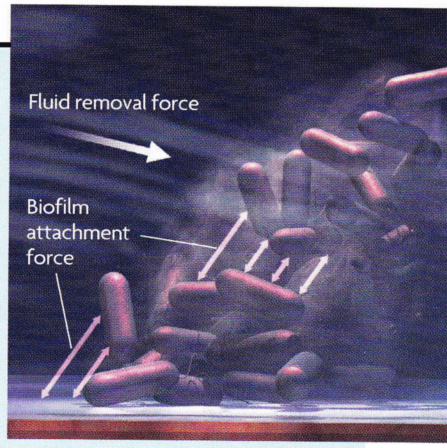
MEASURING FLUID SHEAR

By Paul Stoodley

Very little is known about the material properties of dental biofilms. Unlike conventional materials like plastics, which can be molded into uniform test pieces, biofilms are nonuniform, microscopically small and attached to surfaces. Removal from the surface will inevitably disrupt the sample, and it is difficult to reproduce in the lab the varying and complex physical forces existing in the mouth, so testing remains a challenge.

In our laboratory at the Center for Biofilm Engineering at Montana State University we have developed methods for testing the material properties of biofilms using fluid shear as the deforming force. By measuring the deformation to biofilms caused by long- and short-term exposure to elevated fluid shear, we have found that various pure and mixed-species aerobic and anaerobic biofilms grown in glass flow cells were in fact viscous fluids that behaved elastically over short loading time periods (seconds or less) but could flow like viscous fluids when the load was sustained. Also, biofilms grown at higher shear were more firmly attached and cohesively stronger than those grown at lower shear.

This has a number of implications. Because the mouth has an incredibly wide range of shear and normal stresses, we might expect that the biofilms will also exhibit a wide range of cohesive and adhesive strengths depending on the local growth environment in the mouth. The material properties of dental plaque will also likely change with time. As calcification occurs, the plaque will be expected to become more rigid and solid-like and behave less like a fluid. In this case, instead of flowing it may fracture in response to an applied physical force. Also, because biofilms can flow, albeit slowly, it is likely that the action of chewing or movement of the tongue may actually smear biofilm from one place to another. By looking at biofilms from a materials standpoint and refining our methods, we can begin to design new technologies to address their control.



A BIOFILM'S ABILITY to anchor to a surface is determined by the interplay of the bacterial colony's surface adherence versus the strength of fluid movement to shear off the biofilm. The sum of the forces determines whether the biofilm will remain attached, stretch, or break free.

Not all forces in the oral cavity are conducive to biofilm growth. The natural production of saliva helps wash away nonadherent or loosely adherent bacteria. Fluids commonly introduced into the oral cavity through dietary intake, which may provide nourishment for biofilms, also act to dislodge and wash them away. Water and toothpaste act to dislodge biofilms.

The fluid forces are aided by mechanical action. The tongue, cheeks and lips continuously rub against the tooth surface, abrading attached biofilm. During the process of mastication, the impact of food particles scraping across teeth helps limit biofilm development. These biological forces are aided by the mechanical forces of oral hygiene whether from a toothbrush, pick or floss. These actions may not totally eliminate the biofilm from the exposed surfaces, but they do contribute to keeping the biofilm development in check. But these forces may also help overall bacteria growth by weeding out the less adaptable bacteria in favor of microorganisms that bind more firmly to the oral surface. Mechanical forces may also flatten the biofilm, making it more difficult to remove, or force it into sheltered areas such as in between teeth or below the gum line.

Recent research at Eastman Dental Institute for Oral Health Care Sciences at University College, London and at the Center for Biofilm Engineering at Montana State University has shown that dynamic fluid motion generated by oral hygiene devices, such as a power toothbrush with high bristle tip velocities, generates sufficient forces to dislodge a portion of biofilm from model dental surfaces. Continued study of biofilm morphology and behavior will elucidate the nature of biofilms' interaction with the fluid environment. Such understanding has the potential to revolutionize the means to treat conditions in which biofilms can have negative impacts. The future of oral hygiene may very well build on the current technology and take advantage of the fluid in the oral cavity to penetrate areas traditionally not reached by mechanical cleaning methods.

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MORE TO EXPLORE

Biofilms on Oral Surfaces: Implications for Health and Disease. 14th International Conference on Oral Biology. *Advances in Dental Research*, Vol. 11, Number 1; April 1997.

Images and information about measuring biofilms under fluid stress can be found at the Eastman Dental Institute for Oral Health Care Sciences at University College, London, at **www.eastman.ucl.ac.uk/~microb/flowcell.html.**

Life in Moving Fluids: The Physical Biology of Flow (Second Edition). Steven Vogel. Princeton University Press, 1996.