TGF-β and interferon-γ levels were detected at the same time, hence silver nanoparticles have positive impact on wound care.[58]

Bone Healing: Silver nanoparticles used as synthetic scaffolds or doping material is used for bone regeneration and restoration. AgNPs integrated hydroxyapatite or titanium scaffolds exhibits strong antibacterial ability and promote bone or fracture healing by acting on microorganisms involved at the site of bone infection. [59]

Antidiabetic Agent: AgNPs also have influence on the secretion and sensitivity of insulin as these nanoparticles activate PI3K pathway and protein kinase C, at insulin receptor level while inhibiting protein kinase C isozymes. AgNPs show effectiveness in reducing insulin resistance and DNA damage.[60]

Biosensing and Imaging: AgNPs coated nanoparticles can be effectively used as biosensors to detect enzymes, pathogens, molecular markers, etc. these silver nanoparticles improve the compatibility and conductivity of nanocomposites and aid them in making more steady for enzyme activity.[61]

Dental Applications

As silver nanoparticles exhibit antibacterial activity these are used in dentistry by integrating these nanoparticles with biomaterial to reduce the dental plaque formation or any related periodontal diseases. Further these nanoparticles have been used with acrylic resin to enhance the antibacterial effect of denture resins along with improvement in mechanical properties. Since these silver nanoparticles have remarkable properties and features they are also used in orthodontics where micro implants are coated with AgNPs, AgNPs-integrated PMMA used for acrylic plates and also to achieve better treatment outcome if any orthodontic induced gingival swelling is present.[62] Along with these advantages of silver nanoparticles, there is potential toxicity associated with silver nanoparticles which includes potential damages of silver to many organs and systems consisting of respiratory system, central nervous system, hepatobiliary system, urinary system, reproductive system and immune system.[63] Further studies are required to assess the potential toxicity and biocompatibility of silver nanoparticles, to evolve safer silver nanoparticles coated agents.

Bentonite

Bentonite consists of clay crystalline minerals that belongs to hydrous aluminium silicates which contains iron or magnesium and sodium or calcium. Bentonite also composed of montmorillonite along with colloidal silica which is produced from the alteration of volcanic glass. Bentonite material shows variation of basaltic or adhesive properties. The main content of bentonite is montmorillonite having the chemical formula $M_x(Al_{4-x}Mg_x)Si_8O_{20}(OH)_4 \cdot nH_2O$.

Other components in bentonite are impurities from various minerals such as illite, quartz, calcite, chlorite and mica. Bentonite has distinctive adsorption and catalytic properties. Therefore, bentonite is one of the most favourable type of material considered as safe nano-technology material [64]. The natural bentonite can be modified based on its ability of adsorption. Several modification have been carried out to enhance the property of bentonite with various solutions such as H_2SO_4, HNO_3 and HCL[65,66]. The process of pillarization, calcination and polycations intercalation also produce a layer of bentonite that is constant and steady at high temperatures.

Bentonite is pillared with Titanium oxide which results in increasing the surface area and basal distance of the material, because TiO_2 has greater surface area, hence it is possible to unite these particles with other materials as it does not block the pores of materials. The bentonite synthesis is carried out by performing the coprecipitation method by mixing HCl at 70°C for 4 hours.[67]

Bentonite shows excellent adsorption, swelling and colloidal properties. Because of these properties, it is widely used industrial applications, including bleaching agents, adhesives, sealants, waste absorbents,etc.[68]. Bentonite shows great bond strength and is used as bonding agent during metal casting.

Bentonite can be purified to montmorillonite to be used in pharmaceutical industries. As montmorillonite has rheological, swelling, adsorption and moisture-retaining characteristics. Montmorillonite has excellent adsorption properties which removes toxic metals and thus can be used for healing purpose. These can adsorb metals (Mn, Ni, As, Pb, Cr and Cd) from aqueous solution.[69]

In addition to metals, this biopolymer can adsorb anions like fluoride. Montmorillonite when integrated with magnesium adsorbs fluoride, which decreases the fluoride concentration in drinking water.[70] This biopolymer shows antiviral and detoxification abilities, as these have abilities to adsorb rotavirus.

Bentonite can be used as a probiotic agent or an intestinal-healing agent. Li et al.2014 showed the rate of Lactobacillus casei survival onto montmorillonite elevated under gastrointestinal conditions[71]. Bentonite is also used for cutaneous therapy, by balancing emulsifying oil and water or zinc ointment.[72]

Factors affecting adsorption of drugs onto Bentonite/ montmorillonite

1. Solvent pH: adsorption and desorption of drug are usually dependent on the solvent pH. The increase in pH is noted when adsorption of fluoride on montmorillonite and vitamin B6 decreases.[73]
2. Temperature- It is not significant when compared to pH. Temperature alters the adsorption of the drug, depending on the surrounding environment.
3. Ionic strength- with increase in ionic strength the sorption coefficient decreases and this factor is not associated with all drugs [74]
4. Initial drug concentration- more drug adsorption is seen on montmorillonite when initial drug concentration is increased.

Administration of montmorillonite along with drugs causes decrease in oral bioavailability[75] as montmorillonite adsorbs toxins, such as nitroaromatic compounds and aflatoxin, this can decrease side effects while reducing bioavailability. Like other polymers, Bentonite has been studied in drug delivery systems. This biopolymer enhances the drug entrapment by its adsorption property. In addition, it affects the mechanical and physical properties, including tensile strength and elasticity of a gel.

Bentonite has various application when combined with different formulations such as-

1. Bentonite-alginate formulations: Alteration in mechanical properties is seen when montmorillonite increases tensile strength and tear resistance by decrease in percent elongation.[76]

2. Bentonite-Polyacrylic acid formulations: It is designed for drug carrier system, in which cationic drug release decreases and gel strength of the hydrogel increases. [77]
3. Polyester formulations: Bentonite is used in formulation with polyesters, including, polylactic acid, polyglycolic acid, poly(lactic-co-glycolic acid) and polycaprolactone are biodegradable and biocompatible, because of nontoxicity and hydrolytic degradation polyesters these are used for different biomedical applications.[78]
4. Chitosan-bentonite formulations: Hybrid composites are formulated by Chitosan-montmorillonite, this formulation improves the anticancer activity as both biopolymers have outstanding characteristics of increased cell surface-adhesive properties which improves the therapeutic effect.[79]

Bentonite/Montmorillonite biopolymer is useful in various pharmaceutical and biomedical applications. As this compound is known to have remarkable characteristics including adsorption and swelling, which contribute to improve or modify drug delivery systems. Montmorillonite forms hybrid composites with different polymers, such as alginate, chitosan and polyacrylic acid which modifies the characterisitcs of the polymers and their mechanical properties. Hence this biopolymer has great advantage and tremendous scope in health care industry.

Zwitterion nanoparticle biopolymer coatings:

The term zwitter means “hybrid” or “Hermaphrodite” in German and roughly translates to something in between ot neutral. These Ions are electrically neutral with a net charge of 0. Zwitter ions can form from other ions like ampholytes or amphoteric compounds and behaves as an acid and a base. zwitterionic materials provides improved biocompatibility, decreases immune response, increases the distribution and uptake of conventional therapeutic drugs and genes. zwitterionic modifications of drug carriers add special features such as stimuli-response and tumor targeting abilities to the drugs. According to whether the groups are cationic and anionic on same unit of zwitterions, they can be further classified as betaine-like zwitterions and mixed-charge zwitterions. Betaine like zwitter ions form the majority and they always take quaternary ammonium as cations and combine with phosphonates , sulfonates and carboxylates to constitute phosphorylcholine, sulfobetaine and carboxybetaine . Other than zwitterionic polymers containing both charged segments on the same side chains, there are some mixed-charge materials containing balanced positive and negative charged moieties in different monomer units or binding to the same media .These “false” zwitterionic materials exhibit similar antifouling properties. Since amino acids are a category of natural zwitterions,there have been attempts to use amino acids or peptides to develop zwitterionic carriers .[80]

Conclusion : Nano biopolymers are being increasingly used in the healthcare field particularly so in the field of dentistry. Extensive research is being conducted on the possible antibacterial effects of these biopolymer materials. Biopolymers like heparin, cellulose, and chitosan can help reduce the toxicity associated with other materials in use and can be used for the synthesis of several other nanoparticles. Nanotechnology ,in future will incorporate nanofillers with biopolymers which will result in the extensive use of these materials for various applications in healthcare sectors.

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