Chitosan: Applications in Dentistry – A Review Article

Dr. Snehal Chavan
PG Student
Dept. of Conservative dentistry & Endodontics
Dr. D.Y. Patil University School of Dentistry
Nerul, Navi-Mumbai

Dr. Leena Padhye
Professor & Guide
Dr. D.Y. Patil University School of Dentistry
Nerul, Navi-Mumbai

Dr. Lalitagauri Mandke
Professor & H.O.D
Dr. D.Y. Patil University School of Dentistry
Nerul, Navi-Mumbai

Abstract

Chitosan, a versatile hydrophilic polysaccharide derived from chitin, has a broad antimicrobial spectrum to which gram-negative, gram-positive bacteria and fungi are highly susceptible.The chitosan minimum inhibitory concentrations (MIC) are summarized according to recent data found in the literature. In the current review the possible applications ofchitosan in dentistry are briefly discussed.

Introduction

Dental caries is a chronic and multifactorial disease. Dental caries is the most prevalent oral disease that affects a significant part of the world population, especially in less developed countries[1,2]. Recent developments in the areas of biomaterials devices have resulted in a number of advances in the searches of natural substances which may inhibit the dental plaque formation and/or the hydroxyapatite demineralization[3,4].

Chitosan is a non-toxic and natural polysaccharide, which have many biological applications, mainly as antimicrobial agent4. Chitosan is already in widespread use as a biomaterial in the field of soft tissue and hard tissue repair. The biological activities of chitosan of interest in the oral cavity are above all osteoconduction, stimulation of soft tissue repair, drug release and use in productsfor oral hygiene, such as toothpastes and mouthwashes based on chitosan.[5] Throughout this review our aim is to present and discuss the possible various applications of chitosan in dentistry.

Chitosan general considerations

Chitin is the most abundant naturally found cellulose derivative consisting of 1,4-β-N-acetyl-2-aminodeoxyglucose units.[6] Chitosan is the most abundant basic biopolymer and is structurally similar to cellulose, which is composed of only one monomer of glucose. Chitosan solubility, biodegradability, reactivity, and adsorption of many substrates depend on the amount of protonated amino groups in the polymeric chain, therefore on the proportion of acetylated and non-acetylated D-glucosamine units. Structurally, chitosan is a straight-chain copolymer composed of D-glucosamine and N-acetyl-D-glucosamine being obtained by the partial deacetylation of chitin.[7]

Chitosan has numerous applications in several areas, mainly biomedical and pharmaceutical fields, due to its specific properties Among their properties we highlight the excellent biocompatibility; almost any toxicity to human beings and animals; high bioactivity; biodegradability; reactivity of the group amino deacetylated; selective permeability; polyelectrolyte action; antimicrobial activity; ability to form gel and film; chelation ability and absorptive capacity. These peculiar properties provide a variety of applications to the chitosan, such as: drug carrier of controlled release, anti-bacterial and anti-acid; inhibition of the bacterial plaque formation and decalcification of dental enamel; promotes the osteogenesis; and promotes the healing of ulcers and lesions.[8]s

Sensitivity of Microorganism Strains to Chitosan

MIC is defined as the lowest concentration of an antimicrobial that will inhibit the visible growth of a microorganism after overnight incubation. Chitosan has several advantages over regular type of disinfectants owing to its broad spectrum of activity. Chitosan has been observed to act more quickly on fungi than on bacteria.[9]

There are many studies about the minimum inhibitory concentration (MIC) for chitin, chitosan, their derivatives or combination, with different results for different microorganism. It is dependent of many factors and the non-standardized procedures make difficult to compare MIC.

Table 1. Minimum inhibitory concentration (MIC) for chitosan against several microorganisms (concentration normalized to ppm).

Sensible Or Ganisms	Mic (ppm)
Gram Negative Escherichia Coli Xanthomonas Campestris Salmonella Enteric	1000 500 20003000
Pseudomonas Aeruginosa	2001700
Aeromonas Hydrophila Shigella Dyse Nteriae Vibrio Cholera	1000 <200 200
Pseudomonas Fluorescens Enterobacter Aerogens	250500-1000 250
Gram Positive	
Bacillus Cereus Staphyloc Occus Aureus	<10001000 20100>800700>1250
Candida Albicans Bacillus Me Gaterium	500600>1250 800

Applications of chitosan in dentistry

1) Removal of smear layer after root canal instrumentation

A study was conducted to evaluate by scanning electron microscopy, the efficacy of smear layer removal using chitosan compared with different chelating agents and to quantify ,by atomic absorption spectrophotometry,the concentration of calcium ions in these solutions after irrigation. Results had shown that 15% EDTA, 0.2% chitosan and 10% citric acid had similar smear layer removal capacity with a significant difference from 1% acetic acid and the control group.The highest calcium ion concentration was observed with 15% EDTA and 0.2% chitosan,with no significant difference and the lowest calcium ion concentration was obtained with 1% acetic acid whilst 10% citric acid had intermediate results, differing significantly from the other solutions.[10]

2) Effect of chitosan as a new chelating agent on the microhardness of root dentin:

Endodontic instrumentation, using manual or mechanized techniques during cleaning and shaping procedure, produces smear layer on the root canal walls and smear plugs into dentinal tubules.The smear layer can be removed using different solutions, but currently the most commonly employed method used by endodontists is varied concentrations of EDTA combined with sodium hypochlorite. However, the search for more biocompatible solutions than EDTA has increased over the years. Therefore, a study was done to evaluate comparatively the action of 0.2% chitosan, 15% EDTA and 10% citric acid on root dentin microhardness.its mechanism of action, it is believed that adsorption, ionic exchange and chelation are responsible for the formation of complexes between the substance and the metallic ions.

The type of interaction that occurs depends on the ion involved, the chemical structure of chitosan, and the pH of the solution [11]. Currently, there are two versions that try to explain the chelation process of chitosan. The first, known as the model of the bridge, is grounded in the theory that two or more amino groups of one chitosan chain will bind to the same metallic ion. The other defends the thesis that only one amino group of the structure of the substance is involved in the binding, that being the metallic ion "anchored" to the amino group . Anyway, the mechanism of chelation of calcium ions in dentin might also be responsible for the depletion of the inorganic portion of the smear layer, as observed in the SEM micrographs. Particularly the group treated with chitosan presented patent dentinal tubules without alteration of the intertubulardentin.The results of this study indicated that chitosan, EDTA and citric acid reduced root canal microhardness with no statistically significant difference amongthe solutions.[11]

3) For Bone defects

Bone defects may develop in various systemic and dental disorders. The conventional methods of bone repair which commonlyare used, such as autografts and allografts have theirown shortcomings and drawbacks.To overcome these limitations, various synthetic bone substitutes made of metal, ceramics, polymers,
and various composite structures have been introduced to accelerate and improve the process of bone regeneration;though their safety, effectiveness and efficacy remain uncertain.

The new materials which are used should help us reduce the operationtime, scar size, post-operation pain, and alsoimprove patient recovery.[12]Recently a special attention has been made toward using the materials which are derived from nature.Such materials would have some advantages over syntheticones. Most notably, they have been shown toyield faster healing with less incompatibility in human beings.Several desirable properties have been described for chitosan including high osteoinductivity,osteointegratability easy application and gradual biodegradabilitythat makes it a good candidate for bone regeneration.Some researchers have studied the effects of chitosan compounds on animal bone repair.[13,14]

Several studies have investigated various effects of chitosan on bone healing and raised some hypotheses onits mechanisms. For instance, according to a study by Chevrier and co-workers, chitosan increases Thevasculariza tion of blood vessels and stimulates buddingtissue (tissue comprising of budding capillaries and fibroblasts.Park and co-workers[15] reported that spongy chitosanac-tivates osteoblasts and could increase osteogenesis.In a study conducted by F. Ezoddini-Ardakan et al, chitosan powder was used to see its effect on bone regeneration. Itwas interestingly found that after a period of 10 weeks,the bone density in the apical zone of the sockets treatedwith chitosan was 98.2% of maximum mandibular bonedensity, which was 29.3% more than that of untreatedsockets.

4) Anticariogenic property of chitosan against dental caries

Chitosan has a recognized antimicrobial activity, being this, one of the main properties of the polysaccharide. Several researchers demonstrated that this polysaccharide has antimicrobial action in a great variety of microorganisms, included gram-positive bacteriaand various species of yeast. In the literature is described that chitosan acts in the cellular wall of the microorganism modifying the electric potential of the cellular membrane [46]. This polysaccharide also actspoten-tiating other inhib-ition drugs, as the chlorhexidinegel, once it increases the drug permanence time action place.

5) Chitosan based cements

Cements based on chitosan would appear to make a positive contribution to this delicate and complex problem: chitosan being resorbable allows the replacement with bone tissue to co-occur during regeneration, terminating with complete replacement. Furthermore as well as high biological and structural compatibility, the possibility of modifying physical and mechanical properties gives cement based on chitosan a wide and safe field of application.[5]

Conclusion

In the light of the above it appears clear that also in the dental field the increasing of chitosan, as a bioactive material in different organizational forms is an indication of the desire to interact positively with biological tissue structures in order that, in the near future, it will be increasingly possible to aid biology, also in treasting diseases of the oral cavity.

References

[1] Tahmourespour A, Kermanshahi RK, Saleh R, Pero NG. Biofilm formation potential of oral streptococci in related to some carbohydrate substrates. African Journal of Microbiology Research. 2010; 4 (11) 1051-1056.

[2] Stamford-Arnaud TM, Barros Neto B, Diniz FB. Chitosan effect on dental enamel deremineralization:
an in vitro evaluation. Journal of Dentistry. 2010; 38 (11) 848-852.

[3] Alexander C, Marsh L. Creating the optimum environment for pressure area care. Brazilian Journal of Nursery. 1992;1(15),751-757.

[4] Ji QX, Zhong DY, Lu R; Zhang WQ; Jing D; Chen XG. In vitro evaluation of biomedical propesties of chitosan and quaternized chitosan for dental applications. Carbohydrate Research. 2009; 344, 1297-1302.

(5) M.Mattioli Belmonte, R Mongiorgi, G. Dolci. Bioactivity of chitosan in dentistry. Minerva Stomatol 1999; 48:567-76 .

(6) Michael Ioelovich Crystallinity and Hydrophility of Chitin and Chitosan; Research and Reviews: Journal of Chemistry, 3(3), pp.7-14 (2014)

(7) Elson Santiago de Alvarenga. Characterization and Properties of Chitosan Biotechnology 92 of Biopolymers;

(8) Thayza Christina Montenegro Stamford, Thatiana Montenegro Stamford- Arnaud. Microbiological Chitosan: Potential Application as Anticariogenic Agent; Practical Applications in Biomedical Engineering.

(9) Rejane C. Goy, Douglas de Britto, Odilio B. G. A Review of the Antimicrobial Activity of Chitosan; Polímeros: Ciência e Tecnologia, vol. 19, nº 3, p. 241-247, 2009.

(10) Silva PV, Guedes DFC, Nakadi FV, et al. Chitosan: a new solution for removal of smear layer after root canal instrumentation. IntEndod J 2013; 46(4): 332-338 .

(11) Josilaine Amaral Pimenta; Danilo Zaparolli; Jesus Djalma Pécora. Chitosan: effect of a new chelating agent on the microhardness of root dentin. Braz Dent J. 2012; 23(3):212-7.

(12) Lui, H., Li, H., Cheng, W., Yang Novel injectable calcium phosphate/chitosan composites for bone substitute materials. Acta Biomater, 2006; 557-565.

(13) Burngardner, J.D., Wiser, R., Gerard, P.D., Bergin, P.,et al Chitosan: Potential use as a bioactive coating for orthopedic and craniofacial/dental implants. Journal of Biomaterials Science, Polymer Edition, 423-438.

(14) Yao, Z., Xing, L., Qin, C., Schwarz, E.M. and Boyce. B.F. Osteoclast precursor interaction with bone matrix induces osteoclast formation directly by an interleukin-1-mediated autocrine mechanism. Journal of Biological Chemistry,2008, 283, 9917-9924.

(15) Park, Y.J., Lee, Y.M., Park, S.N., Sheen, S.Y., Chung, C.P. and Lee, S.J. 2000. Platelet derived growth factor releasing chitosan sponge for periodontal bone regeneration. Biomaterials, 21, 153-159.