Dental caries: a biofilm disease

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Figure 1. High risk patient with a highly active caries process. These lesions have developed in less than 5 years and are progressing rapidly.

Figure 2. High risk patient with a low activity caries process. These lesions have taken more than 20 years to develop and are progressing very slowly.

Biofilms are found in nature wherever there is a fluid, a surface and bacteria. Biofilms are found lining waterlines, oil pipelines, on river rock and the surfaces of living creatures. Biofilms may be symbiotic or they may be harmful and cause damage. In the past decade, the biofilms found lining waterlines inside dental units have been recognized as a potential source of bacteria which pose a risk to medically compromised patients, and this has been a concern for the dental profession. Biofilms are now recognized as a highly organized and very sophisticated community of multiple species of bacteria with a functional infrastructure. A biofilm consists of about 85% structure and 15% bacteria. Bacteria that exist in a planktonic form undergo major genetic changes as they become sessile and exist in the biofilm environment. Within the biofilm environment, the bacteria switch on/off up to 85 genes and behave so differently that they almost appear to be different species. The biofilm has a rudimentary circulatory system, metabolic and waste channels, and the bacteria communicate with each other and even share genetic material.[1] Not surprisingly, bacteria in a biofilm are up to 1000 times more resistant to antibiotics and antimicrobial agents than when in planktonic form.

Dental plaque is a sophisticated biofilm which develops rapidly and forms continuously on teeth and other structures in the mouth. The first layer of the biofilm, the pellicle, serves as a protective coating that reduces erosion-related tooth wear, and limits the movement of ions between the enamel and saliva. In so doing, it helps to maintain ionic stability with the enamel surface. On a professionally cleaned or acid etched tooth surface, biofilm development begins immediately on contact with saliva, with precipitation of salivary proline rich casein-micelle globules. Calcium ions bridge between the globules, and within 2 hours, streptococci adhere to the pellicle with exopolysaccharides and start to form a multilayered structure. Pioneering species generally include *S. sanguis*, *S. gordonii*, with co-aggregation of *A. naeslundii*. As it thickens with time, the biofilm then becomes progressively more anaerobic in nature, and more complex, with multiple bacterial species. The biofilm may reach a mature state (the climax community) and be only 100 microns thick within 24 hours, and it may be stable for long periods.[2] While it is generally assumed that teeth that are visibly "clean" do not decay, normal brushing and flossing does not remove pellicle or all of the overlying layers of bacteria that are present in the thin biofilms that are invariably present on all surfaces in the mouth. The presence of thick plaque does not necessarily result in cavitation (since pathogens may not be present), and conversely a visibly clean appearing tooth may have a biofilm which contains cariogens.[3]

Under certain conditions, the normal, healthy biofilm may be replaced with a cariogenic biofilm that through acid production eventually causes cavitation of the enamel. Dental caries has been recognized as a biofilm disease for the past decade. In a normal biofilm, acidogenic/aciduric bacteria like mutans streptococci and lactobacilli account for about 1% of the bacteria, while in a cariogenic biofilm these bacteria dominate the community and make up to 96% of the bacteria. At this point the pH of the biofilm fluid becomes acidic, and this low pH favours the growth of additional aciduric bacterial species. It also drives the loss of calcium and phosphate mineral from the enamel. In the low pH biofilm, the cariogenic bacteria have a high metabolic rate

Figure 3. ATP swab used to screen for ATP levels in a patient's oral biofilm.

Figure 4. Rapid microbial culture of Mutans streptococci from patient's biofilm.

and expend a great deal of ATP to pump protons (H+ ions) out of the bacterial cell in order to maintain intracellular neutrality.[4] To effectively treat dental caries, not only must the teeth be restored to function, but the dental biofilm which caused the disease process needs to be converted back to a healthy biofilm. In recent decades, the profession has come to realise that inserting fillings, even with great technical efficiency, has little to do with treating or arresting the disease process, although it has the temporary effect of relieving pain and restoring function to the teeth.[5]

Caries risk assessment is a common but important part of contemporary dental practice. It is a philosophy that identifies and addresses the risk factors that are responsible for the biofilm shift from healthy to cariogenic. Local factors, diet, exposure to fluoride, quantity and quality of saliva, in addition to other factors, play a role in the caries process. By thoroughly identifying known risk factors, and examining (and modifying) the number or activity of bacteria in the biofilm, dentists can address the disease process and not just the signs and symptoms. As a standard of care, caries risk assessment is being used by a growing number of clinicians in general dental practice, and it is taught formally in dental schools in both dentistry and dental hygiene/oral health programs. Patients can go through a standardised caries risk assessment and then be assigned a rating for the activity level of the caries process, as well as a caries risk score (low, moderate or high, in both cases). A patient may have several risk factors and be high risk for caries, and show a highly active disease (Figure 1), or may be high risk but have low disease activity (Figure 2). The first patient has developed the caries lesions in a relatively short time span, and the destruction is progressing rapidly. The second patient has had the lesions for over 20 years, and they are developing slowly. The restorative treatment approach to these two patients will be the same in many respects, but the activity level differences will create differences in requirements for successful therapy which addresses the disease process. Treatment decisions are individualized and made based on the caries risk assessment and activity level and address the entire disease process rather than just a one-size-fits-all restoration of cavities.

A probiotic approach to treating the bacterial process of dental caries has become a popular concept in the past decade since the seminal work of Marsh and others in the mid 1990's.[6-8] It focuses on supporting an oral environment that favours healthy bacteria and a protective biofilm, and discourages the pathogenic bacteria and cariogenic biofilm. The probiotic approach is based on altering microbial ecology, and it recognizes that a healthy biofilm is the body's first line defence mechanism against pathogenic bacteria, in this case the cariogenic, acidogenic, aciduric bacteria.

A more biologically focused approach to diagnosing and treating dental caries requires clinicians to become familiar with new terminology, procedures, instruments, materials and education. The biological approach to dental caries is a well established part of minimal intervention dentistry in the Australia/New Zealand region. There is a wide range of commercial products to support this type of approach, including saliva tests, plaque fermentation tests, risk assessment forms, bacterial culture tests and an assortment of supportive products which use proven anti-caries agents such as fluoride and CPP-ACP formulated into topical creams, gums and mints.

In recent years, a number of tools have become available to assist in screening for a cariogenic biofilm. Newly released products include CariFree™ ATP bioluminescence, and rapid microbial culture using selective growth media. Because cariogenic bacteria use a tremendous amount of ATP to maintain intracellular neutrality, ATP bioluminescence may be a promising screening test for cariogenic bacteria in the biofilm. By swabbing the tooth surface (Figure 3), and measuring the ATP levels present, the cariogenic potential of the biofilm may be estimated, on the basis that ATP is a surrogate measure of proton pump activity and thus of the aciduric nature of the biofilm. This test is a quick and simple low cost screening procedure that helps clinicians to routinely monitor caries risk for their patients. While ATP levels are nonspecific and the reading does not identify specific bacteria present in the biofilm, it does show promise as a screening test.

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Microbial culture tests can be used to give an estimation of the level of mutans streptococci in the patient's biofilm (Figure 4). While caries is not a single pathogen disease, numerous studies over the past 25 years have established the relationship between the level of these particular bacteria and the incidence, severity and rate of dental caries at a population level. By monitoring the bacterial levels at the individual patient level, clinicians can assess the effectiveness of aspects of their caries treatment.

A number of antimicrobial oral care products have been developed to provide short term therapy against the cariogenic biofilm, and to assist with long term maintenance of a healthy biofilm. Some rinses contain antibacterial agents such as chlorhexidine and xylitol, which impair growth of cariogens, or ingredients such as bicarbonate to specifically raise the oral pH to favour the growth of a non-aciduric biofilm.

It is well established that dental caries is a biofilm disease. By treating the entire caries process, the clinician can restore health to the patient and provide better treatment outcomes.

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