Chitosan: A potential local drug delivery agent

[1] Dr. Pradnya Mali, [2] Dr. Shivani Kondhalkar, [3] Dr. Aishwarya Jadhav, [4] Dr. Vinayak Meharwade, [5] Dr. Rutuja Mohire,

[1]Periodontology and Oral Implantology
[1]Sinhgad dental college and hospital, Pune, India

Abstract - Chitosan is a non -toxic biodegradable natural polymer. Chitosan & its derivatives have been used for potential tissue engineering biomaterials. Chitosan proves to be a complete package of properties necessary for repair and regeneration with an advantage that it can be moulded according to therapeutic remedy. Chitosan derivatives (marine sources) have a large impact and show potential in biomedicine for the development of drugs in future. Chitosan uses in periodontics such as PDL regeneration, bone repair, wound healing, haemostasis, & local drug delivery in form of films & gel enhances its prospective application. This presents the latest results and challenges in the preparation of chitosan and chitosan-based scaffold/hydrogel for wound healing applications. A detailed overview of their behaviour in terms of controlled drug delivery, divided by drug categories, and efficacy was provided and critically discussed. Increased usage of chitosan in periodontics will be more beneficial in periodontal treatments.

Index Terms - Chitosan, Chitosan-potential local drug delivery agent, Periodontal diseases, Chitosan in dentistry, Use of marine sources in dentistry, LDD in dentistry

Introduction

Periodontium, the tissues that support teeth, is composed of alveolar bone, cementum, gingiva, and periodontal ligament (PDL).[1] An inflammatory condition called periodontitis causes the periodontal tissues to deteriorate, resulting in tooth mobility and finally tooth loss.[2]
Recently plaque removal, scaling, root planning these local inflammation controls and some surgical treatments are mainly focused for the treatment of periodontitis.[3]
Chitin is a naturally occurring polysaccharide that can be found in the cuticles of insects, crab shells, and fungal cell walls. It is the second most common polymerized carbon in nature. Chitosan is created by alkaline deacetylation of chitin. The resulting biodegradable copolymer, which consists of D-glucosamine units with a free amino group.[4] Among the many advantages of chitosan and its derivatives are their excellent biocompatibility, nontoxicity to humans, biodegradability, reactivity of the deacetylated amino groups, selective permeability, polyelectrolyte action, antimicrobial activity, ability to form gel, film, and sponge, absorptive capacity, anti-inflammatory properties, and wound healing properties.[5] One of chitosan's most notable qualities is its high bioactivity, which makes it a very interesting material to use in the development of new biomaterials for application in the field of dentistry.[6]
Chitosan is used in a wide range of industries, including the paper industry, cosmetics, agriculture, medicine, and wastewater treatment.[7] Chitosan has attracted a lot of interest in the biomedical fields over the last 20 years, including wound dressings, cholesterol-lowering agents, haemostatic agents, skin-grafting templates, and drug delivery systems[8]. Local delivery of the medication/agent lowers the potential for the emergence of systemic adverse effects, raises the overall concentration of medication at the sick site, and reduces the potential for the emergence of drug resistance.[9]

History

Chitin had first been isolated from fungi in 1811 by Braconnot, who called it Fongine before Odier renamed it to chitin.[10] Rouget devised chitosan, the principal chitin substitute, in 1859 by reacting chitin with a heated potassium hydroxide solution. Gilson established glucosamine in chitin in 1894, and Hoppe-Seyler gave chitosan its name in the following year. [11]

Preparation and structure

Chitin is subjected to alkaline deacetylation to create chitosan, a naturally occurring polysaccharide biopolymer.[12] In the exoskeleton of crustaceans like crabs and shrimp, chitin is a straight homopolymer made of (1,4)-linked N-acetyl glucosamine units. The primary product of chitin deacetylation is chitosan, whose mean level of deacetylation, measured as the proportion of free NH2 groups, is more than 60%. Chitin's acetamide groups are hydrolysed to create chitosan. Due to the resistance of such groups imposed by the trans arrangement of the C2-C3 substituents in the sugar ring, this is often accomplished by strong alkaline hydrolysis treatment.[13]
In general, there are two main ways to make chitosan from chitin with differing degrees of acetylation. They include the homogeneous deacetylation of pre-swollen chitin under vacuum (by lowering pressure) and the heterogeneous deacetylation of solid chitin. Each C6 structural unit of chitosan has one main amino group, two free hydroxyl groups, and copolymers of glucosamine and N-acetyl glucosamine. Chitosan receives a positive charge from these free amino groups, enabling it to react with negatively charged surfaces.[14]

Properties

Biological properties

Chitosan is a non-toxic, biodegradable natural polymer. Mammalian and microbial cells can attach firmly to chitosan. In addition to having a restorative impact on gum connective tissues, it also hastens the development of osteoblasts, which build bones[15]. The properties of chitosan include those that are haemostatic, fungistatic, antibacterial, anticancer, anticholesteremic, and immunoadjuvant. However, they also function as CNS depressants and spermicidal drugs.[16]

Antimicrobial action

Chitosan's antibacterial properties would stop any potential illnesses. Quaternary ammoniumly, guanidinyl, carboxyalkyl, hydroxyalkyl, thiol-containing groups, and hydrophobic groups such lengthy alkyl chains and substituted phenyl and benzyl rings are among the functional groups found in chitosan derivatives.[17] Chitosan induces the agglutination of microbial cells and the prevention of their growth by binding with the anionic groups of bacteria.[18] In its gel form and hydrogel foundation, chitosan demonstrates antibacterial activity in decreasing germs in the oral cavity when used with toothpastes, mouthwashes, and chewing gum.[19] Additionally, chitosan has antiplaque efficacy against a number of oral infections, including Aggregatibacter actinomycetemcomitans, Prevotella intermedia, and Porphyromonas gingivalis.[20]

Anti inflammatory

It reduces the levels of prostaglandin E2, and the inflammatory cytokines interleukin (IL)-6 and IL-12 produced by human monocytes and keratinocytes, respectively. At the m-RNA level, there is a downregulation of IL-6 and tumour necrosis factor-alpha expression.[21] Chitosan attenuates the lipopolysaccharide-activated signal pathways c-Jun NH terminal kinase and p38 mitogen-activated protein kinase. According to studies, periodontal and gingival fibroblasts' anti-inflammatory response to chitosan lowers inflammation in certain conditions.[22]

Chemical Properties

Reactive functional groups like amino and hydroxyl groups are present in chitosan. Amino groups with a positive charge aid in preventing plaque development.[23]
Chitosan creates water-soluble salts with inorganic and organic acids such glutamic, hydrochloric, lactic, and acetic acids but is insoluble at neutral and alkaline pH levels.[24]

Application of chitosan in dentistry

Gram-negative, gram-positive, and fungus are all particularly vulnerable to the antibacterial properties of chitosan, a versatile hydrophilic polymer derived from chitin. [25]Chitosan is mostly utilised in dentistry as an antibiotic and antibacterial agent.[26]

Antimicrobial activity of chitosan

Chitosan has active amino and hydroxyl functional groups and are polycationic in nature. Chitosan adheres effectively to salivary pellicles and modify their surface so that it is positively charged and more hydrophobic.[27] Chitosan's positively charged amino groups interact with the negatively charged surfaces of microorganisms, causing the microbial cell wall to lose its barrier function and to spill proteinaceous and other intracellular materials.[28] Chitosan-treated pellicles' positive charge contributes to the reduction of S. sanguinis viability attached to saliva-coated enamel. When combined with chitosan, chlorhexidine has a greater impact on cell viability reduction than when used alone.[29]

Chitosan in Dentifrices

Chitosan functions well as a gelling agent, has strong antibacterial characteristics, and doesn't need preservatives. Chitosan-based polyherbal toothpastes showed promise as a viable oral hygiene solution since they reduced the development of the bacteria that cause cavities and gingivitis and enhanced the antibacterial and anti-inflammatory effects of toothpaste's active components.[30]

Chitosan based adhesives

With different degrees of effectiveness, several substances, including chlorohexidine, methacryloxyethylcetyldimethyl ammonium chloride, inorganic agents, and it was discovered that S. Mutans responded better to adhesives that contained less chitosan.[31] However, microtensile bond strength, degree of conversion, and pH are negatively impacted by chitosan content. [32]As the chitosan concentration rises; the adhesive resin's viscosity increases and inhibits it from penetrating the demineralized dentin.[33]

Chitosan as implant surface modifier

The biocompatibility of the Ti6Al4V implants was greatly increased through the electrodeposition of chitosan in combination with calcium phosphate, with no negative effects on the implants' other attributes.[34] Increase in the concentration of chitosan has the negative effects on both the coating thickness and surface roughness.[35]

Chitosan as dentin collagen

The biological and mechanical qualities of collagen constructions are considerably enhanced by chitosan incorporation. [36]More recently, the impact of carboxy methyl cellulose on the structural integrity of dentin was assessed, and it was discovered that by chemically and photodynamically crosslinking the collagen matrix with carboxy methyl cellulose chitosan, the chemical stability, tensile strength, and toughness of dentin collagen were significantly improved.[37]

Dental scaffold material

To offer a surface on which cells may cling, proliferate, and spatially arrange, an organic scaffold is utilised.
The most crucial feature of a scaffold to prevent negative tissue reactions is biocompatibility. The most often utilised synthetic polymers in tissue engineering include poly(lactic) acid (PLA) and poly(glycolic) acid (PGA). [38]Due to its excellent biocompatibility and natural enzyme-based degradation, chitosan is now regarded as a scaffold material and has been used in several dental tissue engineering applications.[39]

Chitosan Use in periodontics

Chitosan stimulates directed tissue regeneration and has antimicrobial properties. In periodontal tissue engineering, it serves as a cutting-edge scaffold and encourages epithelial adhesion and regrowth. Chitosan gels are a non-surgical option for treating periodontitis that uses periodontal therapy. [40]

Periodontal regeneration

Formulations containing chitosan last longer at the application site, and their haemostatic and tissue-regeneration capabilities do away with the need for additional materials like barrier membranes and bone grafts in regenerative therapies. Additionally, chitosan exhibits osteoconductivity and induces neovascularization, both of which speed up bone development. Demineralized bone transplants can be successfully combined with chitosan gel. [41]

Bone repair
Because of its biodegradability and biocompatibility, chitosan can be used as a biomaterial and scaffold for the regeneration of hard tissues. Spongy chitosan supports osteoblast proliferation, can increase osteogenesis, and aids in guided bone regeneration, according to a study. Bone density is higher in chitosan-filled tooth sockets than in untreated ones .[42]

Wound healing and haemostasis

Chitosan affects specific cells involved in the healing process and causes macrophages to release IL1, which promotes the growth of fibroblasts. It also causes the release of acetylglucosaminidase N, which boosts the production of hyaluronic acid and other extracellular substances involved in scarring and wound healing.[43] The wounds treated in this way have increased collagen levels, more active fibroblasts, and osteopontin, along with significant polymorphonuclear leukocyte infiltration .[44]

Chitosan as a local drug delivery

Antibiotics like metronidazole, chlorhexidine, and nystatin are delivered to periodontal tissue by chitosan nanoparticles.[45] In addition to scaling and root planning, chitosan gel with or without 15% metronidazole was used in individuals with chronic periodontitis. When a local medication delivery system containing chitosan and chlorhexidine is utilised, there is a reduction in the depth of probing and the amount of clinical attachment. [46]

A Potential Local Drug Delivery System for Antibiotics was the title of a paper given in 2008 by Scott P. Noel MS, Harry Courtney, Joel D. Bumgardner, and Warren O. Haggard. A biocompatible, biodegradable polymer called chitosan has been employed in numerous medication delivery applications.[47] Chitosan was examined as a possible localised medicine delivery system. They specifically tested whether chitosan could elute antibiotics in an effective manner that would prevent the growth of S. aureus.[48]

A research article was published by Gupta *et al* in 2009, Pluronic and Chitosan based in situ gel system for periodontal application. [49]Chitosan, a mucoadhesive and pH-simulating polymer, was combined with Pluronic F-127, a temperature-simulated gelation polymer. To check the efficacy of the developed in-situ gel system prilocaine hydrochloride was used as model drug. At pH 7.4

and 37°C, the system that was constructed was discovered to be clear, have good viscosity, and have prolonged release. With the technique used, the formulation may be simply packaged and sterilised. [50]Gel was determined to be stable in accordance with ICH requirements, and a shelf life of two years was given to the formulation.[51]

Periodontal Chitosan-Gels Designed for improved local intra-pocket drug delivery by Popa *et al in 2013*. This study suggested a method for administering two medications, tetracycline hydrochloride and metronidazole benzoate, to treat periodontal disease locally and intra-pocket. It was based on a series of formulations with chitosan gels. An ideal concentration of chitosan in gel (3%) for useful modification of drug loading, as a success factor in local therapy for periodontitis, was provided based on the experimental data.[52]

In 2014 Muge Kilicarslan *et al* proposed a study, preparation and characterization of chitosan-based spray dried microparticles for the delivery of clindamycin phosphate to periodontal pockets. The periodontal pocket can be directly injected with microparticles, or microspheres made from biodegradable or non-biodegradable polymers as a chip, as a component of a gel or paste, or as part of a paste or gel. Chitosan has good drug penetration across the nasal and buccal mucosa. Clindamycin is a broad-spectrum antibiotic in periodontal therapies it has mainly bacteriostatic action against gram-positive aerobes. The study found that the chitosan's antimicrobial and bioadhesive properties, the spray-drying method's ease of scaling up, the microparticles' proper particle size and size distribution, the delayed release with delayed efficacy release, and other characteristics made clindamycin phosphate-loaded chitosan microparticles suitable for use in the periodontal pocket.[53]

In 2017, Abeer S. Gawish and May M. Bilal, they stated Ofloxacin is a fluroquinolone antibiotic that has antibacterial activity against periodontopathic bacteria. After 7 days, ofloxacin liposomal autogel showed a significantly lower anaerobes bioburden in subgingival samples than did ofloxacin solution, according to the microbiological analysis. Additionally, the three-month evaluation of the liposomal autogel formula revealed a considerable improvement in the various clinical indicators. Chitosan/β-glycerophosphate (C/β-GP) system was recently explored as thermo-responsive gelling
systems in many applications.[54]

A study was proposed in 2018 by Junyu Liu *et al*, Glucose-sensitive delivery of metronidazole by using a photo-crosslinked chitosan hydrogel film to inhibit Porphyromonas gingivalis proliferation.
In this study, a photo-crosslinked Chitosan hydrogel film containing metronidazole was used to create a glucose-sensitive drug delivery system. According to the findings, this hydrogel has excellent mechanical properties, strong enzymatic activity, and perfect biocompatibility. Furthermore, as the glucose content rises, this substance may increase metronidazole release. As a result, in a solution with a high glucose concentration, it exhibits higher antibacterial efficacy against Porphyromonas gingivalis. This information offers a fresh approach to creating a biocompatible local medication carrier for the treatment of periodontitis in diabetics.[55]

In 2020 Asdar Gani *et al*, *the effect of white shrimp head chitosan gel on inhibitory strength of periodontopathogenic bacteria and accelerating wound healing*. According to them Chitin contains polyelectrolyte characteristics, is non-toxic, biodegradable, and biocompatible qualities. It has been demonstrated to have antibacterial properties and hasten wound healing. An innovative new product that is effective at reducing periodonto-pathogenic bacteria and accelerating wound healing is chitosan gel, which is made from the waste of white shrimp heads.[56]

Results

We got many articles about the chitosan in dentistry. We have gone through total 50 articles regarding chitosan in periodontology from the PubMed, after that 25 articles were decided for this review article, out of them 6 were excluded afterwards. 19 articles were studied then we excluded four more article as two of them were about the evaluation CHX with chitosan, an article was excluded as it was about the chitosan delivery system for the treatment of oral mucositis, the last one was about the chitosan in local anticancer therapy. This review article is based on 15 articles out of them 7 articles are taken for role of chitosan as a gel form in local drug delivery in periodontitis.

Authors	In vivo / In vitro	LDD form	Concentration	Result
Scott P et al	In vitro	Chitosan films	2% (w/v)	The data from this study suggested effective release of amikacin and daptomycin. The eluants inhibited growth of Staphylococcus aureus. Chitosan incorporated with antibiotics provide alternative method of treating infections.
Himanshu Gupta et al	In vitro	Gel form	0.5% w/v chitosan combined with 10% w/v Pluronic F-127	This study revealed that gel system formed with combination of chitosan and pluronic F-127 has very good gelling capacity and great strength at low polymeric concentration. It is a very good vehicle for delivery of drugs like anaesthetics, antibiotics etc for periodontal application.
Lacramioara Popa et al	In vitro	Gel form combined with tetracycline hydrochloride and metronidazole benzoate	Chitosan gel (3% and 4% w/w) with tetracycline hydrochloride (1% and 3% resp.) and metronidazole benzoate (1% and 2% resp.)	When chitosan gel was prepared with concentration 3% w/w and 4% w/w along with antibiotics resulted in controlled release of the drug in crevicular fluid. Moreover, chitosan concentration of 3% offered a base for optimum drug dose modulation making them efficient in local delivery of treatment.
Muge Kilicarslan	In vitro	Spray dried chitosan microparticles loaded with clindamycin phosphate	Chitosan solution 1% w/v with clindamycin phosphate in concentration 0.25/1 w/w (F1), 0.5/1 w/w (F2), 1/1 w/w (F3), 2/1 w/w (F4), 3/1 w/w (F5) & 4/1 w/w (F6) respectively.	Clindamycin phosphate loaded chitosan microparticles yielded efficient antimicrobial and bio adhesive properties. The delayed release of drug in the periodontal pocket allowed the distribution of microparticles increasing the efficacy of the drug.
Abeer S. Gawish and May M Bilal	In vivo	Chitosan with ofloxacin liposomal chitosan-based auto gel	0.1% ofloxacin liposomal chitosan-based auto gel	Ofloxacin liposomal chitosan-based auto gel proved to have a greater efficacy in treatment of periodontitis as it showed marked suppressed anaerobes bioburden in the subgingival milieu. Along with this advantage it also released therapeutic levels of ofloxacin in the periodontal pockets resulting in improvement in all clinical parameters.
Junyu Liu *et al*	In vitro	Photo-crosslinked Chitosan hydrogel film loaded with metronidazole	Chitosan hydrogel film immersed in 1% (v/v) glutaraldehyde solution, glucose oxidase solution, 0.5% (w/v) metronidazole	Photo-crosslinked chitosan hydrogel film loaded with metronidazole has good mechanical property, favourable enzymatic activity, and ideal biocompatibility. It has shown better antibacterial ability against Porphyromonas gingivalis in high glucose concentration. This is a better biocompatible local drug carrier for diabetic periodontal therapy.
Asdar Gani et al	In vitro	Chitosan gel from white shrimp head (Litopenaeus vannamei)	Chitosan 1%, 2%, 3% against Aggregatibacter actinomycetemcomitan	Chitosan gel from Litopenaeus vannamei waste can inhibit growth of periodonto-pathogenic bacteria. It decreases number of PMN cells and increases number of fibroblast cells as a result accelerates wound healing.

Discussion

An article Potential Local Drug Delivery System for Antibiotics by Scott P. Noel MS, Harry Courtney, Joel D. Bumgardner, and Warren O. Haggard was published in 2008. They looked at the in vitro elution of two widely used antibiotics from the chitosan matrix, a resorbable polymer. Amikacin or daptomycin was preloaded with 5% (w/w) on the chitosan films utilised in this study. For the purpose of determining the drug release profiles, films were made and put through both elution tests. The effectiveness of the medicines' ability to inhibit when combined with the chitosan matrix was also evaluated by activity testing.[57]

They created chitosan films by combining 2.0 g of deacetylated chitosan (AgraTech International, Inc., Goose Creek, SC) with 98.0 mL of weak acid solvent at a ratio of 1% to create a 2.0% (w/v) film.
They showed that it was possible to include widely used antibiotics in a chitosan matrix. During the first several hours following testing, there was a significant release of the drug, just like with other degradable delivery methods.[57]

Himanshu Gupta, Aarti Sharma, Birendra Shrivastava, and others released a study on the use of a periodontal in situ gel system based on Pluronic and chitosan. According to the findings, the in-situ gel system made from chitosan and Pluronic F-127 can be a good vehicle or system for the administration of medications like anaesthetics and antibiotics for periodontal use. Thus, the developed approach produces a stiff gel with a prolonged action at mucosal pH and body temperature that may be useful against conventionally unpleasant periodontal application, where systemic distribution and surgical procedure are needed. The formulation has a two-year shelf life and is simple to package and sterilise. As a result, the constructed system can be examined for in vivo and clinical efficacy in
the future.[50]

The study Periodontal Chitosan-Gels Designed for improved local intra-pocket drug delivery, proposed by LĂCRĂMIOARA POPA, MIHAELA VIOLETA GHICA*, CRISTINAELENA DINU-PÎRVU They made chitosan gels (3% and 4% w/w) manually combining enough citric acid (0.33M) with the chitosan in a continuous stream. At a pH of 7, chitosan (C) dissolves. Both metronidazole benzoate (M) (1% and 2%, respectively) and tetracycline hydrochloride (T) (1% and 3%, respectively) were dissolved in citric acid 0.33M and manually added to the chitosan-gels. Chitosan hydrogels that were uniform and transparent were created.[52]
The chitosan gels suggested in this work are suitable for local, intra-pocket medication administration due to specific properties. The rheological profile and features of the gel formulations play a crucial role in their clinical performance since they are subjected to non-deformable stresses after syringe administration. It is preferable to keep the gel in the pocket after injection while also presenting a controlled release of an antibiotic or antibacterial agent into the crevicular fluid. The release of the medication gradually decreased as chitosan concentration rose. They may anticipate that a chitosan concentration of 3% w/w could provide a base for an optimal modification in medication dose and make them effective in a local strategy of treating periodontal disease based on the kinetic release data and the rheological profiles for periodontal gels.[52]

Muge Kilicarslan, Mehmet Gumustas, Sulhiye Yildiz and Tamer Baykara published a study; Preparation and Characterization of Chitosan-Based Spray-Dried. Microparticles for the Delivery of Clindamycin Phosphate to Periodontal Pockets. In this study clindamycin phosphate (CDP)-loaded biodegradable spray-dried chitosan microparticles were developed to administer medication locally into the periodontal pocket. By assessing process yield, encapsulation effectiveness, particle size and size distribution, surface morphology, drug release, release kinetics, thermal analysis, and antimicrobial efficacy of formulations, the effects of spray dryer conditions, drug/polymer ratio, and added amounts of glutaraldehyde (GA) solution on the characterization of microparticles were investigated.[53]
By putting the drug inside the chitosan microparticles, it was possible to achieve a drug release that was delayed for longer than a week. Positive drug release profiles were seen in antimicrobial efficacy investigations. These findings suggest that clindamycin-loaded microparticles that have been spray-dried and exhibit persistent antibacterial effectiveness could be a useful periodontal therapy for delivering medications to the periodontal pocket.[53]

A study was published by Abeer S. Gawish* and May M. Bilal, in that study; Twenty patients with chronic periodontitis and at least two contralateral intrabony abnormalities were chosen at random from a split mouth design. All sites received non-surgical treatment (subgingival scaling and root planning). Twenty of the pockets received liposomal auto gel, one of the two types of ofloxacin. The remaining twenty pockets served as the control sites and underwent non-surgical periodontal treatment with ofloxacin solution. Mucoadhesion, syringe ability, and gelation onset were assessed for the autogel made from chitosan that had been neutralised by -glycerophosphate. Drug release from the gel, liposomes, was 80% within 7 days. At baseline and three months after non-surgical periodontal therapy, clinical data comprising plaque index, gingival index, bleeding on probing, probing depth, and clinical attachment level (PI, GI, BOP, PD and CAL) were recorded. Additionally, a microbiological analysis was performed to evaluate the sustained release effect at the baseline, 1, 3, and 7 days afterwards. The developed ofloxacin liposomal auto gel is considered to be promising in the management of chronic periodontitis based on the microbiological and clinical findings of the current experiment.[54]

Using biocompatible photo-crosslinked chitosan hydrogel film, a novel metronidazole drug delivery method with controlled release was created. In particular, photosensitive methacrylic anhydride was first grafted onto the molecular chains of chitosan, and then UV irradiation was used as the crosslinking method. By immobilising glucose oxidase on the surface of chitosan film, glucose sensitivity was conferred. The physicochemical features, such as chemical composition, degree of crosslinking, mechanical strength, and associated enzyme properties, were examined in turn. A cytotoxicity test, a drug release test, and an anti-bacterial test were each completed. The findings demonstrate that this photo-crosslinked hydrogel film has strong mechanical properties, and that the immobilised enzyme can maintain a relatively high degree of bonding capacity and activity even after surface activation.[55]

Laboratory experimentation was used in the study. This study had a post-test only, control group-only design. Chitosan gel was used as a positive control (Metronidazole disc) and a negative control in a 6-team, 5-times-repeat, 5-treatment study on bacterial inhibition. The concentrations used were 1%, 2%, and 3%. 24 white mice (Mus musculus) with incisions on their backs served as

the test subjects for this study on wound healing. Glycerol was used to split them into treatment and control groups. On days 1, 3, and 7, clinical and histological observations were made. White mice (Mus musculus) with back wounds can recover more quickly thanks to chitosan gel from waste from white shrimp heads (Litopenaeus vannamei), which also reduces the number of PMN cells while increasing the number of fibroblast t cells.[56]

CONCLUSION

The review summarizes all the specific studies related to chitosan and its application in dentistry and Periodontology. Chitosan as mentioned above proves to be a complete package of properties necessary for repair and regeneration with an advantage that it can be moulded according to the clinicians' will and wish. The review enhances the facts that chitosan can be in multiple combinations i.e it can carry itself with other drugs as well, giving a further advantage of its ability to act like a catalyst. Apart from this the review focuses on the properties that chitosan showcases. There are number of interventional studies that have used chitosan in various forms but there is lack of literature regarding the stability of chitosan or its role in those interventional procedures. It is necessary to further contemplate the studies that are mainly focused on stability of chitosan. This will necessarily prove as an advantage for us in biomedical and pharmaceutical point of view.

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