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QUORUM SENSING: A REVIEW

Raktapratim Borgohain, Lynn Johnson, Neebha Kumari, Chandni Ghildiyal, Sunil Kumar Singh, Lenrik Taning

Rama Dental College Hospital and Research centre, Rama University, Mandhana, Kanpur (UP), India

Abstract: Bacteria use quorum sensing to coordinate their actions and communicate with one another.The growth and development of plaque are largely dependent on interactions between oral bacteria in humans. A number of mechanisms are involved in these interactions, including physical contact, metabolic exchange, communication via tiny signal molecules, and genetic material exchange.The majority of quorumsensing-controlled operations are ineffective when carried out by a single bacteria operating alone, but they become effective when simultaneously carried out by a large number of cells.Many strategies are being researched to prevent this communication in order to manage bacterial infections.Additionally, quorum sensing is a means of communication for periodontal pathogens. The benefits of interspecies interaction for microorganisms include expanded habitat range, efficient metabolism, increased resistance to host defense, and increased virulence. This typically has a negative impact on the host and is linked to a number of persistent illnesses, which make treatment difficult. Therefore, novel strategies for treating periodontal disease by quorum sensing suppression require investigation.This review focuses on the architectures of chemical communication networks in bacteria, the integration, processing, and transduction of chemical information to regulate gene expression, the mechanisms involved in intra- and interspecies cell-to-cell communication, and the intriguing prospect of prokaryote-eukaryote cross-communication.

Keywords: Biofilm, Auto inducers, Quorum sensing, Quorum quenching, Periodontal pathogens.

Introduction: Microorganisms in plaque do not exist as independent units but as a highly complex interacting colony—the biofilm. Within the biofilm, microorganisms not only get a favourable environment for growth but are also protected from the antibacterial substances. The role of plaque in the aetiology of the periodontal disease has been established beyond doubt. The interspecies communication within the biofilm plays a major role in the initiation and progression of the periodontal disease. Therefore, understanding the mechanical and chemical interaction between the microorganisms becomes indispensable to formulate a successful treatment regime for the periodontal disease[1].

Communication is a key element in successful organisations. Numerous studies have shown that a very sophisticated communication system exists in the oral biofilm. There are over 700 different bacterial species in the oral microflora. Some of these species are considered commensal and a positive feature of our healthy microflora, while others are considered pathogenic. It is unlikely that various species within oral biofilms function as independent, discrete constituents rather, these organisms function as a coordinated community that uses intra- and interspecies communication[1.]

The term quorum sensing was first used by Fuqua et al (1934)[2], which reflects the minimum threshold level of individual cell mass required to initiate a population response. With the increase in number of cells in a bacterial colony the concentration of the auto Inducers in extracellular environment also increases.

Quorum sensing systems

QS system can be divided into three phases[3,4,5]

1.LuxI/ Lux R type quorum sensing system utilizing fatty acid derivatives, called acyl homoserine lactones (AI1) in gram negative bacteria.

2.Oligopeptide/ two component type quorum sensing system utilizing amino acids and short peptide derivatives (AI2) in gram positive bacteria.

3.Lux S encoded autoinducer-2 in both gram positive and gram negative bacteria

Majority of gram-negative bacteria possess LuxIR- type proteins with AHL signals, used predominantly for interspecies communication. Gram-positive bacteria use modified oligopeptides as signals and histidine kinases as receptors. Interspecies quorum sensing is mostly facilitated through small peptides and has been linked to autoinducer2 (AI2).[5]

Quorum sensing -process

It begins with the synthesis of small biochemical signal molecules by the bacterial cell, which causes the release of the signal molecules into the surrounding medium, once the signal molecules are recognised by specific receptors, they exceed a threshold concentration and causes change in gene regulation[6].

Quorum-sensing network architecture:

There are various signalling architectures, and each network arrangement leads to distinct signalling features.

Competitive Quorum-sensing circuits: These quorum sensing networks are arranged such that the signals antagonize one another. Bacillus subtilis has two auto inducing peptides functioning in a network arrangement that allows B.subtilis to regulate two different developmental pathways: competence and sporulation[7].

Quorum- sensing Circuits with on-off switches: These allow bacterial transition from a set of low cell density behaviours to a different set of high cell density behaviour, promote transient expression of particular traits followed by reversion to the original set of behaviours. Such an on-off switch controls competence development in the gram-positive bacterium Streptococcus pneumonia by autoinducer-competence stimulating peptide to monitor cell density[8.]

Quorum sensing in Periodontal Pathogens:

Culture medium from Fusobacterium nucleatum, Porphyromonasgingivalis, and Prevotella inter-media induced bioluminescence in the reporter strain, suggest that these organisms produce autoinducer2.Aggregatibacter actinomycetemcomitans, possesses an AI2 dependent quorum-sensing system, regulates expression of virulence factors, biofilm formation, iron uptake, influences the planktonic growth of the organisms under conditions of iron limitation and upregulates leukotoxic activity and production of leukotoxin polypeptide. AI2 induced expression of AfuA, a periplasmic iron transport protein, fec BCDE, a putative ferric citrate transporter, and ftn AB, ferritin, suggest the role of LuxS dependent signalling in the regulation of iron acquisition in A.actinomycetemcomitans. Iron acquisition is required for pathogens to survive within a host, so factors related to iron acquisition are considered as virulence factors. P. gingivalis obtains iron preferentially through the acquisition of hemin.

According to Shao et al.,(2007)[8]LuxS mutant strain exhibited differential regulation of genes that are involved in various pathways of hemin uptake and acquisition. (Figure 1)

Quorum Sensing and Biofilm formation: The intra and interspecies bacterial communication play role in the formation, growth, and maturation of the dental plaque and improves their chance of survival. Physical communication provides the site for adherence, metabolic communications favour the environmental changes for the growth of pathogens, signalling molecules help to regulate their response to changes in the environment, and genetic communication helps to attain the microbial resistance against the antibiotics[1].

Quorum sensing play diverse roles such as modulating the expression of genes for antibiotic resistance, encouraging the growth of beneficial species in the biofilm, discouraging the growth of competitors. Thus, the bacterial communication has a major role in the etiopathology of the periodontal disease. Autoinducer 2 quorum sensing is closely linked to the ability of A. actinomycetemcomitans to grow in a biofilm[9].

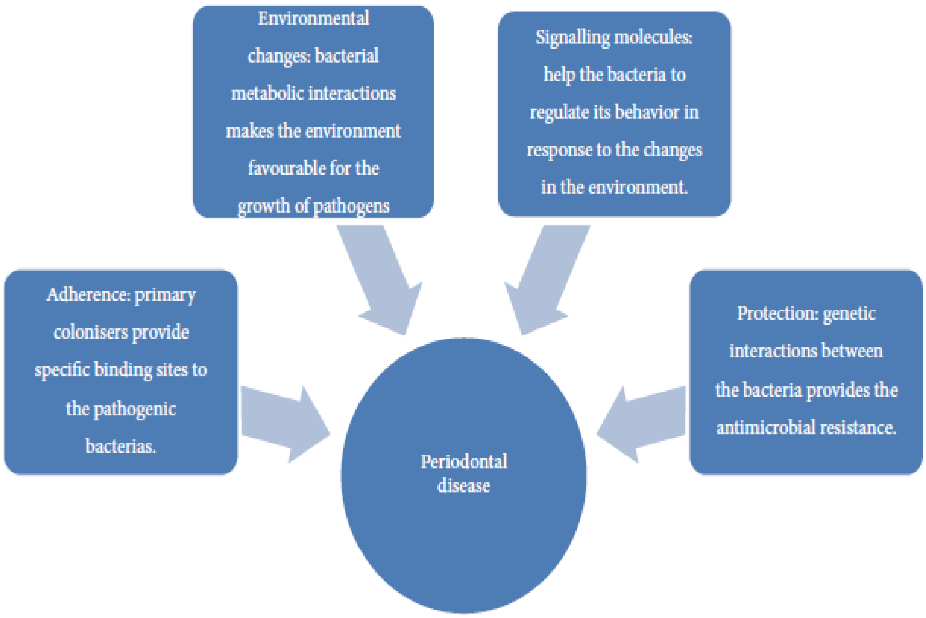

Fig 1: Showing the relation between the interspecies communication and the periodontal disease.

Quorum sensing as a therapeutic target:

Compounds that inhibit quorum sensing have been emerging as potentially novel class of antimicrobial agents[10]. Pharmacologic inhibition of quorum sensing is an attractive approach for the prevention or treatment of chronic infections like cystic fibrosis or chronic wound infections[9,]

Quorum Quenching:

The biofilm formation can be controlled by inhibiting the quorum sensing mechanism of bacteria that form the plaque biofilm. The process of inhibition of quorum sensing is commonly referred to as quorum quenching. This can be accomplished by [11]

1. Enzymatic degradation of signaling molecules
2. Blocking signal generation and
3. Blocking signal reception.

The inhibitors of quorumsensing can be roughly grouped into two categories according to their structures and functions. One groupconsists of molecules that structurally mimic quorumsensing signals, such as halogenated furanones and syntheticAI peptides (AIPs) that are similar to acyl-homoserine lactones (AHL) and autoinducing peptide (AIP)signals, respectively. These inhibitors interfere with thebinding of the corresponding signal to the receptor ordecrease the receptor concentration. The other groups ofsmall chemicals include enzyme inhibitors. For example,triclosan, a potent inhibitor of the enoyl-acyl carrierprotein (ACP) reductase that is involved in the synthesis ofacyl-ACP, one of the essential intermediates in AHLbiosynthesis, reduces AHL production, and closantel is apotent inhibitor of histidine kinase sensor of the two-component system[1.]

Future trends: The past decade has seen a remarkable increase in research on prokaryoticcell-cell communication systems, and these systems have been shown to playcritical roles in controlling the expression of some of the most important biologicalfunctions of these organisms. It is not unreasonable to assume that,yet undiscovered signalling systems will be shown to affect many more, perhapseven most, of the microbial processes that have a great impact on humans.Some microbial signalling systems may represent useful models for regulatorypathways that were previously believed to be limited to higher organisms.Also, an increased understanding of these systems will be crucial for futureadvancements in areas such as ecology, physiology, and pathogenesis. Finally,an increased understanding of extracellular signalling mechanisms may lead tomany useful applications, including an improved ability to control the expressionof useful metabolic functions for biotechnological applications, as well asthe identification of novel targets for the development of new drugs or vaccines against microbial pathogens[1.]

Conclusions:

Understanding and exploring the interspecies communication will open the new era of periodontal therapy. By specifically promoting and inhibiting these interactions, we can control the microbial structure of the oral biofilm. Oral health could be achieved by promoting the interactions between the health-promoting bacteria, while the development and progression of the periodontal disease can be inhibited by blocking the interaction among the periodontalpathogens. However, much research is required before we can enter this fascinating therapeutic regime. Hopes are high with the emergence of latest microbiological and genetic innovations in the field[12.]

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