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Review

Dental plaque as a biofilm and a microbial community—Implications for treatment

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ABSTRACT

Background: The mouth supports a diverse microbiota which exists as structurally-organised biofilms on mucosal and dental surfaces. The oral microbiota provides major benefits to the host including: (a) colonisation resistance, (b) down-regulation of potentially damaging host inflammatory responses, and (c) active contributions to the normal development of the physiology of the mouth and the host defences.
Highlight: Generally, these communities live in harmony (symbiosis) with the host but, on occasions, this symbiotic relationship breaks down and disease occurs (dysbiosis). Disease is associated with shifts in the balance of the oral microbiota driven by changes in the local environment. These changes include more regular conditions of low pH in the biofilm, as a result of an altered diet or reduced saliva flow, thereby favouring the growth and metabolism of acidogenic and acid-tolerating bacteria, at the expense of beneficial oral micro-organisms, and increasing the risk of dental caries. The host mounts an inflammatory response if biofilm accumulates around the gingivae beyond levels compatible with health. If this fails to reduce the biomass, the altered environment selects for increased proportions of obligately anaerobic and proteolytic species that can subvert the host response leading, ultimately, to pocket formation and loss of attachment.
Conclusion: An appreciation of ecological principles can lead to new strategies for treatment by identifying and removing the factors that drive dysbiosis, while actively supporting the growth of the natural oral microbiota. Also, the beneficial activities of the resident oral microbiota are retained and the risk of dysbiosis is reduced.

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1. Introduction

From birth, the infant is exposed to and colonised by a wide range of micro-organisms, derived mainly from the mother, although only a subset are able to establish successfully. The biological properties of each habitat determine which micro-organisms can colonise and grow, and dictate which will be major or minor components of the resident microbiota of a site. This results in different surfaces having distinct but characteristic microbiotas [1–5].

In their natural environment, micro-organisms revert to their so-called 'biofilm phenotype', and down-regulate certain activities, e.g. those related to motility, and up-regulate the production of polymeric substances that act as viscoelastic inter-cellular binding material and extra-cellular energy storage compounds, amongst other roles [6,7]. This mode of existence offers protection against external stresses, e.g. by limiting the penetration of antimicrobial agents, and by providing mechanical resilience to shear generated by saliva flow, etc., and promotes interactions among neighbouring microbial cells [8], as well as between the biofilm and the host, resulting in a complex and dynamic interplay.

2. Benefits of the resident human microbiota

The human microbiota and the host have co-evolved to have a symbiotic or mutualistic relationship [9]. The resident micro-organisms gain a secure, warm, nutritious habitat from the host, and, in return, contribute to food digestion, nutrition, regulation of human metabolism, differentiation of the host mucosa, immune development and function, and prevention of colonisation by exogenous and often pathogenic microbes [10]. This relationship between the resident microbiome and the host is dynamic and, whilst the composition of resident populations in health is remarkably stable [11], this can be perturbed by changes in lifestyle, immune status or by broad spectrum antibiotic therapy. Such perturbations have been associated with a number of clinical disorders such as obesity, allergy and a variety of inflammatory diseases [4,12].

3. Dental biofilms and oral health

The mouth is similar to other habitats in the body in having a characteristic microbiota, with different surfaces in the oral cavity supporting distinct microbial communities [13], the composition and metabolism of which are dictated by the local environmental conditions. The microbiota grows on oral surfaces as structurally- and metabolically-organised communities of interacting species, termed biofilms [14]. These communities are in a dynamic equilibrium with their environment, and there can be significant re-assortment and rearrangement of the composition and metabolic activity of these microbial consortia in response to changes in the biology of the mouth (e.g. eruption of teeth; flow of saliva; subversion of the host defences) and in the lifestyle of the individual (e.g. in response to smoking, dietary alterations, or to the side effects of medication, etc) [1,5].

The bacteria found in occlusal fissures are mainly Gram positive (especially streptococci), are facultatively anaerobic and primarily metabolise host and dietary sugars; these sites are particularly influenced by the properties and flow rate of saliva. In contrast, the biofilms from the healthy gingival crevice contain many more obligately anaerobic and proteolytic species, and the community is influenced predominantly by gingival crevicular fluid, GCF [15].

The composition of the oral microbiota at a site can remain stable over time (microbial homeostasis) [16]. This is not due to any biological indifference among the members of the biofilm community, but is a consequence of many highly regulated inter-dependencies among the resident microbes. These basic observations on site distribution of oral bacteria are highly significant. They provide direct evidence that the composition and metabolism of the oral microbiota at a site is sensitive and responsive to the oral environment, and that there is a dynamic relationship between them both. Biofilm composition can shift in response to changes in local environment and lifestyle.

4. Significance of a biofilm and microbial community life-style to the oral microbiota

Oral micro-organisms gain substantial advantages by growing as a biofilm and by developing as a microbial community [17]. Micro-organisms are in close proximity to one another in biofilms, thereby providing many opportunities for synergistic interactions. For example, bacteria can co-operate with one another to metabolise complex host molecules, such as glycoproteins, that would be recalcitrant to the action of single species. The metabolism of these communities is also more efficient, with food chains and food webs developing to catabolise substrates to the simplest end products of metabolism. Also, oral microbial communities display a broader habitat range, for example, with obligate anaerobes persisting at sites that are overtly aerobic. Biofilms are inherently tolerant to environmental stresses, the host defences, and antimicrobial agents, for example, due to limited access or penetration of molecules, while cross-protection of sensitive species by neighbouring organisms that produce neutralising enzymes (e.g. β-lactamase, catalase, etc) can occur. In this way, the properties of microbial communities are more than the sum of the component species [17].

5. Benefits of the oral microbiota to the host

As with other habitats in the body (see earlier), the general relationship between the oral microbiota and the host is mutualistic. The micro-organisms are maintained in an environment which is supplied with a diverse array of host molecules which serve as nutrients, and the resultant microbiota provides benefits to the host.

The resident oral microbiota prevents the establishment of the many exogenous micro-organisms that the host comes into contact with on a regular basis. This 'colonisation resistance' is because the natural oral microbiota is better adapted at attaching to oral surfaces, is more efficient at metabolising the available nutrients for growth, and can produce inhibitory factors and create hostile environments that restrict the growth of potential microbial invaders. Colonisation resistance can be 'lost' if the resident microbiota is disrupted, for example, by long-term exposure to