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RESEARCH NEWS

Testing toothpastes and toothbrushes

Improving dental hygiene products through virtual brushing

Designing toothpastes and toothbrushes is a time-consuming process involving the production and testing of numerous samples. Using a new type of simulation, various parameters such as bristle shape and abrasive particle size can be modified with just a click. This enables manufacturers to improve the quality of new dental care products and bring them to market more quickly.

When we wake up in the morning, there is a fur-like coating on our teeth: this is a biological film that forms overnight. Over time, this can lead to the development of caries – which is why it is critical that we remove this "rug" using a toothbrush. There is a large selection of dental hygiene products on the market, including brushes whose bristles are rounded, pointed, hard, and soft. There are also brushes with bristles of varying lengths. Until now, to determine which ones clean the most thoroughly while doing as little damage to the tooth enamel as possible, manufacturers have had to conduct experiments. This was also the case when selecting the right abrasive particles to be used in toothpastes. Various toothpaste formulations had to be mixed and then tested on artificial tooth enamel models – a laborious task. Another drawback to this approach is the fact that the brush, paste and enamel can be analyzed only as a complete system, which means that manufacturers have a difficult time determining which effects observed in these experiments are derived from which of the various parameters.

Simulated tooth brushing

Help has arrived in the form of a new type of simulation developed by researchers at the Fraunhofer Institute for Mechanics of Materials IWM in Freiburg. "With our procedure, manufacturers of dental hygiene products can determine the cleaning effectiveness of each individual parameter in a fast, economical and reliable manner," says IWM scientist Dr. Christian Nutto. "Unlike in real-world experiments, the individual parameters in the simulation can be easily modified – be it the size, shape and quantity of abrasive particles in a toothpaste, or the material from which they are made, or the shape and elasticity of the bristles." We can increase the scope of the experiments far beyond what is possible in real-world testing, and that makes a noticeable difference in the quality of the products. What effects do the shape and stiffness of the bristles have when brushing? How do the different abrasives or toothpaste viscosity affect the enamel, and how do they affect their intended target, the biofilm on the teeth? Simulation

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testing can deliver reliable answers to questions such as these, and it does so long before the manufacturer ever mixes the toothpaste.

Dr. Nutto relies on SimPARTIX® simulation software developed at the IWM, which uses the Smoothed Particle Hydrodynamics (SPH) particle simulation method. "We specify characteristics for the abrasive particles such as density, shape and fill factor," he says. Even parameters for the tooth enamel are included. The virtual toothbrush bristle is then rubbed over the tooth enamel, with the simulation providing data on how the scrubbing particles interact with the elastic bristle. It also calculates cleaning effectiveness, as well as the aggressiveness of the abrasives against the tooth enamel. Here, the team from the Powder Technology, Fluid Dynamics group can vary the speed at which the bristles pass across the enamel as well as their pressing force. The SimPARTIX® team, together with the Fraunhofer Institute for Algorithms and Scientific Computing SCAI, designed an additional software tool to integrate the particle simulation into standardized simulation programs.

Software computes effect of toothpaste on tooth enamel

But do the findings correspond to reality? The comparative experiments were conducted by Dr. Andreas Kiesow and his staff at the Fraunhofer Institute for Microstructure of Materials and Systems IMWS in Halle as well as the MikroTribologie Centrum µTC in Karlsruhe. In the tests, a brush bristle was placed in a fastener and brushed at a constant speed across an artificial tooth enamel model onto which toothpaste had been applied. It was concluded that the simulation can precisely predict how the toothpaste and bristles will affect the tooth enamel. At a later stage, it will also be able to predict the effectiveness of the toothpaste and brush at removing the biofilm from teeth.

Risk of wear from abrasive particles

Abrasive particles are a key component of toothpastes and serve to mechanically remove plaque from the teeth. But a good toothpaste should not be overly abrasive, as over the years the friction can damage the enamel, which does not regenerate. Furthermore, this damaging effect is far more pronounced on the soft dentine. For this reason, the representative body for dentists in Germany recommends that patients with exposed root surfaces choose a toothpaste with a low abrasive effect.

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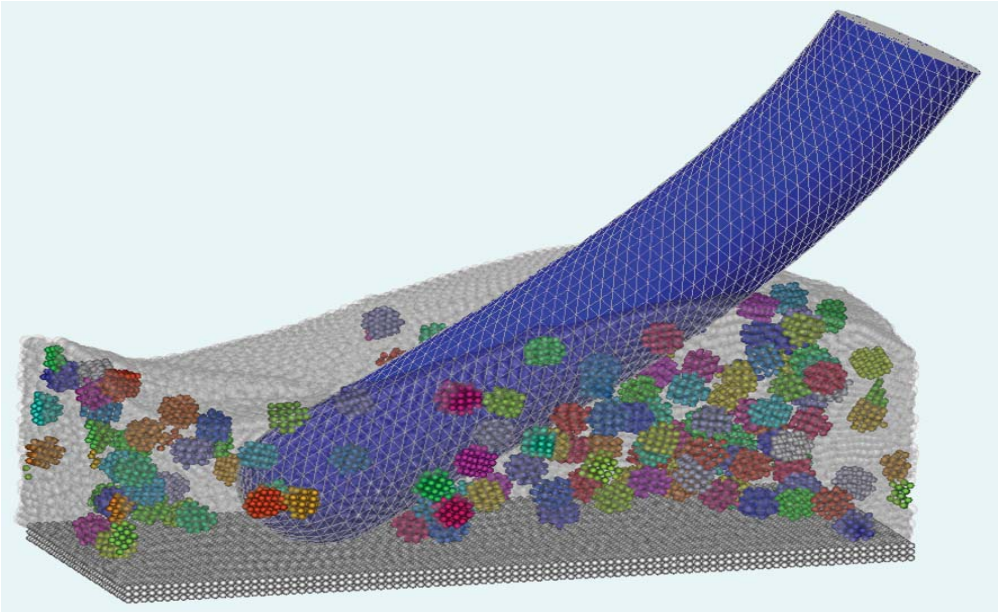
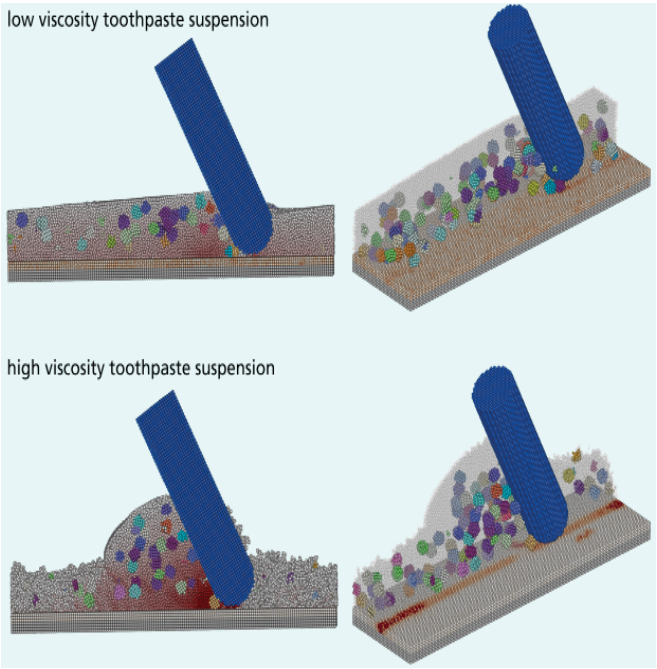


Simulation of interaction between a toothbrush bristle and a suspension with spherical abrasive particles. © Fraunhofer IWM | Picture in color and printing quality: www.fraunhofer.de/en/press.



Simulation of pressure distribution in suspensions of varying viscosities with spherical abrasive particles as a toothbrush bristle rubs against the tooth enamel: the more viscous toothpaste suspension leads to greater abrasion on the tooth enamel. Above: lower viscosity 1 mPas, below: higher viscosity 20 mPas. Left: pressure distribution in the suspension (a deeper red indicates higher pressure), right: stress input against the tooth enamel by abrasive particles (a deeper red indicates greater abrasion). © Fraunhofer IWM | Picture in color and printing quality: www.fraunhofer.de/en/press.