Toothsome Technology

Scientists strive to improve dental materials

By CORINNA WU

In George Washington's time, a set of wooden dentures was the only fashionable remedy for a lifetime of poor dental hygiene. Nowadays, people needing dental work can opt for more durable materials, such as metal, not to mention more aesthetically pleasing ones, such as composites and ceramics.

The desire for a more natural-looking mouth has increasingly driven the search for new dental materials. People are no longer content to flash a metallic smile, but neither will they accept better-looking repairs that necessitate more visits to the dentist.

Researchers are trying to combine high strength with dental glamour. At a meeting of the American Chemical Society (ACS) in Las Vegas last month, researchers described recent work on polymers and polymer composites designed for dental use. Although these materials have cosmetic advantages over metal, those currently available are not strong enough for use in all teeth.

Other chemists are focusing on ceramics and new metal amalgams. Ceramics are more brittle than dentists would like, and traditional amalgams have been accused of leaking mercury into the body.

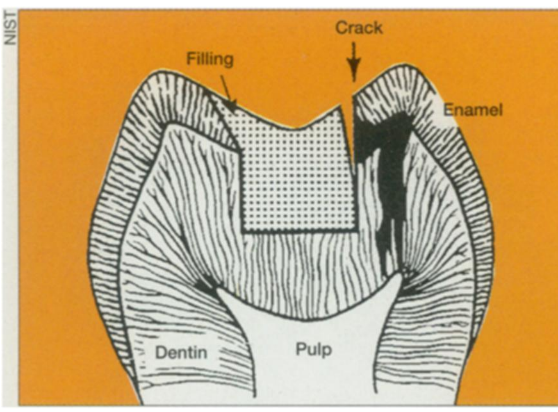
Improving the material properties of fillings, inlays, and crowns can reduce the number of trips a patient has to make to the dentist. On average, most traditional dental materials last about 10 years, says Stephen Bayne of the University of North Carolina at Chapel Hill School of Dentistry. "We'd love for that to be 20 to 25 years."

Teeth are made mostly of a natural ceramic and a natural composite: enamel and dentin, respectively. The thin surface layer of enamel consists mainly of a calcium-based mineral called hydroxyapatite. Underneath, the bulk of the tooth is made of dentin—a mix of hydroxyapatite, collagen, water, and salts. A third type of tissue, cementum, lines the dentin under the gum line.

The mouth is a harsh environment. Acids from foods and plaque-forming bacteria erode not only teeth but dental materials too (SN: 10/8/88, p. 238). The act of chewing hits a restoration or filling with what amounts to a series of hammer blows. To choose appropriate materials, dentists have to assess what mechanical stresses the material will encounter.

For example, a molar in the back of the mouth, which does a lot of chewing, experiences greater stresses than a tooth in the front. Also, the center of a tooth surface flexes more than the edges, so a restoration located there runs the risk of popping out if not properly bonded, Bayne says. Artificial dental materials are some of the most durable substances used in the body. "People say that if it works there, it'll work anywhere else," Bayne remarks.

NIST



Composite fillings sometimes shrink as they set, leaving a crack that can collect bacteria, which may trigger new decay.

Gold is the ultimate filling material, at least for durability, but it is prohibitively expensive, says Jack Ferracane, president of the Academy of Dental Materials and a biomaterials researcher at the Oregon Health Sciences University in Portland. On the other hand, dental amalgam—an alloy of silver, tin, copper, zinc, and mercury—is reasonably priced, strong, and dependable, which has made it the workhorse material for the past century.

Recent concerns that mercury may leach out and cause adverse health effects have fueled some of the research into alternative filling materials (SN: 4/10/93, p. 230). Scientists at the National Institute of Standards and Technology (NIST) and the American Dental Association Health Foundation are developing metal alloys, based on silver and tin, that do not contain mercury. The challenge is to get the new mixtures to solidify properly. In the old mix, mercury, a liquid at room temperature, coats the other metals and helps them all to solidify.

Many scientists say that the risk of mercury seeping out of the solid filling is low. "Once it's fully set, the mercury is bound up and won't come out," says Bayne. In the past, the greatest danger was to the dentists who prepared the amalgams. Now, all the materials are combined in a sealed capsule to minimize exposure, says research chemist Joseph M. Antonucci of NIST.

Safety concerns aside, newer materials have been gradually replacing traditional amalgams because of their cosmetic advantages. Composites, generally made of silica glass particles bound with a polymer resin, look more natural than metal because the color can be matched to the patient's teeth. The dentist mixes the silica and polymer, applies an adhesive to the tooth, fills the cavity, and shines a high-intensity light on the material to set it. The light causes the polymer molecules to react with one another, linking them to form a solid resin.

During the setting process, however, the polymers tend to shrink, thus weakening the bond to the tooth. In addition, tiny gaps created between the filling and the tooth can harbor cavity-causing bacteria, says Ferracane.

The trick, then, is to produce a polymer that doesn't shrink as it sets. Several research teams are investigating one approach, which is to add ring-shaped monomers such as spiral orthocarbonates to the resins. As these molecules react with each other, they open up, expanding the material's volume slightly.

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linked to cataracts," SN: 7/26/97, p. 60). One thing was missing from the article, though: dosages.

Just how often do you have to use the inhalers before these effects appear?

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There is no clear-cut answer. "We just do not have enough data to say how many puffs a day and how many years of use are unsafe for the lens," replies Robert G. Cumming, an epidemiologist at the University of Sydney in Australia and lead author of the study. For posterior subcapsular cataracts, the most serious kind, more than 2 grams of beclomethasone, a corticosteroid, in a lifetime imparts about double the risk of a 1-gram dose, his research shows.

Asthmatics who use steroids should discuss proper dosage with their physicians, he says, but should remember that asthma, which can be fatal, is a more serious condition than cataracts, which can be treated surgically.

—N. Seppa

Gamma rays combat restenosis

In regard to Richard Petrasso's letter (SN: 8/23/97, p. 125) about "Unclogging arteries? Radiation helps" (SN: 6/14/97, p. 364), the distance from the Ir-192 source to the cells of the vessel at risk of restenosis can be measured in centimeters. As such, gamma rays are the treatment, not beta rays. Further, the iridium sources are encapsulated in metal, thereby attenuating and eliminating the beta emission. Indeed, when beta emitters are used, they are placed in contact with the vessel wall, usually by radioactive stent, because beta rays' effective range is so small.

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New vantage on theropod flight

Why hasn't anyone proposed that smaller theropods were arboreal ("A Fowl Fight," SN: 8/23/97, p. 120)? If kangaroos, leopards, and bears can climb trees, why couldn't those short forearms have been used to scramble up bare trunks?

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Denton, Md.

Some paleontologists are beginning to explore the idea that small theropods climbed trees and evolved flight from this vantage point. Alan Feduccia, however, argues that the anatomy of theropod pelvic bones precluded them from climbing trees. —R. Monastersky

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Another approach taken by a group at the University of Texas Health Science Center at San Antonio is to use liquid crystal monomers. These molecules align themselves, creating a partially crystalline material. As they harden, the material becomes more disordered, which offsets the contraction.

Composites that expand upon reaction and wedge themselves into the cavity could do away with the need for an adhesive, suggests Antonucci. Currently, dentists etch the surface of the exposed dentin with a mild acid, roughening it so the adhesive can fill the spaces.

The acid removes the minerals in the dentin, however, leaving behind a shaky framework of collagen. "If the collagen fibrils collapse, you don't get a good interlocking system," Antonucci says. At the ACS meeting, T. Nikaido of the Tokyo Medical and Dental University described newly developed acids that both etch and stabilize the collagen structure.

Materials that bond directly to enamel and dentin would obviate the need for an adhesive, but the high protein content of dentin complicates the search for appropriate materials.

While materials with a paste-like consistency work best for filling cavities, ceramics can be shaped into other restorative features such as crowns. Ceramics tend to be brittle, though, so porcelain crowns are usually made with metal supports. Several groups are working toward materials that are tough enough to form more attractive, all-ceramic crowns.

At the ACS meeting, J. Robert Kelly of NIST and the Naval Dental School in Bethesda, Md., described a more flexible ceramic that is reinforced with polymer resin. The material is solid enough to be carved with a CAD-CAM machine, which a dentist can use to design and quickly make a crown or inlay in the office (SN: 12/10/88, p. 376).

In the future, dentists may not need to concoct artificial materials in a dish. Molecular biologists may be able to recreate the biological processes that generate teeth and thus grow perfectly matched replacements, Bayne suggests. Then, not even the most intimate observer will be able to distinguish an artificial tooth from one that nature made. □

Filling microchannels instead of cavities

Bacteria love to hide in the natural grooves and fissures of a tooth. Tucked safely away from the probing bristles of a toothbrush, they are free to form plaque and cause tooth decay. To forestall this process, dentists often apply surface sealants that physically block the hiding places for bacteria.

Now, researchers at the Karolinska Institute in Stockholm have applied this idea to teeth on the microscopic level. Tiny natural channels that run through dentin allow acids and other damaging substances to penetrate teeth. The scientists are filling these tubules with polymers called calcium alginate hydrogels. "If we can block the channels, we can make caries-resistant dentin," says Lars-Åke Lindén. He presented the findings at last month's American Chemical Society meeting in Las Vegas.

Scanning electron micrographs show that the tubules, about 2 micrometers in diameter, are completely filled by the hydrogels. In human trials, a 10-minute application cured people who had sensitive teeth, suggesting that the material could also guard against cavities if used as a preventive treatment. The gel penetrates more deeply than regular sealants and is permanent.

Lindén and his colleagues developed this approach after discovering that the insides of the tubules are coated with a natural hydrogel composed of a fibrous protein and water. Not much is known about the native substance, Lindén says, but they don't think it's collagen. Because the tiny amounts of hydrogel are bonded to the tubule walls, it's difficult to remove enough for thorough identification. —C.W.