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Characterization of Nanoscale Biomechanical Properties of Streptococcus mutans Biofilm with Atomic Force Microscopy — Kun-Lin Li, Bernard Haochih Liu, Wen-Ke Huang, and Jiunn-Der Liao — National Cheng Kung University, Tainan, Taiwan (ROC)

Streptococcus mutans is considered a primary pathogen associated with dental caries [1], and the biomechanics of S. mutans reflect the degree of its vitality. In this study, we measured the biomechanical properties of live S. mutans biofilms with atomic force microscopy (AFM). Typically, biomechanical properties, such as Young’s modulus, can be obtained using a nanoindentor. A nanoindentor, however, is not suitable for nanomechanical measurement due to its large tip radius of curvature (typically > 50 nm). Atomic force microscopy (AFM) with its nanoscale needle-like tip (tip ROC < 10 nm), on the other hand, can be used to acquire detailed information in selected regions of a biofilm. In a previous study [2], AFM was used to characterize cell-surface properties of S. mutans biofilms with and without sucrose treatment; however, the biomechanical properties of different regions of the biofilms were not well discussed. In this study, we used force-displacement curve measurement with AFM in distinct regions of S. mutans biofilms to characterize their biomechanical properties.

The mechanical properties and tip-cell interactions of S. mutans were analyzed in four regions under different biofilm growth time: Z-ring [3], cell wall, the interconnecting region between two bacteria, and extracellular polysaccharide (EPS). We measured Young’s moduli of these regions and found that bacterium cell wall has the highest Young’s modulus after both 24- and 48-hour biofilm growth. The elastic moduli increased substantially in each region after 48-hour growth, presumably as a result of strengthened cell structure upon cultivation. The elastic moduli of the EPS region and of the interconnecting region between two cells are very similar, suggesting that the chemical composition and molecular structure of these regions might be similar. The Young’s moduli of different regions of S. mutans in trace (indentation) are higher than those in retrace (withdrawal) procedure; which was resulted from the recovery of cell membranes of S. mutans. The attractive force of secretion on the surface of S. mutans was also observed in the retrace force curve; the pulling of AFM tip caused a deep sink in the force curve during tip withdrawal. The force-displacement curve of Z-ring region shows a distinct serrated behavior, which was caused by the tip-sample interactions in Z-ring structure assembled by FtsZ polymers [4]. Specifically, we observed serrated pattern that indicate breaking of FtsZ molecules during tip indentation; the broken FtsZ molecules interfered with tip under lateral pressure, thus caused serrated peaks during tip withdrawal.


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