

# NANOCHITOSAN AND DENTAL BIOFILMS – A REVIEW

MAYMA NATHASHA M<sup>1\*</sup>, SANGEETHA DURAISAMY<sup>2</sup>, RAVI KANNAN<sup>3</sup>

<sup>1</sup>Postgraduate student, Department of Orthodontics, SRM Dental College, Ramapuram, Chennai,  
Tamil Nadu, India.

Email ID: [nathasha1208@gmail.com](mailto:nathasha1208@gmail.com)

Ph no: 9789998311

<sup>2</sup>Reader, Department of Orthodontics, SRM Dental College, Ramapuram, Chennai, Tamil Nadu,  
India.

Email ID: [sangeetha.guhan@yahoo.com](mailto:sangeetha.guhan@yahoo.com)

<sup>3</sup>Professor and Head, Department of Orthodontics, SRM Dental College, Ramapuram, Chennai, Tamil  
Nadu, India.

Email ID: [drviortho75@gmail.com](mailto:drviortho75@gmail.com)

## Address For correspondence :

**Mayma Nathasha M,**

71-B , Poes Road , M.M.Garden , Teynampet , Chennai – 600018

Email id : [nathasha1208@gmail.com](mailto:nathasha1208@gmail.com)

## ABSTRACT:

*Dental biofilms harbor harmful microorganisms that causes dental caries and periodontal diseases. Chitosan is a naturally occurring polysaccharide with antimicrobial properties against a wide spectrum of bacteria and fungus. Chitosan nanoparticles possess unique physicochemical characteristics, when utilized properly can be used to prevent the formation or reduction of plaque bio mass by acting against the microbes present in the plaque and disruption of mature biofilm.*

**Keywords:** Chitosan , Nanochitosan , Antimicrobial agent , Dental biofilms

## INTRODUCTION:

Chitosan is a macromolecule that consists of repeating chains of N-acetyl D- Glucosamine and D-glucosamine which is derived by alkaline or enzymatic deacetylation of chitin. Chitin is the second most abundant natural polysaccharide after cellulose and is found in shells of marine crustaceans.<sup>[1]</sup>The name Chitin is derived from the Greek word “Chiton” meaning a Coat of mail. In Greek Chiton is also used to refer a rock clinging marine mollusc covered with overlapping shell plates resembling a coat of mail.<sup>[2,3]</sup>

Chitosan is widely used in medical and pharmaceutical field due to its antimicrobial properties, biodegradability, biocompatibility and non-toxicity.<sup>[4,5,6]</sup> The antimicrobial activity of chitosan was noted against a broad variety of microorganisms including fungi, algae and bacteria whereas high molecular weight chitosan is specifically more active against Gram positive bacteria.<sup>[5]</sup>

Dental Biofilms harbor bacteria that causes dental caries and periodontal disease and are resistant to penetration of antimicrobial substance due to the unique composition of the extracellular matrix. Nanoparticles due to the characteristic of superior penetration and antimicrobial efficiency are often used against the microorganisms in dental biofilms.<sup>[6]</sup> The current review focus on the effect of nanochitosan against the microbes present in dental biofilms and the scope of using nanochitosan to prevent the formation of dental biofilms and reduce the number of microorganisms present in the biofilms .

### **STRUCTURE OF CHITOSAN :**

The chemical structure of chitin and chitosan is very similar to cellulose with repeating units of N-acetyl D- Glucosamine and D-glucosamine.<sup>[1,4]</sup> In chitin chemical structure the hydroxyl unit at C-2 position in cellulose is replaced by acetamide group.<sup>[7]</sup> (Fig.1) Chitosan is an N-deacetylated derivative of chitin obtained by transforming the acetamide groups into primary amino groups.<sup>[1,7]</sup>

### **PROPERTIES OF CHITOSAN:**

The presence of reactive amine and hydroxyl group is responsible for the distinctive biological functions and application of chitosan. The properties of the chitosan can be suitably altered by changing the deacetylation degree, pH and ionic strength during its synthesis. Excellent properties like biocompatibility, biodegradability, bioactivity, bioresorptivity, non-toxicity and good adsorption makes chitosan a very suitable biomaterial as an alternative to synthetic polymers in medical and pharmaceutical field.<sup>[8,9]</sup> Studies have reported that chitosan has potent antimicrobial, anti-inflammatory, analgesic, antitumor, antioxidant, haemostatic and hypocholesterolemic properties.<sup>[9,10]</sup>

The antimicrobial property of Chitosan is noticeable and is active against a wide spectrum of including gram positive, gram-negative bacteria and fungi. Chitosan can effectively interfere with adhesion of *Streptococcus mutans*, completely inhibiting adhesion and disrupt the formation of mature biofilms.<sup>[11,12]</sup>

### **USES OF CHITOSAN IN DENTISTRY**

The wide spectrum antimicrobial property and good gelling potential without any preservatives makes chitosan a suitable ingredient for dentifrices. Chitosan based toothpaste can inhibit the growth of *Streptococcus mutans* and *Poryphyromonas gingivalis* in oral cavity and dental plaque.<sup>[13]</sup>

Chitosan when added to orthodontic bonding resins can effectively reduce enamel demineralization around orthodontic brackets in patients undergoing fixed orthodontic treatment without compromising the and shear bond strength while not leaving any residual adhesive on the tooth surface after removal of brackets.<sup>[13,14,15]</sup>

Chitosan incorporated dental resin cements improved the antimicrobial properties. Lower concentrations of chitosan was proved to be more effective against *Streptococcus mutans* in the demineralized dentin as increased concentration of chitosan increased the viscosity of the resins, preventing resin infiltration into the demineralized dentin.<sup>[16]</sup> Methacrylate modified chitosan as a component of the etch and rinse adhesive system can improve the durability of resin tooth interfaces and improved the durability of dental restorations.<sup>[17]</sup> Chitosan biopolymers incorporated in root canal irrigants were reported to promote crosslinking of collagen and improve the structural integrity of the radicular dentin during root canal treatment.<sup>[8]</sup>

Surface electrodeposition of chitosan along with calcium phosphate on titanium dental implants improves the biocompatibility, osseointegration, osteoconduction and wound healing after implant placement.<sup>[8,18,19]</sup> Chitosan is also used as a scaffold material in tissue engineering due to its biocompatible and biodegradable property.<sup>[8]</sup>

Chitosan coated on NiTi alloy using pulsed laser deposition technique showed improved corrosion resistance.<sup>[20]</sup> Addition of chitosan fibre to polyether -based thermoplastic polyurethane improved their mechanical properties, antibacterial activity, biological properties and elastic modulus without any decrease in the shape memory effect expanding the clinical application of these polymer materials in orthodontics.<sup>[21]</sup>

## **NANOCHITOSAN - SYNTHESIS**

Nanochitosan are chitosan particles with particle size ranging between 420-600 nm with markedly superior properties than the larger particle chitosan.<sup>[22]</sup> Nano chitosan can be synthesized from chitosan by either one of the four basic methods namely ionotropic gelation, micro emulsion, emulsification solvent diffusion or Polyelectrolyte neutralization.<sup>[23]</sup> The method of synthesis of nano chitosan based particulate system can be selected based on the required size, stability and safety of the nanoparticles.<sup>[24]</sup>

Ionotropic gelation method involves centrifugation of chitosan dissolved in acetic acid, polyanionic polymers and stabilizing agents. Electrostatic interaction between the amine group of chitosan and negatively charged polyanion results in the formation of chitosan nanoparticles.<sup>[23]</sup> Microemulsion method is a very time-consuming procedure where continuous stirring of chitosan to acetic acid, glutaraldehyde solution and a surfactant results in formation of nanochitosan.<sup>[23]</sup> In emulsification solvent diffusion method, nanoparticle formation is based on the partial miscibility of an organic

solvent with water which leads to diffusion and polymer precipitation leading to formation of nanoparticles.<sup>[23]</sup>

The polyelectrolyte complex method is a simple technique, where nanoparticles are formed as a result of neutralization between the cationic chitosan and cross linking anions.<sup>[23]</sup>

### **Nano chitosan properties:**

Chitosan nanoparticles are determined by their morphological characteristics like size of the particle, surface charge, polydispersity index (PDI) and zeta potential.<sup>[25]</sup> The size of the chitosan nanoparticle ranges from 420-600nm depending on its molecular weight and are classified into low, medium and high molecular weight chitosan based on the size. The molecular weight has an effect on the surface morphology of the nanoparticle and hence the antibacterial property.

The zeta potential which is a measure of the electric charge on the surface of nanoparticles signifies particle interaction and stability. A linear relationship between molecular weight and particle size and zeta potential is established in several studies. This physicochemical properties directly affect the antibacterial and antifungal properties of the nanochitosan.<sup>[22, 23, 25,26]</sup>

Polydispersity index (PDI) is the distribution of particle size in a given sample. The PDI ranges from 0 for a perfectly uniform sample in respect to the size of the particles to 1 for a highly polydisperse sample. Nanochitosan have a low PDI value indicating high particle size homogeneity and better stability.<sup>[22,26]</sup>

### **USE OF NANOCHITOSAN IN DENTISTRY:**

Nanochitosan added to root canal irrigants results in effective removal of smear layer due to its superior penetration property.<sup>[27]</sup> Nanochitosan particles added to orthodontic bonding resin can produce similar effects as chitosan particles in reducing the microbial colonies in the plaque around the orthodontic brackets without affecting the shear bond strength.<sup>[28,29,30]</sup>

Nanochitosan particles added to glass ionomer cement can improve the compressive strength, flexural strength, wear resistance and fluoride ion released due to its catalytic effect resulting in increased formation of calcium and aluminum polyacrylate complexes in these cement matrix.<sup>[31]</sup> Nanochitosan added to dental sealants have shown to improve the wear resistance of the sealants.<sup>[32]</sup>

Nanochitosan particles to denture base resin may inhibit biofilm formation and reduce the attachment of candida species on dentures.<sup>[33]</sup>

Nanochitosan hydrogel membrane formed using nanochitosan and gelatin was found to effectively absorb nickel ions from artificial saliva and inhibit *Strep. mutans* and *Candida albicans* growth on

orthodontic appliance. This Nanochitosan hydrogel membrane has a potential to be used reduce the corrosion and microbial adhesion in fixed orthodontic appliance.<sup>[34]</sup>

### **NANOCHITOSAN IN THE CONTROL OF BIOFILM FORMATION:**

Dental biofilm is a structured conglomeration of bacteria in a self-produced extracellular biopolymer matrix with glycopolysaccharides as principle constituent, where the microbes are embedded in a glycovalyx that is attached to the tooth surface. Dental biofilm allows micro-organisms to stick to and multiply on the tooth surface and lead to formation of dental plaque. The extracellular matrix makes the biofilm resistant to antimicrobial agent by preventing their diffusion.<sup>[35]</sup>

Nanoparticles have gained popularity in recent times as antimicrobial agents to reduce the microbial count and prevent formation of dental biofilms because of its unique physico-chemical characteristics. The reduced particle size, increased surface area, surface charge and degree of hydrophobicity of nanochitosan results in increased surface area to biofilm mass ratio and improved capacity of the particle to be adsorbed on the surface of biofilm. These properties make nanochitosan a more potent antimicrobial agent than Chitosan in prevention of dental biofilm.<sup>[35]</sup>

The polycationic nanochitosan with high surface energy density results in electrostatic attraction to the biofilm interface and further allowing it to penetrate into the biofilm to target the negatively charged surface of the bacterial cell wall to a greater degree than chitosan.<sup>[35]</sup>

Nanoparticles gets tightly adsorbed to the bacterial cell surface leading to disruption of the membrane and leakage of intracellular components, thus killing the bacteria cells.<sup>[36]</sup> Low molecular weight nanochitosan have more antimicrobial potential than high molecular weight nanochitosan due to the reduced number of triphosphosphate molecules making it more susceptible to disaggregation of biofilm by affecting the membrane integrity of the bacteria cell wall.<sup>[37]</sup>

Nanochitosan have improved antimicrobial and anti-adhesion effects due to its smaller size and significantly reduce the bacterial count in dental biofilms and dental biofilm formation than chitosan. Nanochitosan has better antibacterial property than chitosan against all the four strains of cariogenic streptococci- *S. mutans*, *S. sobrinus*, *S. sanguis* and *S. salivarius*.<sup>[38]</sup>

### **CONCLUSION:**

Nanochitosan not only reduces the microbial mass in mature biofilms because of its potent antimicrobial properties, but they also disturb the adhesion of biofilm resulting in prevention of formation of dental biofilms. The unique properties of Nanochitosan makes it a promising antimicrobial agent for control of dental plaque.

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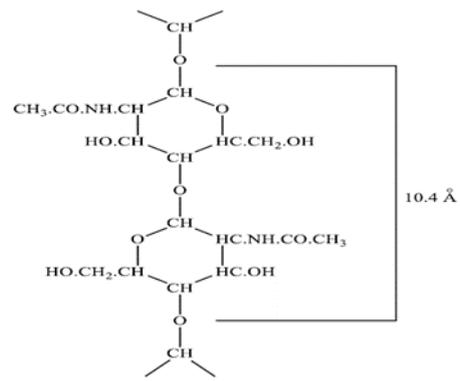


Fig 1: Chemical structure of Chitosan (Meyer and Mark)<sup>7</sup>