Engineering breakthrough can mitigate COVID-19 contamination in dental clinics

27 August 2020, by David Staudacher

The University of Illinois Chicago College of Dentistry clinic is made up of 350 chairs in multiple a large, open bays. Researchers from UIC's College of Engineering have developed a way to mitigate COVID-19 contamination in dental clinics. Credit: University of Illinois Chicago College of Dentistry

Dental practices have been shuttered since March after being cautioned by the American Dental Association and the Centers for Disease Control and Prevention to close their offices to all but emergencies. Recently, they provided a framework for reopening facilities, which calls for offices to carry extra personal protective equipment (PPE) like face masks, shields, eye protection, gowns and gloves, and to change them frequently. The guidelines call for the complete cleaning of workspaces between patients and a pause to allow air filtration systems to remove potentially infectious particles.

UIC's College of Dentistry is following the guidelines to protect patients, faculty, staff and students against COVID-19. However, these measures do not guarantee complete protection against the inhalation of aerosols generated by some of the essential tools used by dentists.

To mitigate the aerosols, the dental school leaders reached out to experts at the UIC College of Engineering to help them solve the problem.

The unique risks for a school of dentistry

"For years, we have been vigilant about infection control, and the COVID pandemic has focused a lens on the issues," said Clark Stanford, UIC distinguished professor and dean of the College of Dentistry. "With billions of viruses in the world, we have been pretty lucky. COVID is a wake-up call, and there could be something else down the road."

Threats of highly-infectious and airborne viruses pose a unique threat to the school. Unlike a three-chair dental office, the College of Dentistry is much bigger. Multiple large, open-bay clinics make up 350 chairs and nearly 1,000 people working in the building. It's much more of a hospital atmosphere that creates a unique and complex set of issues.

"This is a real challenge for several reasons," said Lyndon Cooper, associate dean for research in the College of Dentistry and head of oral biology at UIC. "One is that many patients are asymptomatic or pre-symptomatic, and people walking into a dental clinic don't necessarily present themselves as a risk to us. So, our guard is down. Secondly, aerosols are unseen. They exist in speaking, shouting, sneezing, and all these things can transmit a virus. In an open dental setting, such as a dental school or a dental practice with multiple chairs, you're confronted with an invisible threat that has to be contained. And that really puts this in the sphere of the unknown."

The dentistry officials worked with facility managers and consultants, who have reviewed the HVAC system and air quality to increase the air exchange to provide 100 percent outside air, which will minimize recirculation. They also added building-wide HEPA filtration and bipolar ionization technology to provide additional layers of protection.

They also are taking measures to deal with human behavior to make sure the air quality is safe. This will be accomplished by limiting the number of people, and reducing the density and distance between people.

A third measure they wanted to figure out is how to reduce the amount of aerosols generated and how far they can spread. While there exist instruments to move the aerosol away from the patient and dentist, the idea of reducing the aerosol is a novel approach. To answer this question, the dental leaders turned to the UIC College of Engineering.

"The fascinating aspect of this is the collaboration between engineering and the college of dentistry. To have the engagement of individuals who can look into some of the mitigation efforts we are considering and evaluating that in real time with their equipment and expertise so that we are not making assumptions is reassuring," said Susan Rowan, Executive Associate Dean and Associate Dean for clinical affairs at the UIC College of Dentistry. "We, as a college, are data driven and want to make sure what we are doing is in the best interest of our patients as well as our staff, faculty and students."

Engineering a solution

UIC's engineering team, made up of faculty and students from Mechanical and Industrial engineering (MIE) and Electrical and Computer Engineering (ECE), are studying how aerosols are dispersed from dental instruments.

Constantine Megaridis, a UIC distinguished professor in MIE, and post-doctoral researcher Tamal Roy are looking at coarse droplets that are generated by the dental instruments, including how an ultrasonic, vibrating tool called a Cavitron sheds droplets from its tip.

"These devices are ubiquitous in dental practice and generate large amounts of tiny water droplets that could pose a threat to dental practitioners and patients if they carry the virus from the saliva of an infected patient," Megaridis said. "There is potential for spreading of COVID-19 in dental offices and clinics when the spray generated by this device strikes a tooth or other tissue in the mouth, picks up some saliva, and is released out of the mouth cavity with the breath. My lab is using high-speed imaging and optical tools to observe the shedding of droplets form the Cavitron tip in terms of their size and concentration in space."

MIE Associate Professor Parisa Mirbod and her team, including Ph.D. students Eileen Haffner and Maryam Bagheri, used Particle Image Velocimetry and Particle Tracking Velocimetry for flow visualization to track, measure, and examine individual droplet velocities and distance. They also used shadowgraphy techniques to define the droplet distributions, focusing on coarse and fine droplets.

"Dental procedures produce airborne particles that are responsible for transmitting viruses, including SARS-CoV-2, into the air. We studied the droplets produced by the Cavitron using state-of-the-art experimental techniques to understand how far they move and with what velocities. This data can be used in the CFD analysis to further analyze the viral titer into the clinic," said Mirbod.

ECE Associate Professor Igor Paprotny and his Ph.D. student Anuj Singhal are contributing to the research by looking at fine and ultrafine particles.

"What we're looking at are aerosols—droplets and particles—that are fewer than 10 micrometers in diameter, focusing on aerosols that are two-and-a-half micrometers and smaller. Recently, we have been looking at particles that are nanoscale sized, so called ultrafine aerosols, in general below one micrometer in size," said Paprotny

He noted that aerosols larger than 10 microns are not going to settle quickly. Aerosols smaller than 10 microns, and those that are two-and-a-half microns or smaller will remain suspended in the air for a long time and follow the air streams. With increasing evidence that COVID-19 is an airborne disease, these tiny aerosols have the potential to transmit the virus to other patients and people working in dental settings.

"We're using a number of aerosol measurement instruments that record the concentration of airborne aerosols and can map flumes of these droplets emanating from different sources," Paprotny said. "This allows us to build a picture of what size aerosols are floating around in the dental procedure used, and in turn determine the concentration of these aerosols throughout the dental clinic."

MIE Department Head Farzad Mashayek is leading the engineering team and leads the Computational Fluid Dynamics (CFD) team, which includes Lecturer Jonathan Komperda and Ph.D. students Dongru Li, Ahmad Peyvan, and Babak Kashir.

"We used computer simulations to determine air velocity, temperature, and humidity at different locations in the clinic. With this information, we applied computer simulations to track droplets and aerosols to predict the viral load in the clinic," said Mashayek, who is working with the data gathered from the other members of the engineering team.

This work is related to UIC's large dental clinic that is used for multiple patients simultaneously. The size of the room and the details of the furniture and equipment pose a challenge, so the simulations must be carefully planned and conducted with the available computational resources during a short period of time.

"Our group assembled three new computers in a very short time for sole utilization in this project," Mashayek said. "Our work bridges the engineering data generated by the simulations and the published data on viral load in order to create a heat map for the room, thus enabling the dentists to evaluate the risk in different locations inside the clinic."

While this research is focused on UIC's dental clinic, Mashayek said the approach could be used to create heat maps for risk mitigation in other enclosed spaces on the campus and beyond.

Is a polymer solution the answer?

While the researchers continue to gain a better understanding of the droplets that are formed and how they travel, they still have one big question to answer: How do they mitigate the aerosols?

"What I proposed and demonstrated is that you can completely suppress the formation of sprays using a diluted aqueous polymer solution," said Alexander Yarin, a UIC distinguished professor in MIE. "Essentially, I can take over-the-counter materials and use them in this operation without any droplets being formed."

The researchers identified several FDA-approved polymer solutions that can replace the water in the Cavitron and dental drill. They discovered that when the fluid is dispensed from the ultrasonic Cavitron scaler, spray droplets are not formed at all, being fully suppressed by elastic forces. The same occurs with the spinning drill, where instead of droplets, long filaments are formed, which are not dangerous anymore because they do not fly away from the drill head.

Yarin said the viscoelastic solutions they studied have similar characteristics to saliva, albeit with higher elastic stresses. He demonstrated this by placing saliva between his fingers and slowly pulling them apart, which formed a thread that displays the elastic forces and is held intact by the latter.

With the polymer solution, threads and filaments do not break up and droplets do not detach, as demonstrated in the lab experiments and in the dental clinic. Yarin and his Ph.D. students tested the solutions at low speeds and at the highest speed of the dental drill and all Cavitron powers, which provided the same suppression of droplet formation.

"This appears to be a totally new method of mitigation for this type of problem," Yarin said. "This approach is not costly at all and doesn't require any device changes, and, with formal approval, the College of Dentistry can start using it right now."

Ph.D. students Yasmin Dias, Jevon Plog and Jingwei Wu worked under the direction of Yarin on this research. "These three students were very instrumental and heroically came to UIC when everything was closed, and we worked alone there for quite some time," Yarin said.

UIC is now filing a patent for this new technology and working with companies to get the process implemented, which will allow dental schools and clinics to reopen and operate safely. Their research will be published as a feature article in the journal Physics of Fluids under the title *Reopening Dentistry after COVID-19: Complete Suppression of Aerosolization in Dental Procedures by Viscoelastic Medusa Gorgo*.

More information: Physics of Fluids - "Reopening Dentistry after COVID-19: Complete Suppression of Aerosolization in Dental Procedures by Viscoelastic Medusa Gorgo"
aip.scitation.org/doi/10.1063/5.0021476

Provided by University of Illinois at Chicago, College of Engineering