Researcher contributes engineering expertise to solving dental maladies

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Dentistry is often described as part art, part science. Geelsu Hwang, a research associate in the University of Pennsylvania School of Dental Medicine, wants to add engineering to the mix.

Hwang's training as an engineer is allowing him to bring a unique perspective to the investigation of dental plaque. Plaque is what's known as a biofilm, a sticky mix of microbes and matrix molecules. Untreated, plaque can cause serious oral diseases. Hwang is working with Penn Dental Medicine's Hyun (Michel) Koo, a professor in the Department of Orthodontics and Pediatric Dentistry & Community Oral Health, to elucidate how dental biofilms form, with a goal of finding therapies that can break them apart.

A new grant from the National Institutes of Health, for which Hwang is the primary investigator, will support his research into the physical interactions between microbes, matrix materials and the surfaces to which they adhere.

"Engineers have been contributing in medical fields for a while now, but introducing engineering methods into dental medicine is fairly new," Hwang says. "I think engineers have a lot to contribute."

Hwang studied engineering as an undergraduate and doctoral student, but his interest always had a biological bent. As an undergrad at Yonsei University in South Korea, he took several courses on biochemistry, and for his Ph.D., also at Yonsei, he applied thermodynamics and colloid

particle theory to understand how microbes adhere to solid surfaces.

"I considered the microbe as a kind of particle and estimated the interaction energy using mathematical modeling to understand that phenomenon," he says.

It was in a postdoctoral position at the University of Alberta, however, that Hwang began to focus his attention on biofilm formation. His work there looked at the positive side of biofilms, using their microbial properties to break down toxic components that are present in wastewater as a potential means of water treatment.

"At that time I was working to improve wastewater treatment by promoting biofilms," he says. "Now my focus is on a totally different project, trying to break apart disease-causing biofilms."

He started looking at dental biofilms during a postdoc with Koo, who was then at the University of Rochester. Even Koo required some convincing that an engineer would be an appropriate hire for a lab interested in dental medicine.

"It's not so common in dental schools to have engineers there, so I think he was hesitant," says Hwang. "But he also saw that there were specific niches where engineers and dental researchers could work together and one was looking at the properties of biofilms."

Koo says, "I thought Hwang's engineering skills and ingenuity could help us to decipher fundamental questions, such as why biofilms are so cohesive and how biofilms stick to the tooth surface."

In Koo's lab, first at Rochester and now at Penn, Hwang focused on measuring the biophysical properties of biofilms. To do so, he adapted devices that measure, for example, shear forces required to break apart a

biofilm.

"We brush our teeth every day with the intention of breaking up these biofilms, but we don't know how much force is needed," says Hwang. "This device can quantify the force that is required."

He has also used single-molecule atomic force spectroscopy to measure how the products secreted by microbes can bind to surfaces and mediate biofilm formation at specific sites.

"Geelsu can dramatically advance the field of dental medicine by providing 'out-of-the-box' thinking and novel engineering approaches," says Koo.

With the new grant from the NIH, Hwang will work to advance findings that have come out of Koo's lab showing that fungus and bacteria play a symbiotic role in early childhood caries, a condition in which pre-school-age kids suffer from severe tooth decay. That work found that the primary bacteria responsible for tooth decay, Streptococcus mutans, produce an enzyme that enables the fungus Candida to produce a sticky molecule that allows it to bind firmly to teeth and also bind S. mutans. The combination makes for stubborn, glue-like plaques and contributes to childhood caries.

The new research will use Hwang's biophysical methods as well as genetic assays to determine how the enzyme product of S. mutans mediates the interactions between bacteria and fungi and to look for the counterpart of the enzyme on the fungal cell surface.

"If we find the fungal counterpart, my expectation is we can develop a new drug that blocks formation of this particular cariogenic biofilm," Hwang says.