

Chemical Technology for Dentistry

History of Dentistry

Most American children today visit the dentist for regular check-ups, cleaning and perhaps to obtain a referral to an orthodontist. However, this was not always the case. Much like any other profession, dentistry has evolved over time. In the middle ages, people didn't brush their teeth with toothpaste if they brushed them at all. Going to the dentist, meant seeing a butcher-like person who would brutally pull out teeth, without sedation. Teeth rotted and as a consequence, diseases spread. The 17th-century book by Charles Allen "The Operator for the Teeth" (1685) is the earliest known dental book that emphasizes the importance of dental hygiene and the effect of unhealthy teeth, leading to toothaches, especially while chewing.¹

Starting in the 18th Century, strong teeth were regarded as vital not only for eating, but also for speech and beauty. In addition to beauty, healthy teeth reflected a high quality of life. But good dental hygiene was hindered by sugar, for example. How were teeth kept clean? Salt solutions, as well as horse-hair bristle brushes, much like painting brushes today, were used to clean teeth. In addition to these primitive cleaning techniques, artificial teeth were fashionable; ivory, silver, agate, walrus and pearl teeth were used. More recently, porcelain replaced these materials. False teeth helped to avoid toothaches and to reduce costs.

Since the 1970s, helped by chemical technology, modern dentistry has made much progress. Not only has dental hygiene improved with fluorides and regular dental visits, but attention has also been given to dental beauty with the development of tooth whitening, braces,

¹ Worsley, Lucy. "Oral history." *History Today* 61, no. 5 (May 2011): 5-6.

implants, veneers and crowns. The influence of modern dentistry goes beyond health. The “perfect smile” can help boost self-esteem, and lead to clearer speech.

Dental Health

Home Care

Dental hygiene helps to maintain healthy teeth. Eating less of damaging foods can improve dental hygiene. For example, eating fewer sweets and aggressive acidic foods helps to reduce tooth decay. Chewing sugarless gum also provides a way to neutralize acid that causes tooth decay. Some types of food including apples, pears, celery and carrots trigger saliva and thereby help to remove dental tartar (hardened dental plaque) caused by minerals from saliva². Due to its uneven surface, tartar causes further plaque formation.

Teeth must be kept clean. Brushing teeth multiple times a day and using mouth wash increases dental hygiene. Daily flossing, especially at the gum line, helps to prevent gum disease. Electric and sonic toothbrushes may be more effective than the traditional toothbrush in removing plaque³ and surface stains. Fluorides⁴ in food can help decrease tooth decay. Fluorides have been incorporated into toothpastes or gels to provide a concentration of fluoride higher than that in food. Fluorides decrease demineralization that results in tooth decay. For children, fluoride is especially important for strengthening developing adult teeth. Therefore, fluorinated water is helpful for preventing cavities. Many communities in the US add fluorides to the water supply.

² [http://en.wikipedia.org/wiki/Calculus_\(dental\)](http://en.wikipedia.org/wiki/Calculus_(dental))

³ dental plaque = the white to pale-yellow, sticky film on teeth that feels rough to the tongue. It develops when food containing carbohydrates settle on teeth. Bacteria in the mouth accumulate and produce acids that can destroy tooth enamel and thereby cause tooth decay. <http://www.webmd.com/oral-health/guide/plaque-and-your-teeth>

⁴ <http://www.webmd.com/oral-health/guide/fluoride-treatment>

What can the Dentist do?

While the health of teeth can be improved by home-care, regular visits to the dentist help to prevent serious dental problems. The dentist can fill tooth cavities ⁵, or replace the top of a worn tooth by a crown ⁶. Thanks to chemical technology, new material for fillings are now more consumer-friendly, because they are more aesthetically pleasing, durable, and cost-effective. Fillings or crown materials include gold, porcelain, silver amalgam, plastic and glass. An amalgam is an alloy containing mercury.

Gold-alloy fillings are durable and strong for chewing. However, they are expensive, aesthetically not appealing, and can cause “galvanic shock” when implemented next to a silver amalgam.⁷ Silver-alloy fillings are also durable and strong, and less expensive, but aesthetically they are not attractive because they don’t match the color of teeth, and they can crack.

Composite resin⁸ restorations were first used as a substitute for silicate cement in the late 1960s⁹, but they were deficient due to insufficient wear resistance, irritations, sensitivity, insufficient color matching and polishing methods.¹⁰ Today, after years of material-science development, including laboratory and human-subject trials, composite resins have been revalidated as a restorative material. Advances in adhesive restorative biomaterials have increased the longevity of composite restorations due to increased adhesion materials used for bonding restorative materials to teeth. Composite materials are a combination of materials that

⁵ <http://www.webmd.com/oral-health/guide/dental-health-fillings>

⁶ <http://www.webmd.com/oral-health/dental-crowns>

⁷ <http://www.webmd.com/oral-health/guide/dental-health-fillings>

⁸ Dental composite resins are synthetic resin materials used for restoration and adhesives. They are used because they are durable, aesthetically pleasing, easy to work with and reasonably inexpensive.

http://en.wikipedia.org/wiki/Dental_composite

⁹ Douglas A. Terry D.D.S. Karl F. Leinfelder, D.D.S., M.S. Willi Geller. *Aesthetic & Restorative Dentistry. Material Selection & Technique*. (Stillwater, MN: Everest Publishing Media, 2009)

¹⁰ Douglas A. Terry D.D.S. Karl F. Leinfelder, D.D.S., M.S. Willi Geller. *Aesthetic & Restorative Dentistry. Material Selection & Technique*. (Stillwater, MN: Everest Publishing Media, 2009)

differ in their properties but, when mixed, bond together, and retain some of their original desired properties, thereby providing improved characteristics not obtained by a single material. Composites are made of an inorganic filler such as “ground quartz, alumina silicate, pyrolytic silica, lithium aluminum silicates, borosilicate glass”¹¹ bonded to a “polymeric or resin matrix”¹². The filler must be strongly bonded to the matrix. Therefore, it is often coated with a silane coupling agent.¹³ Tooth composites are aesthetically attractive, and particularly useful because they chemically bond to teeth, thereby creating increased longevity of composite restorations. However, composites are not yet as durable as traditional restorative materials, and they are expensive.

Amalgam fillings are considered unsafe due to leaking mercury that is believed to be responsible for adverse effects to the brain, causing migraines. Mercury also damages the kidneys, as well as the fetus in pregnant women. Some people are allergic to mercury, perhaps causing oral lesions.¹⁴ An amalgam filling is a combination of mercury and other metals to create a stable alloy. In 2008, the FDA said “Dental amalgams contain mercury, which may have toxic effects on the nervous systems of developing children and fetuses.”¹⁵ Pregnant women should avoid mercury.

If a tooth is weak, it needs to be removed or restored. Chemical technology has created new materials for crowns: Metals, porcelain-fused-to-metal, all-resin, or all-ceramic. Metals include gold alloys, and alloys containing palladium or nickel or chromium. Metal crowns are

¹¹ Douglas A. Terry D.D.S. Karl F. Leinfelder, D.D.S., M.S. Willi Geller. *Aesthetic & Restorative Dentistry. Material Selection & Technique*. (Stillwater, MN: Everest Publishing Media, 2009)

¹² Douglas A. Terry D.D.S. Karl F. Leinfelder, D.D.S., M.S. Willi Geller. *Aesthetic & Restorative Dentistry. Material Selection & Technique*. (Stillwater, MN: Everest Publishing Media, 2009)

¹³ Douglas A. Terry D.D.S. Karl F. Leinfelder, D.D.S., M.S. Willi Geller. *Aesthetic & Restorative Dentistry. Material Selection & Technique*. (Stillwater, MN: Everest Publishing Media, 2009)

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<http://www.fda.gov/MedicalDevices/ProductsandMedicalProcedures/DentalProducts/DentalAmalgam/ucm171094.htm#2>

¹⁵ <http://www.webmd.com/oral-health/guide/dental-health-fillings?page=4>

strong and durable. However, the color is not satisfactory. While porcelain-fused-to-metal can be matched to fit the color of teeth, it is more taxing on opposing teeth and can chip. All-resin dental crowns are less expensive but wear more quickly. All-ceramic or all-porcelain dental crowns provide the best color. However, they are not as strong as porcelain-fused-to-metal crowns and they wear opposing teeth. Usually they are used for front teeth and for people who have metal allergies.

If a tooth cannot be restored properly, it may be removed and replaced by an implant that serves as a basis for a crown. Figure 1 shows a picture comparing a natural tooth and a tooth replacement.

The center part of the tooth is called pulp. It is made of living connective tissue and odontoblast cells.¹⁶

Dentin¹⁷ is calcified tissue which comprises the next layer of the tooth. It is yellow in appearance thereby affecting the color of the tooth due to the translucency of the enamel. Dentin¹⁸ is less brittle

than enamel and thereby serves as a support structure of the tooth. Enamel¹⁹ is the top layer of the tooth. It is the hardest and most mineralized part of the body.

An implant is a metal replacement for the root of a tooth. Implants replace bridges that cause wear on the teeth needed to connect a bridge.²⁰ To insert an implant, a hole must be drilled. The implant screw is then placed into the bone. A post or abutment is attached to the

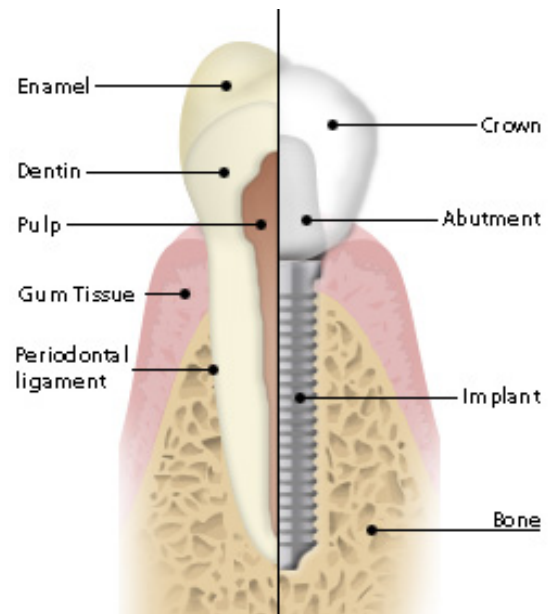


Figure 1: Dental Implant
<http://www.mckinneydentist.com/dental-implants.html>

¹⁶ [http://en.wikipedia.org/wiki/Pulp_\(tooth\)](http://en.wikipedia.org/wiki/Pulp_(tooth))

¹⁷ <http://en.wikipedia.org/wiki/Dentin>

¹⁸ <http://en.wikipedia.org/wiki/Dentin>

¹⁹ http://en.wikipedia.org/wiki/Tooth_enamel

²⁰ <http://www.perio.org/consumer/2m.htm>

implant. Today, zirconium abutments²¹ are used for color purposes because they assure that the porcelain crown maintains translucency mimicking natural teeth.

Lower-speed drills²² are used for polishing teeth. High-speed drilling, used for precision work,²³ as opposed to low-speed drilling which requires higher torque, converts high-pressure air into mechanical energy by an air turbine. The focus has been to increase the drill's number of rotations per minute, now ranging from 300,000 to 800,000 rpm. However, recent technology has moved from faster drills to alternatives such as lasers and air abrasion.

During typical dental procedures, such as filling cavities, extracting teeth, placing implants, or bone grafting, the dentist may prescribe drugs. Anti-inflammatory drugs, acetaminophen, and anesthetics relieve pain or irritation. Local anesthesia, general anesthesia, or sedatives relieve pain. While strong anesthetics are available only by prescription, mild pain-killers and mild bacteria-killing medications are available as over-the-counter drugs . They come in a variety of dosages and forms: as sprays, dental paste, gels, ointments, or solutions.²⁴

Anxiety is a main issue. Sedatives such as inhalation of nitrous oxide are sometimes used to relieve anxiety. The sound of a drill can make patients wince. However, a new drilling technique called air-abrasion²⁵ uses air pressure with tiny aluminum-oxide particles to remove tooth debris and decay without use of a drill. It is a painless technique, often requiring no anesthetic. Air-abrasion can fix tiny cracks in teeth. It is used for bonding procedures or for restoring teeth. Laser technology allows accurate and quick removal of excess gum, replacing the painful technique of cutting away gum tissue.

²¹ http://www.dental--health.com/basic_implant_procedure.html

²² <http://www.enotes.com/how-products-encyclopedia/dental-drill>

²³ http://en.wikipedia.org/wiki/Dental_drill

²⁴ <http://www.webmd.com/oral-health/medications-used-dentistry>

²⁵ <http://www.mffdentistry.com/pain-management.html>

Oral Beauty

Today, good-looking teeth improve a person's image. Therefore, modern dentistry has a psychological effect. Straight teeth can improve speech articulation, especially for certain sounds such as alveolar²⁶ consonants [t] and [l] that require placing the tongue against the upper teeth. Missing or crooked front teeth can result in a lisp. A "perfect smile" can increase chances for a successful career, for example in acting or singing. Singers must have a beautiful smile, especially for high notes where the singer's mouth is wide open. Shining white, straight teeth please the audience.

Braces

Orthodontic care may use braces to straighten teeth, to correct the bite, to prevent erosion of molars, or to create space for implants. Straight teeth can improve health. Irritations in the mouth or in the gums result from crooked or crowded teeth. Commonly used silver braces or those made from steel and nickel are used for straightening teeth.²⁷

However, braces can cause problems. Dietary issues can arise because with braces, it is difficult to eat nuts or raw vegetables like carrots. Braces interfere with oral beauty. Normally, children get braces in middle school. They are worn for a couple of years depending on the initial state of the teeth and on how easily teeth are moved. However, because teenagers are particularly aware of their appearance, braces are often not popular.

²⁶ alveolar consonants are consonants that are uttered with the tip of the tongue touching the alveolar ridge, or alveoli, located behind the upper front teeth. <http://www.merriam-webster.com/dictionary/alveolar>

²⁷ <http://www.bracesquestions.com/static/orthodontic-braces/silver-braces/>

Figure 2 shows a labeled diagram of a mouth with braces. Braces can cause hygienic problems because it is difficult to brush teeth covered by braces.²⁸ As figure 2 shows, the brackets are the metal pieces of the braces. The glue that is used to bond the brackets to the teeth, sometimes causes teeth to appear yellow when braces are removed.²⁹ Chemical research, however, has developed a technique called whitening, as discussed in the next section, which can reduce the yellow appearance of teeth.

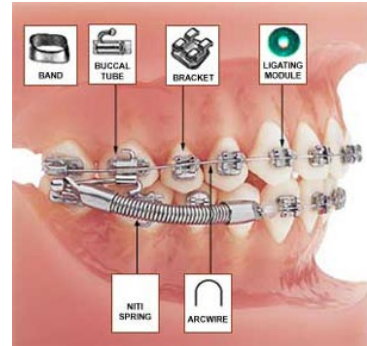


Figure 2: Braces
<http://www.orthodontic-care.com/glossary.htm>

Due to chemical research, we now have plastic materials that can be used to make braces. We now have modern clear braces³⁰ that function as metal braces but are more aesthetically appealing. Also, research in new materials has established a technique called “Invisalign”³¹, a series of removable, clear trays. The tray is made from an impression, or mold of the teeth. This impression is sent to the Invisalign laboratory where a 3D computer model is made and the teeth are aligned in the computer “mock-up”.³² Then a series of smooth, clear, plastic trays is made. Each tray is worn for a month or two, and then replaced by a new tray that has better alignment of the teeth. The trays are clear and smooth as can be seen in Figure 3, and therefore more



Figure 3: Invisalign tray
<http://www.puredentalgroup.com/invisalign-chicago.html>

aesthetically attractive. In addition, they also improve dental hygiene during the straightening-

²⁸ <http://www.invisalign.com/Why-Invisalign/Pages/dental-hygiene.aspx>

²⁹ <http://www.bracesreview.com/cause-of-yellow-teeth-and-yellow-tooth.html>

³⁰ <http://www.bracesquestions.com/static/orthodontic-braces/clear-braces/>

³¹ <http://www.invisalign.com/Why-Invisalign/Pages/dental-hygiene.aspx>

³² <http://www.bracesquestions.com/static/invisalign-braces/invisalign/>

process because they are easily removed before brushing, unlike traditional braces. Figure 3 to the right shows a woman placing the clear Invisalign tray into the mouth. The last image shows her mouth with the Invisalign tray in place.

Whitening

It has become popular to whiten teeth. Especially celebrities seen on television or in magazines have encouraged this trend. Often teeth develop stains due to coffee, braces, smoking or aging. These stains can be removed with whitening products that improve tooth color and raise self-confidence. Teeth are made of dentin³³, a calcified tissue layer made of tubules and tubes covered by a hard tooth enamel. Enamel is a highly mineralized, porous, rigid tissue. It wears away and exposes the dentin layer below. Its crystalline structure consists of a tightly packed pattern of prisms that provides strength to the enamel. High intermolecular forces such as van-der-waals forces attract material that can stain teeth either brown, black, green, orange, or grey metallic.³⁴ Some old remedies such as baking soda are sometimes used to remove discolorations.³⁵

New whiteners include carbamide peroxide or hydrogen peroxide that create an oxidation reaction for decomposing staining compounds leading to whiter teeth.³⁶ More and more do-it-at-home methods are now available including whitening toothpaste, and whitening strips. Gels are squeezed into a molded plastic clear tray that fits over the teeth. Toothpaste has milder chemicals that remove surface stains but do not change the natural color of teeth. If necessary, more

³³ <http://dentistry.about.com/od/termsanddefinitions/g/dentin.htm>

³⁴ Douglas A. Terry D.D.S. Karl F. Leinfelder, D.D.S., M.S. Willi Geller. *Aesthetic & Restorative Dentistry. Material Selection & Technique*. (Stillwater, MN: Everest Publishing Media, 2009)

³⁵ <http://www.webmd.com/oral-health/ss/slideshow-10-secrets-to-whiter-teeth>

³⁶ <http://science.howstuffworks.com/innovation/everyday-innovations/tooth-whitening1.htm>

aggressive bleaching treatments can be performed by the dentist. Such treatments use bleaching gels by companies such as “Opalescence”.³⁷

Veneers and Dental Implants

Veneers can improve a person’s smile and appearance. For example, if teeth are worn, veneers can cover teeth. Figure 4 shows the placement of a dental veneer, a smooth piece of material, such as porcelain, on the front of the original tooth. In the 1930s³⁸, actors in Hollywood wore temporary veneers to improve their appearance. However, since there was no effective adhesive system, they were removed after filming. Acrylic veneers were developed in the 1970s³⁹, but then porcelain veneers were developed in the 1980s⁴⁰. Porcelain is often used in restorative dentistry. It resists abrasion, is color stable, and aesthetically attractive. Therefore, porcelain serves as an alternative to metal-ceramic, or ceramic crowns. Veneers have become thinner, smoother and therefore more comfortable.



Figure 4: Dental Veneer placed on top of the original tooth.
<http://dentalchicago.org/wp-content/uploads/dental-veneers.jpg>

During the process of color-evaluation, the dentist must have an adequate photographic system in place. Photographs of the face and smile provide a visualization for the team in charge of restoring teeth. Black-and-white photographs indicate brightness of the hue, whereas color photographs show discoloration. Surface texture can also be more adequately examined with photographs.

³⁷ <http://www.opalescence.com/index.php>

³⁸ Claude R. Rufenacht. “*Fundamentals of Esthetics*” (Chicago, Illinois: Quintessence Publishing Co, Inc, 1990)

³⁹ Claude R. Rufenacht. “*Fundamentals of Esthetics*” (Chicago, Illinois: Quintessence Publishing Co, Inc, 1990)

⁴⁰ Claude R. Rufenacht. “*Fundamentals of Esthetics*” (Chicago, Illinois: Quintessence Publishing Co, Inc, 1990)

Conclusion

Chemical research and the development of new chemical technologies have made a large impact in dentistry. Inventing new, aesthetically-pleasing, durable, but less problem-causing solutions for a variety of dental problems has been a focus of modern dentistry. Thanks, in part, to research in chemical and materials technology, the past 40 years have seen a significant increase in new technology in dental practice, driven by human needs for health and beauty.

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