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Using nanostructures to fight bacteria

Inspired by insect wings: antibacterial surfaces for implants

What do dragonfly wings and dental implants have in common? Nothing yet but that could soon change. The Karlsruhe-based start-up nanoshape has developed a process for coating medical implants with nanostructures similar to those found on insect wings. The coating makes surfaces bacteria-repellent and is aimed at reducing the risk of post-surgical inflammation. The first product could be on the market as early as next year.

The dragonfly is the mascot of nanoshape GmbH, a company founded in 2022 as a spin-off from the Karlsruhe Institute of Technology (KIT). The two company founders, Litsy Hüschelrath and Dr. Patrick Doll, were inspired by the insect's elegant shape and iridescent colours, but also by its wings – or rather the nanostructures on them. These nanopillar-like structures have fascinating biological functions, notably extremely effective bactericidal properties that protect against bacterial biofilm formation – a kind of non-stick system against microbes.

The founding team of nanoshape: Litsy Hüschelrath and Dr Patrick Doll.
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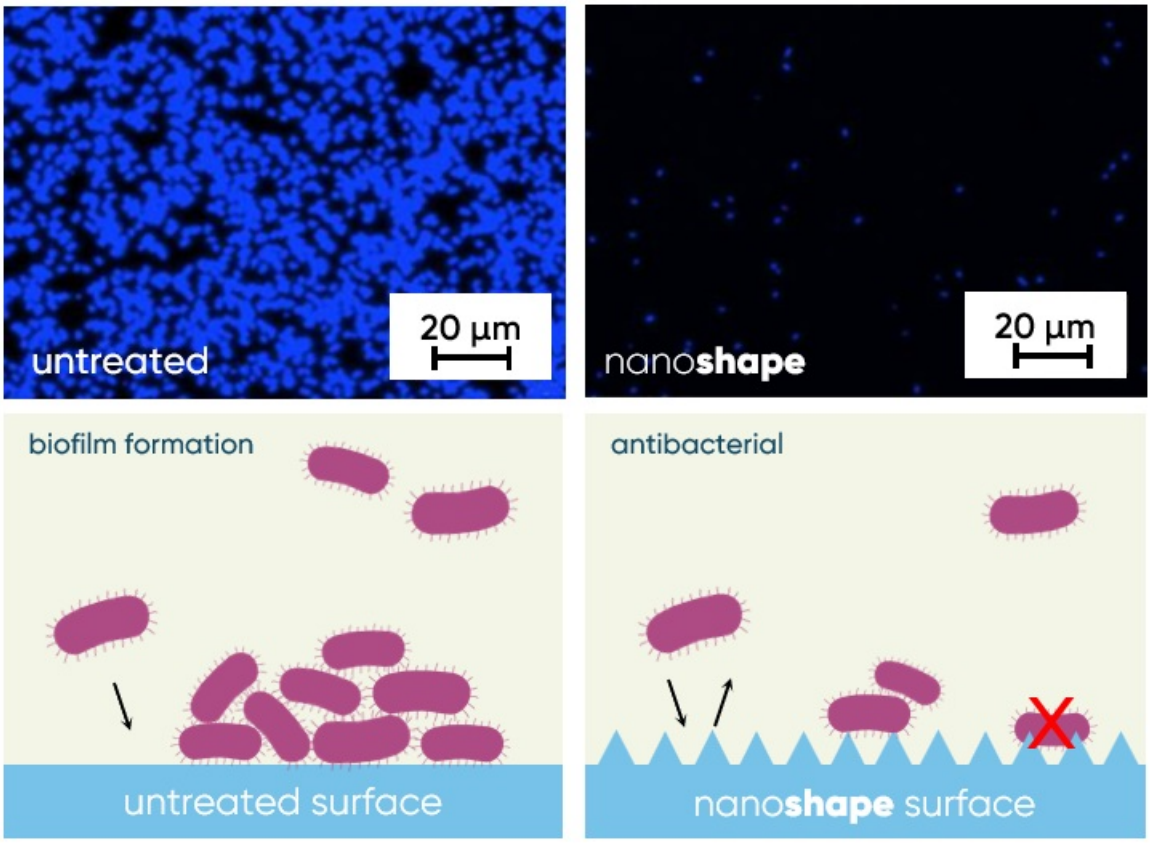
Many years ago, Doll realised that this was a strategy that could also be used in medicine. It was an area he researched as part of his doctoral thesis on micro- and nanostructuring of dental implants at KIT between 2015 to 2019. "Dental implants have become an indispensable part of modern medicine and are used in their millions all over the world. Complications occur in around one in five implants, mostly involving bacterial inflammation. This leads to very costly repeat treatments and additional operations," says Doll. "So it's a relevant problem. Fighting bacteria with nanotechnology was a real hype at the

time. Many scientific publications dealt with nanostructured surfaces. This gave me the idea to try for myself, and so I investigated a range of physical principles.The structures that always worked best were those that most closely resembled nature – such as those found on the wings of dragonflies or cicadas."

Nanostructures exert a dual action: they can kill microbes on contact and reduce microbial adhesion

Having reached this conclusion, one development quickly followed another. Using a specially developed high-pressure oxidation process – a method that transforms surfaces under high temperature and pressure – Doll produced precisely shaped nanostructures on metal that mimic the antibacterial effect found on dragonfly wings. His invention, which can now be applied on a cost-effective industrial scale, was patented in 2019, followed by two further patents under the nanoshape umbrella. The technology is scheduled to be introduced to the dental implants market in 2026.



The upper row of images shows blue-stained microscopic images. On the left, numerous bacterial colonies can be seen on an untreated surface, while on the right, significantly fewer colonies are visible on the nanoshape surface. The bottom row of images illustrates the functional principle: bacteria adhere to smooth surfaces, while the nanostructures prevent bacteria from adhering and forming a biofilm on the implants.

The nanostructures on the titanium surface of the implants look like tiny pyramids that are about ten times smaller than bacteria. "This allows us to achieve biological effects that are comparable in strength to those on insect wings," says Doll. "The special feature of this simple physical effect is that it reduces the contact surface for bacteria. This makes them less likely to adhere and in some cases even kills them on contact. It works very well with Gram-negative bacteria such as *Escherichia coli* or *Pseudomonas aeruginosa*, but not quite as well with Gram-positive bacteria. So it's not necessarily a classic antibacterial effect, but rather a way of helping the body to help itself: by significantly reducing the total number of pathogens, the immune system is much better able to cope with the inflammation."

The company has already demonstrated efficacy *in vitro*. In numerous studies involving a broad spectrum of microorganisms, the nanostructured surfaces significantly reduced overall microbial burden, including multidrug-resistant organisms such as methicillin-resistant *Staphylococcus aureus* (MRSA). Clinical data are anticipated next year; a trial conducted in cooperation with a German university hospital is currently in progress.

No additional strain on the body

Despite the early hype, the development of nanoshape technology – which, among other things, seeks to design metal parts that mimic the surface of insect wings – remains largely uncharted territory. Current implants are already treated with surface features that promote bone ingrowth via sandblasting or etching, but these measures do not prevent bacterial colonisation.

Alternative strategies such as antibiotic or silver coatings have not gained widespread acceptance: "The problem with antibiotic coatings is the well-known issue of increasing resistance," says Hüschelrath. "Silver can be effective, but the risks associated with silver nanoparticles in the body have not been fully evaluated. Both antibiotics and silver are consumed by the organism, in contrast to how our approach works. Here, the base material – titanium, for example – is retained, subjected to minimal structural change and does not release any substances into the body."

Other implants plus alternative sectors

The two founders started with dental implants because that was the easiest way to enter the market from a regulatory standpoint. "We already work with a number of implant manufacturers who have their own production chains. We aim to assist them in developing the next generation of products by providing technology that enhances the implants at the nanoscale in a downstream phase," says Hüschelrath.

This is not the full extent of nanoshape technology's potential. If everything goes as the team has planned, more uses will follow: "Our stated objective is the hip," explains Hüschelrath. "In the long term, we want to equip all kinds of medical implants with nanostructured surfaces – from bone plates and screws to various endoprostheses. We also foresee applications for cardiovascular devices such as pacemakers and stents. Nonetheless, particularly because many of these devices are classified in higher regulatory risk classes, it will be a long time before we get there."

In parallel with medical technology, the Karlsruhe-based start-up is also moving into industries with less stringent approval requirements. "It is better to have several irons in the fire," explains Doll. "We are already working closely with several partners on feasibility studies to adapt our technology to materials such as aluminium. An illustrative example can be found in the automotive industry, where, alongside bacteria-repellent surface structures, advanced technical and decorative surfaces are being developed. These surfaces are designed to effectively repel liquids and minimise the occurrence of fingerprints." There are many other potential application scenarios, including the sanitary sector, the food industry and aerospace technology. "Despite all the promising possibilities, our passion will always remain medical technology and working with patients," say nanoshape GmbH's founders.

Article

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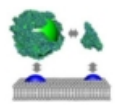

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