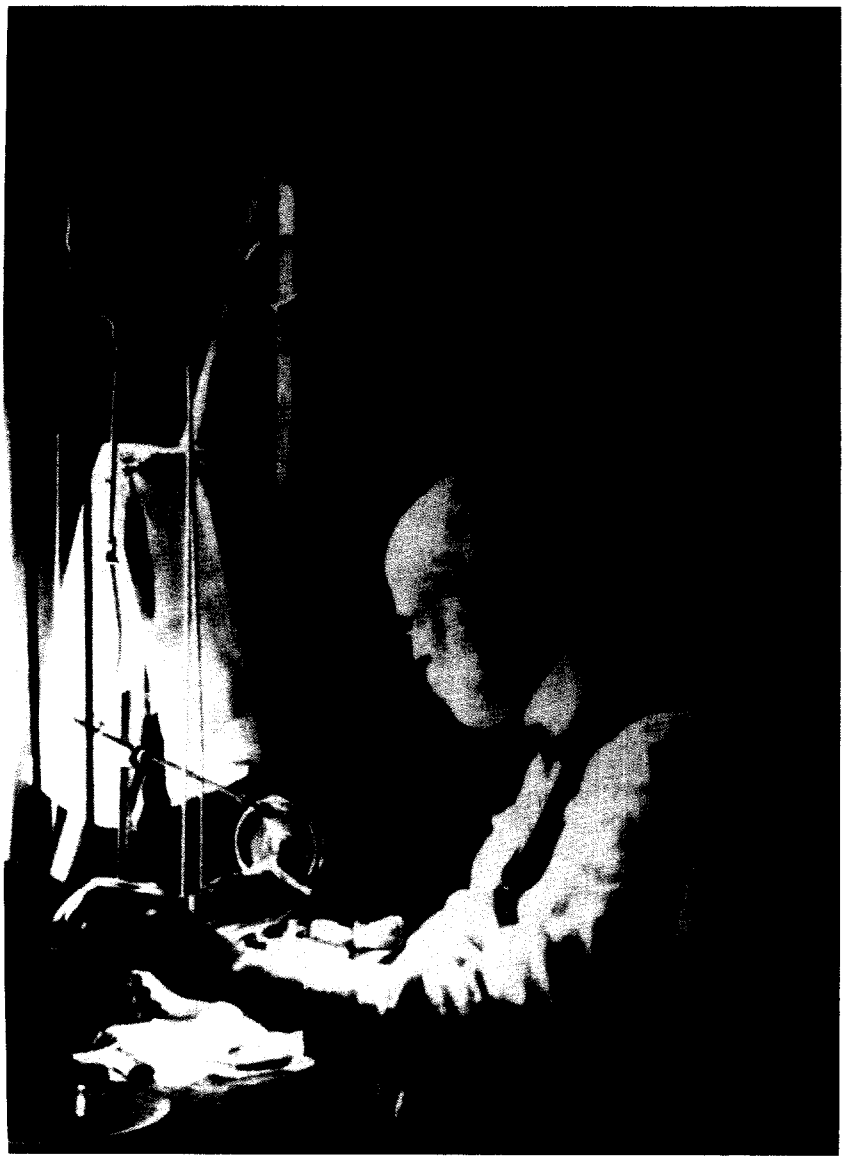
AMERICAN CONTRIBUTIONS TO THE NEW AGE OF DENTAL RESEARCH



U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES

Public Health Service

National Institutes of Health

National Institute of Dental Research

National Library of Medicine

NATIONAL INSTITUTE OF
DENTAL RESEARCH

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Dr. G. V. Black at work in his laboratory.

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May 1988

THE T VOLUME.

"Does your cyclopedy tell anything about the toothache?"

"I think so, mum; it touches on all useful information. We haven't published the T volume yet."

"Well, you can put me down for a T volume, an' if it goes ahead of our almanick on toothache cures, I'll take the whole set."

FOREWORD

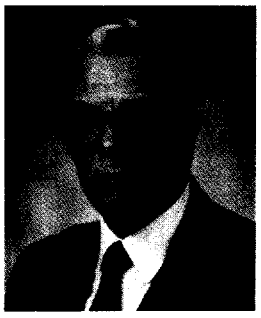
Dental research was in its infancy at the turn of the century. There were excellent practitioners who devised materials and techniques for tooth repair, and a few pioneers with insights into the cause of tooth decay. By the 1930s dental research had gained ground with studies of fluoride. These studies were to lead to one of the most successful disease prevention measures in the history of public health: community water fluoridation. The National Institute of Dental Research, founded in 1948 to improve the oral health of the American people, supported the research on fluoride and fostered the rapid growth of dental research, both in scope and depth.

Now, in celebration of its 40th anniversary, the National Institute of Dental Research and the National Library of Medicine take pride in recording a century of progress. Dental research investigators today are contributing to the fundamental store of knowledge of growth and development, pain and sensory-motor physiology, dental diseases and soft tissue infections, behavioral science and epidemiology, oral cancers and AIDS. The text and the exhibit are dedicated to the men and women who have advanced dental science so notably over the course of the century. They have made invaluable contributions to the improvement of the oral and general health of people everywhere.

Harald Loe, D.D.S., Dr. Odont.

Director

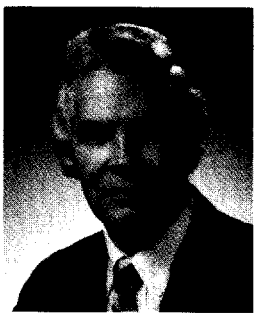
National Institute of Dental Research



Donald A. B. Lindberg, M.D.

Director

National Library of Medicine



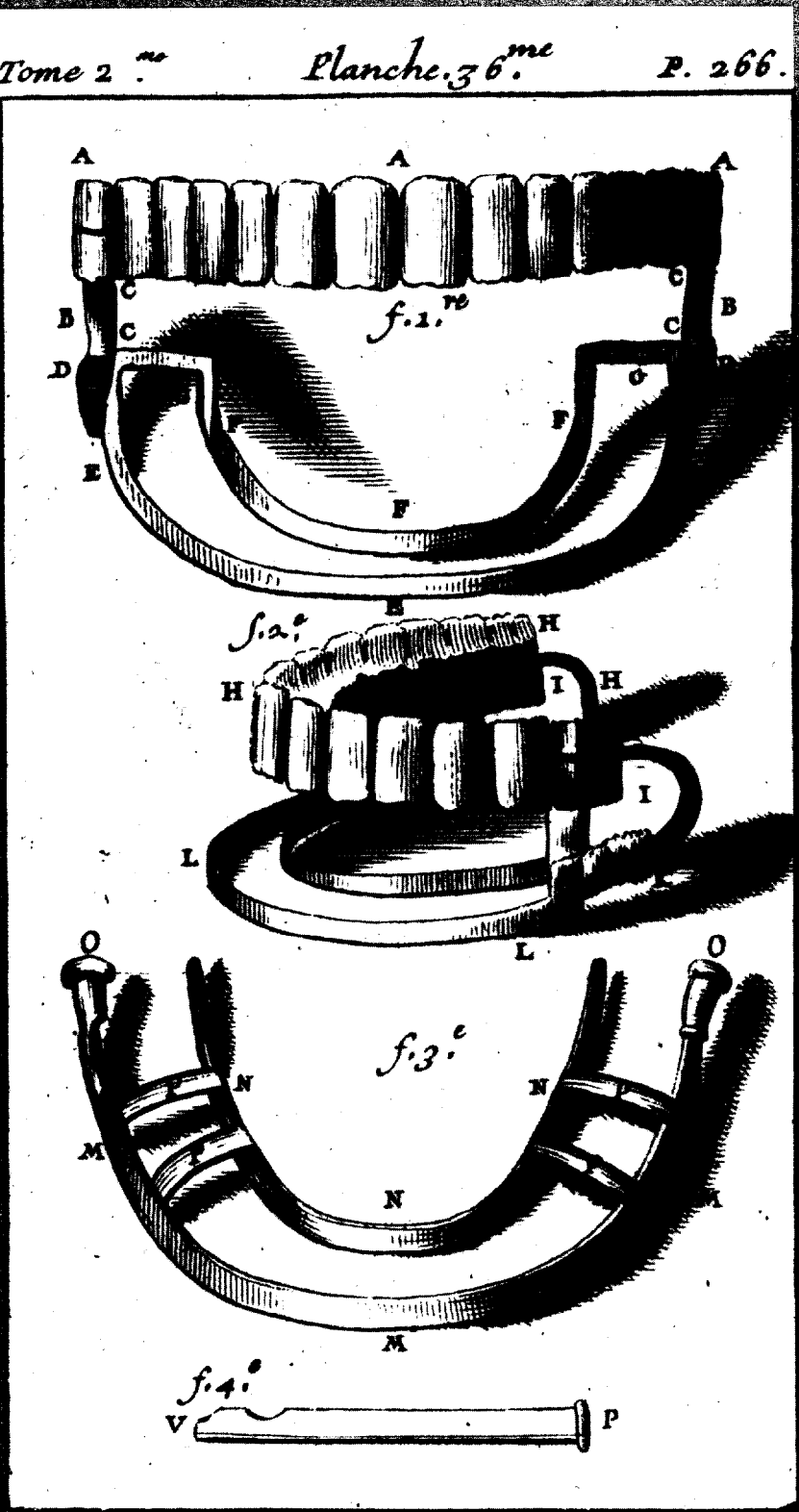
PREFACE

This booklet is published in conjunction with "A Century of American Dental Research: An Exhibit Commemorating the Fortieth Anniversary of the National Institute of Dental Research," on display at the National Library of Medicine (NLM), from May through October 1988. Through these works the National Institute of Dental Research (NIDR) and the National Library of Medicine honor the thousands of American scientists who have contributed to dental research.

While American dentistry has benefited from the contributions of many around the world, the past 150 years have seen many American advances influence the course of dentistry and dental health. Scientists built their achievements upon the painstaking investigations of hundreds of predecessors. This essay presents a few examples drawn from the vast collection of these scientific and technological advances.

Several individuals helped produce these commemorative works. Philip Teigen and Elizabeth Tunis of NLM organized the exhibit. With the assistance of Susan Johnson of NIDR, Ruth Harris, of History Associates Incorporated (HAI), prepared the text and Laura Kells, also from HAI, collected the illustrations for this booklet. John Parascandola, chief of the History of Medicine Division of the National Library of Medicine; Karma A. Beal and Roger Rensberger of the National Bureau of Standards; Dr. Harald Löe, NIDR Director; Brent Jaquet, chief, Mary Daum, Robert Kuska, Patricia Sheridan, and Sally Wilberding of the NIDR Public Inquiries and Reports Section, and Joan Wilentz of the Planning and Evaluation Section, Office of Planning, Evaluation and Communications; Rodney Carlisle, Kim Kilpatrick, and DyAnn Gates of HAI also provided support and advice for these activities.

Ruth Harris, Ph.D.
History Associates Incorporated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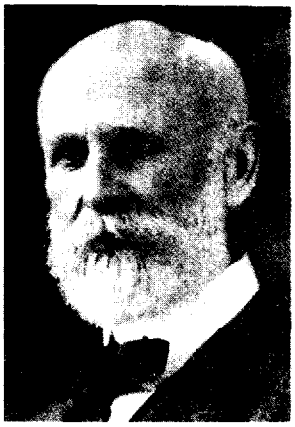
INTRODUCTION

As in many other areas of science, the earliest advances in dental research emerged first in the Old World. The Etruscans, for instance, developed crowns and bridges between 1000 and 400 B.C. In the fifteenth century Giovanni d'Arcola, a professor of medicine and surgery at the University of Bologna, asserted that dental decay could be prevented by cleaning teeth regularly and avoiding honeyed foods.

Modern dentistry evolved during the late seventeenth century. By then, the anatomy, histology, and physiology of teeth were well established. Pierre Fauchard, a French dentist, earned his reputation as the father of modern dentistry by publishing *Le Chirurgien Dentiste ou Traite des Dents* in 1728. His work served as an authoritative guide for the next one hundred years, especially for the French emigré dentists who brought the Fauchard treatise with them to the New World.

In the nineteenth century Americans took the lead in both education and dental therapy. In 1839 four dentists—Chapin Harris, Solyman Brown, Horace Hayden, and Eleazer Parmly—founded the *American Journal of Dental Science,* the first periodical devoted to dental research. The next year Harris and three colleagues established the first major dental college in the United States, the Baltimore College of Dental Surgery, which later became affiliated with the University of Maryland. At an August 1859 meeting in Niagara Falls, New York, twenty-six men formed the nucleus of the American Dental Association (ADA), an organization that has consistently encouraged dental research in the United States.



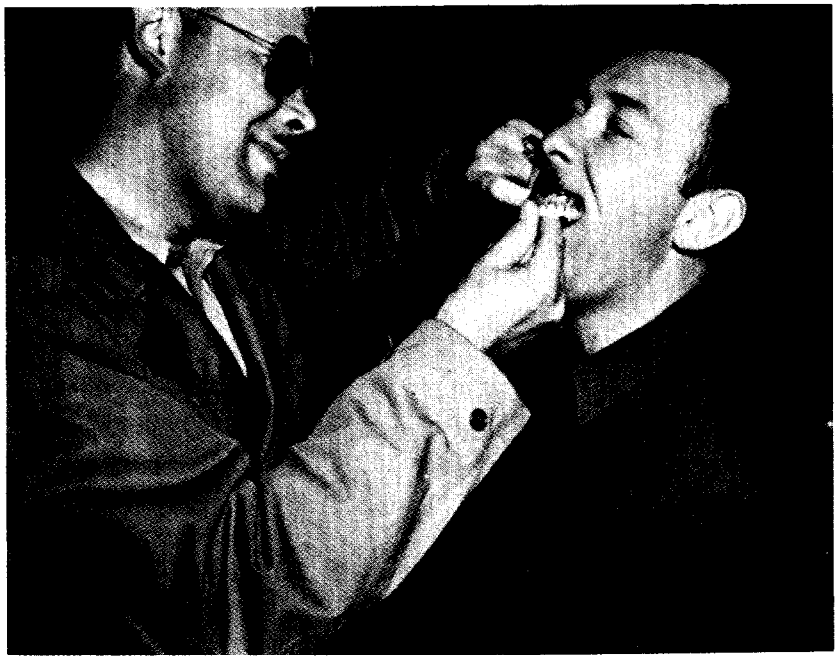
Dr. Greene Vardiman Black (1836-1915).

Dr. Greene Vardiman Black, considered a founding father of modern American dental research, came on the scene in the late nineteenth century. A self-taught scientist who learned dentistry through an apprenticeship, Black influenced virtually every facet of dentistry. He wrote the authoritative works on dental nomenclature and anatomy, *A Descriptive Anatomy of Human Teeth* and *Operative Dentistry and Dental Pathology,* and developed the standardized procedure for filling cavities.

Despite the achievements of Black and a handful of other researchers, dental science lacked a substantial following in the United States during the early part of the twentieth century. Existing resources for dental research came from philanthropists and organized dentistry. Between 1900 and 1920 the Forsyth brothers in Boston and George Eastman in Rochester, New York, endowed clinics that developed into outstanding dental research centers. Also during those two decades the National Dental Association, later renamed the American Dental Association, distributed research grants and supported a research institute.

By 1918 dental research had attracted some dedicated advocates. Among them was Dr. William Gies, professor of biological chemistry at Columbia University. He helped found the *Journal of Dental Research* in 1918 and the International Association for Dental Research in 1920.

Wartime experiences drew the federal government into dental research. Military dentists' dissatisfaction with available restorative materials during World War I led to a federal role in dental materials science. Still, fewer than a dozen dentists and scientists investigated dental problems for the government before the outbreak of World War II.



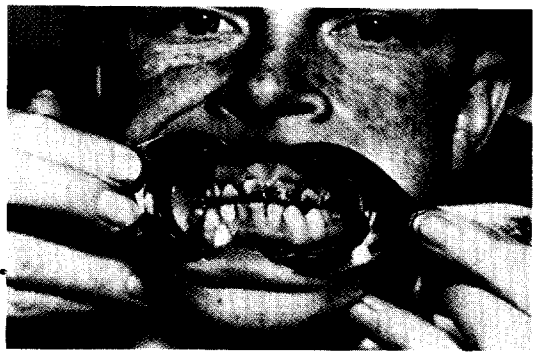
During World War II the armed services were forced to lower dental requirements and administer corrective treatment.

The World War II military recruiting experience revealed the extent of dental disease in the nation. In 1940 almost 400,000 potential recruits lacked the six opposing teeth the military required to "bite the cartridge." "Dental defects" ranked as the leading cause for rejection by the Selective Service in the months before and immediately after the Pearl Harbor attack. To enlist sufficient manpower, the armed services had to lower dental requirements and in numerous cases fit recruits with false teeth. When members of the United States Senate learned of this dilemma, they favored establishing a federal dental research institute. On June 24, 1948, almost three years after the war ended, President Harry S Truman signed legislation establishing the National Institute of Dental Research as the third of the government's National Institutes of Health.

FLUORIDATION

The new Institute's earliest work led to one of the most successful public health measures of the twentieth century: fluoridation of drinking water to prevent tooth decay. The story behind fluoridation began at the turn of the century when reports of an unexplained dental disorder surfaced in Naples, Italy, and Colorado Springs, Colorado.

In 1901 Dr. John Eager, a government physician, reported to his Washington superiors a strange, disfiguring dental condition found in U.S.-bound emigrants from the Naples area. "One is struck with the frequency of a dental peculiarity common among the inhabitants. . .of black teeth apparently strong and serviceable but devoid of enamel and hideously dark," he wrote. Eager's superiors published his report but assigned him to other tasks.



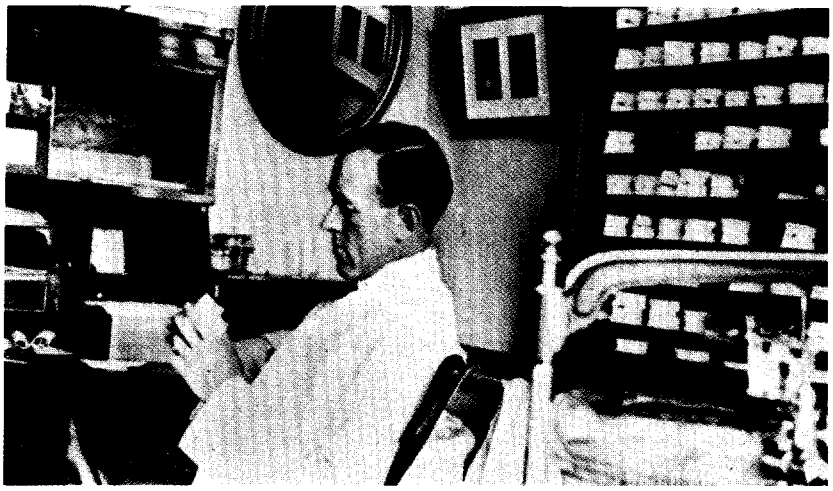
Teeth with mottled enamel.

Meanwhile, Dr. Frederick McKay, who had just graduated from the University of Pennsylvania dental school, noticed a similar disorder in many of his patients in Colorado Springs. Disturbed by the unsightly dark stains on his patients' otherwise healthy teeth, McKay began a decades-long investigation into the disorder.

In 1908 he enlisted the help of the eminent Dr. Greene Vardiman Black. Black, who named the condition "mottled enamel," and McKay found the mysterious defect in numerous areas of the country. Their collaboration continued until Black's death in 1915. Throughout the work McKay pursued his suspicion that the stains were caused by water used for cooking and drinking. But routine analyses of the water in affected areas failed to provide any clues.

In the mid-1920s, McKay appealed to the Public Health Service (PHS) for help in tracking the enamel disorder. That request led to a collaboration with Dr. Grover Kempf of the PHS. In 1928 Kempf and McKay investigated a dental defect in children living in Bauxite, Arkansas, a company town owned by the Aluminum Company of America (ALCOA). They found the familiar dark stains on the teeth of the children in Bauxite but saw only normal teeth in the children of another town just five miles away. Again, standard water analysis offered no explanation for the stains.

McKay's and Kempf's report on their findings reached the desk of ALCOA's chief chemist, H. V. Churchill. At the time Churchill was trying to combat rumors that aluminum cookware was poisonous and he feared that stories of the Bauxite teeth staining might exacerbate his company's problems. Following his instruction, an ALCOA chemist tested the Bauxite drinking water for traces of very rare elements not normally included in water analyses. The results provided the answer for which McKay and others had been searching: the Bauxite water supply contained high levels of naturally occurring fluorine. Analysis of water samples from other communities afflicted by the dark stains revealed that the severity of the dental defect correlated with fluoride concentrations in the water.



Dr. Frederick McKay (1874-1959) in his office.

Internationally known for their pioneering work on fluoridation (L to R) Drs. Elias Elvove, Frank McClure, H. Trendley Dean and Francis A. Arnold were called the "four horsemen" against dental decay. Shown here in Dr. Dean's office at NIDR.

Meanwhile, St. David's, Arizona, parents faced a similar dilemma: their children, too, had brown-stained teeth. Led by Dr. Margaret Cammack Smith, a St. David's resident, state agricultural chemists tested animals to determine the cause of the condition. The Smith team's results implicated fluorine almost at the same time that Churchill announced the ALCOA findings.

Encouraged by the American Dental Association, the PHS's National Institutes of Health assumed responsibility for probing deeper into the "mottled enamel" problem. In 1931 the surgeon general assigned the first NIH dental scientist, Dr. H. Trendley Dean, the task of determining the prevalence of the enamel disorder in the United States. Dean's "shoe leather surveys," as he called them, identified the condition in twenty-four states by 1933. With the help of NIH chemist Elias Elvove, Dean then determined that teeth staining, or fluorosis, occurred only at fluoride levels above one part fluoride per million parts water (1 ppm).

A chemist examining the fluoride content of water samples.

From the start, Dean suspected that fluoride inhibited new tooth decay. By 1938 he, as well as some observant dentists working on Indian reservations in the southwest, had accumulated enough proof to support that hypothesis. NIH shifted its dental research emphasis to examining schoolchildren in an effort to confirm or disprove the link between fluoride and prevention of tooth decay. By 1942 the evidence showed that children who grew up in areas where the drinking water contained 1 ppm fluoride had fewer cavities than their peers who had used fluoride-free water since birth. Moreover, water with 1 ppm fluoride did not stain the youngster's teeth.

After conducting studies that verified the safety of 1 ppm fluoridated water, the Public Health Service initiated a long-term study to determine if artificial fluoridation was as effective as natural fluoridation in curbing new tooth decay. On January 25, 1945, Grand Rapids, Michigan, became the first city in the world to add fluoride to its drinking water. The city had been

using fluoride-free water since 1912. The nearby town of Muskegon, which used non-fluoridated water, served as the control for the study. Aurora, Illinois, where the water supply naturally contained 1 ppm fluoride, served as a comparison for effectiveness.

The Grand Rapids study was operated jointly by the Public Health Service, the Michigan Department of Health, and the University of Michigan. The fifteen-year project included annual dental examinations of the city's schoolchildren, as well as saliva sampling for use in basic research on dental caries and the activity of fluoride. Five years into the study the reduction in tooth decay among Grand Rapids schoolchildren was so striking that the PHS surgeon general acclaimed fluoridation. Muskegon officials persuaded the study's operators to let their city fluoridate its drinking water in 1951.

By 1960, when the Grand Rapids study came to a close, the PHS's National Institute of Dental Research confirmed that 1 ppm fluoride in drinking water safely curtailed new dental decay. Grand Rapids youngsters aged twelve to fourteen had 50-63 percent fewer cavities than their peers in communities using fluoride-free water. The dental decay rate was cut in half among fifteen and sixteen year-olds. Similar fluoridation studies in Canada, Illinois, New York, and Wisconsin produced the same results.

This child is taking a saliva test during the Grand Rapids Study.

Fluoridation, however, proved controversial. Like other large-scale public health measures such as chlorination of water, fluoridation aroused opposition that turned the process into a political issue. Depending on the legal systems of particular communities, fluoridation frequently required approval by referendums. Opponents raised a myriad of charges, including accusations that fluoridation caused cancer, premature aging, heart attacks, and acquired immunodeficiency syndrome (AIDS). No basis has been found for any of the allegations.

By 1988 thirty-one nations and more than half of the communities in the United States with central drinking water supplies had installed fluoridation, a dental benefit resulting from the dedication of a handful of American scientists.

DENTAL CARIES RESEARCH

Although dental caries, commonly called tooth decay, was a disease known for centuries, its origin stirred the imagination. From ancient times to the 1700s physicians and dentists attributed the condition to a worm. European scientists disproved this hypothesis by the mid-eighteenth century, but they disagreed about whether dental caries resulted from an internal or external cause. Those siding with the latter in the United States and Europe pointed to the increase in cavities during the nineteenth century following the improvement of sugar refining processes and a subsequent decline in the price of sweets.

Caries research benefited greatly from the persistence and scholarship of an American dentist, Dr. Willoughby D. Miller, whose investigations spanned the nineteenth and twentieth centuries. The first American with a professional appointment at the University of Berlin, Miller studied during the latter half of the nineteenth century under Robert Koch, one of the founders of modern bacteriology. Like some European researchers who also subscribed to Koch's concepts, Miller suggested that microorganisms

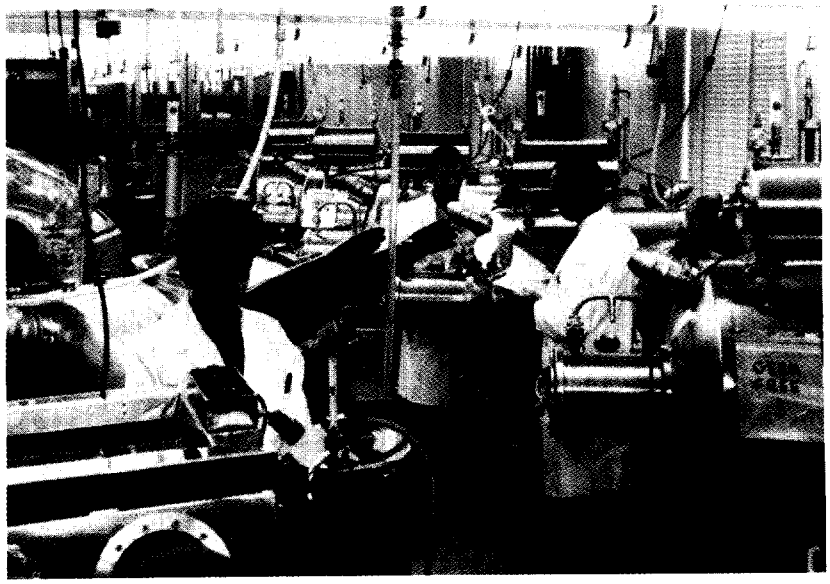
Dr. Willoughby D. Miller (1853-1907).

induced tooth decay. He concluded that oral bacterial interaction with starches and sugars produced acids that destroyed tooth enamel. The American's hypothesis, which he promoted for over twenty years, eventually served as the foundation for twentieth century bacteriological research into dental caries. In 1907 Miller left Berlin to become dean of the University of Michigan Dental School, which became one of the major academic dental research centers in the nation.

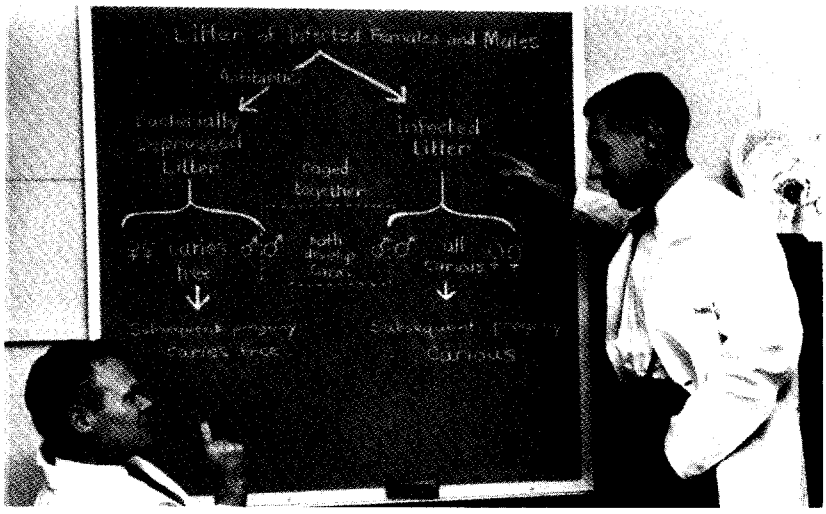
By 1910 dental caries was so widespread in the United States that Dr. Arthur Merritt, later a president of the American Dental Association, called it "the people's disease." Dentists estimated that in the early part of the twentieth century approximately 98 percent of the population had contracted at least one cavity.

While several scientists accepted Miller's hypothesis, researchers in the first half of the twentieth century disagreed about the relative importance of bacteria in causing tooth decay. Some cited nutritional causes, particularly refined sugar, as the key. Others considered oral bacteria as most instrumental but differed on whether a streptococcus or bacillus type bacterium triggered the disease. In addition, investigators were hampered by the lack of a suitable animal model for dental decay.

Major breakthroughs in dental caries research followed advances in laboratory animal usage. In the 1950s scientists at the University of Chicago's Zoller Dental Clinic and in Sweden developed the methodology for studying germ-free animals that helped to clarify the dental caries process. By showing that germ-free, but caries-susceptible, rats did not develop tooth decay after eating a highly cariogenic diet, Dr. Frank J. Orland and his Chicago group demonstrated that diet alone could not induce dental caries. The Chicago researchers proved further that certain microorganisms



Animals housed in germfree tanks were used to clarify the dental caries process. Shown here at NIDR in 1964.



In 1960 Drs. Robert Fitzgerald and Paul Keyes confirmed that dental caries in hamsters was infectious and transmissible.

triggered dental caries when the rats developed dental caries after being infected with a single streptococcal strain.

Dr. Robert Fitzgerald and his NIDR colleagues extended Orland's work. The availability of germ-free animals at NIH in 1955 enabled the dental institute's scientists to conduct their own testing of the caries process. Using the germ-free animals, the NIDR and Chicago researchers narrowed the bacteria involved to a few types of streptococci and lactobacilli.

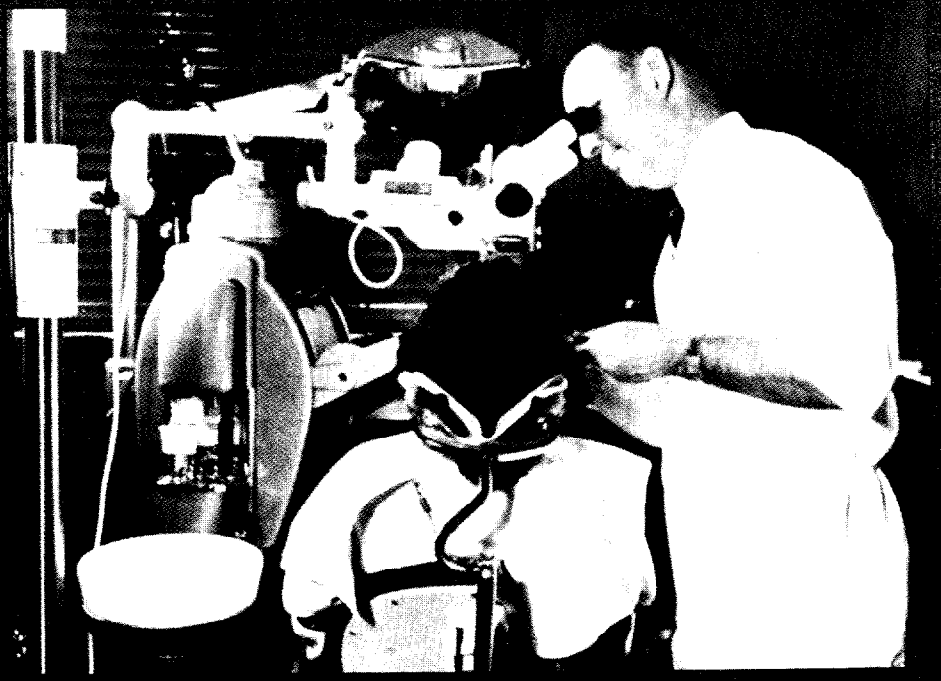
Dr. Paul Keyes of NIDR, however, carried the explanation even further by showing that the disease was infectious. Suspecting that the condition was transmissible, he developed a strain of albino hamsters that lost their susceptibility to dental caries when treated with an antibiotic. His experiments demonstrated that in a germ-free environment descendants of the treated hamster remained caries-free for many generations even when fed sugar-laden diets. But Keyes and Fitzgerald found that if the caries-inactive hamsters were exposed to animals with tooth decay or inoculated with a suspect bacteria, they and their offspring developed extensive caries.

Seen through an electron microscope, S. mutans convert surcrose to sticky polysaccharides that enable them to attach to tooth surfaces.

Fitzgerald and Keyes later isolated a specific streptococcus that induced dental decay in germ-free hamsters free of other microorganisms. They identified the streptococcal strain by a technique known as "tagging," which made caries-producing streptococci resistant to streptomycin. Scientists in Europe and elsewhere in the United States determined in the late 1960s that the microorganism was *Streptococcus mutans*, a bacterium found in early stages of dental decay.

This knowledge enabled the NIDR scientists to trace the mechanisms of dental caries. By 1962 their research identified tooth decay as a multifactorial disease resulting from the interaction of a susceptible host, specific caries-inducing microorganisms, and a cariogenic diet.

These findings prompted the start of efforts in the 1960s to supplement fluoridation with vaccines, antibacterial mouthwashes, and other means of preventing new dental caries.

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PERIODONTAL RESEARCH

For over 4000 years periodontal diseases, ailments of the tissues and bones surrounding the teeth, have baffled sufferers and dentists alike. Before the first century A.D. Hebrew, Greek, and Roman savants advised practicing oral hygiene to control such problems. By the ninth and tenth centuries Rhazes, a Persian physician, and Albucasis, an Arabian physician, described the diagnosis of periodontal disease and explained how to control the problem by scaling and planing the teeth and roots. Eighteenth and nineteenth century European dentists introduced surgical procedures to curtail these illnesses. Despite the development of these treatments, periodontal diseases have been the leading cause of tooth loss in Americans aged thirty-five years and older during the second half of the twentieth century.

Few scientists studied this enigmatic family of diseases until the 1950s. In 1915 in one of his last writings, Dr. G. V. Black described periodontitis as a recurring inflammatory disease that worsened with each occurrence. But the causes of these illnesses eluded researchers. In fact, scientists differed on whether external irritants, such as calculus, or bacteria induced tissue destruction.

By the late 1930s researchers suggested that bacteria might be instrumental in triggering periodontal disease. Successful World War II treatment of trench mouth with penicillin strengthened this hypothesis. Moreover, the refinement of the electron microscope greatly advanced periodontal research. In 1949 Dr. Edward Hampp, an ADA research associate at NIDR, used electron microscopy to isolate *Borelia vincentii,* a microorganism associated with trench mouth, now known as acute necrotizing ulcerative gingivitis (ANUG). Subsequent electron microscopy studies by Dr. M. A. Listgarten of the University of Pennsylvania revealed the actual invasion of tissues by microorganisms in trench mouth.

Research in the 1950s indicated that the accumulation of dental bacterial plaque played a much more important role than mechanical irritants in promoting periodontal disease. By 1952 a Norwegian scientist, Dr. Jens Waerhaug, demonstrated that periodontal lesions were formed by bacteria that colonized on gingival and subgingival areas. In the late 1950s NIDR investigators showed that certain mixtures of microorganisms induced degeneration of periodontal tissue fibers. In addition, Dr. Basil Bibby, at the University of Rochester, and NIDR's Dr. Arden Howell worked out the classification of the actinomyces family, a group of bacteria involved in periodontal disease. Later scientists at the Forsyth Dental Center, the State University of New York at Stony Brook, and NIDR demonstrated that specific microorganisms, with or without plaque, played major roles in destroying the periodontium.

By the mid-1960s Keyes and Dr. Harold Jordan of NIDR demonstrated that periodontal disease, like caries, was infectious. They found that *Actinomyces viscosus* could transmit the condition among laboratory animals through feces, plaque, or pure cultures.

Meanwhile, American epidemiologists provided significant information on the prevalence of periodontal disease. In 1956 Dr. Albert L. Russell at NIDR developed the first periodontal index, a system that relied on the examiner's observations. He also conducted surveys in the United States and abroad in the 1950s and 1960s that helped measure the severity and frequency of periodontal disease. In 1959 Dr. Sigurd Ramfjord of the University of Michigan produced a periodontal disease index that used instrumentation to measure the depth of pockets around the teeth, a consequence of periodontal disease. Because of the Russell and Ramfjord indices, information on the status of periodontal disease became available to the international dental community for the first time. Along with advances in technology, these pioneering indices prompted the creation of other means of assessing the extent of periodontal disease, including the invention of the "Florida probe" at the University of Florida at Gainesville. This instrument more accurately measured tooth attachment loss and reduced the amount of measurement error among examiners.

Meanwhile, clinical trials during the 1950s and 1960s, especially the studies of Dr. Harald Löe in Denmark, provided the scientific evidence for the long-held assumption that plaque bacteria caused gingivitis, the initial state of periodontal diseases. Löe, who later became director of NIDR, and his team found the gingivae, or gums, became inflamed after patients abstained from oral hygiene for ten to twenty-one days. The gingivae appeared healthy again a few days after the subjects resumed tooth brushing.

In the late 1960s American scientists at NIDR and several academic research centers combined their microbiological research with immunological investigations. As a result of extensive research that continued into the 1970s and 1980s, they found that the condition of the body's natural defense system against disease figured significantly in an individual's susceptibility to periodontal disease. By 1976 a team led by Dr. Stephan Mergenhagen of NIDR traced complicated processes of the immune system that resulted in bone destruction. In the late 1970s and early 1980s localized juvenile periodontitis, which causes tooth loss in young people, was considerably clarified because of the microbiological and immunological research by such groups as those working with Dr. Sigmund Socransky at the Forsyth Dental Center and Dr. Robert Genco at the State University of New York at Stony Brook.

To deal with periodontal diseases, American scientists tested antimicrobial agents. In the 1970s Löe and his team completed extensive clinical trials on the safety and effectiveness of chlorhexidine, a plaque-inhibiting substance that helps prevent caries and reduces periodontal inflammation. As a result of such studies, chlorhexidine, used in Europe since the 1950s, became commercially available in the 1980s. Meanwhile NIDR supported investigations of other antimicrobials to control periodontal diseases.

Decades of research by hundreds of scientists contributed toward advances in understanding bacterial adhesion by the 1980s at the University of Colorado Health Sciences Center in Denver, NIDR, and the University of Florida at Gainesville. This progress prompted a team at the Florida institution to initiate studies directed toward the possibility of developing a vaccine against *Actinomyces viscosus*, the microorganism that twenty years earlier NIDR researchers had linked with periodontal disease.

The electron microscope enhanced dental research.

THE ELECTRON MICROSCOPE

The electron microscope, a twentieth century product, enhanced dental research. Because this instrument enabled scientists to examine very minute materials, researchers learned much about pathways of microorganisms and complex dental structures and processes. Drs. David B. Scott and Marie U. Nylen of NIDR and Dr. Max Listgarten of the University of Pennsylvania achieved international renown for their uses of the electron microscope to explain tooth structures and microorganism processes.

RESTORATIVE MATERIALS

Until the middle of the nineteenth century the greatest strides in tooth reparation came from Europe. American influence began emerging after Charles Goodyear's 1844 development of rubber vulcanization allowed dental materials makers to provide the more comfortable rubber bases for false teeth.

Other advances, especially by Dr. G. V. Black, followed an "amalgam war" that started in the mid-1830s. In that dispute dentists disagreed over the use of the amalgam alloy, which they could shape more easily than other materials to fill cavities. Dissension raged over improper cavity preparation for amalgam fillings by unscrupulous practitioners and whether the mercury in amalgam endangered the patient. Through extensive studies in 1895 and 1896 Black standardized the process of cavity filling. He supplied the first comprehensive information on the properties of amalgam that contributed toward the standardization of amalgam manufacturing. In 1907 Dr. William Taggart, a Chicago dentist, introduced a practical casting process for gold inlays.

The frustrating experiences of dentists in the field during World War I led to far-reaching progress in restorative dental materials research. In response to the wartime military problems with unsatisfactory dental filling materials, Dr. Wilmer Souder, a physicist, launched the National Bureau of Standards dental materials research effort in 1919. Souder produced the dental interferometer that came to be used internationally to measure the setting changes in amalgam. His and his colleagues' development of physical techniques to evaluate dental amalgam prompted the establishment of international standards for dental materials and encouraged the creation of better restorative products.

Soldiers with dental splints during World War I.

From 1922 to 1928 the Weinstein Laboratory of New York supported the first dental research fellow at the Bureau, R. L. Coleman. An engineer experienced in weights and measures research, Coleman produced the first research that resulted in building the Bureau's standard steel die used in setting the standard for precision casting for both dental materials and industry.

The 1928 establishment of American Dental Association fellowships at the Bureau enabled the national organization to exert greater influence to improve the quality of products used in dental practice. The ADA adopted its initial amalgam specification the following year and established a uniform set of tests to define the composition of that alloy. Souder, W. T. Sweeney, and the first two ADA fellows, Dr. Norris O. Taylor and Dr. George Paffenbarger, were among those who introduced standards and specifications for dental materials.

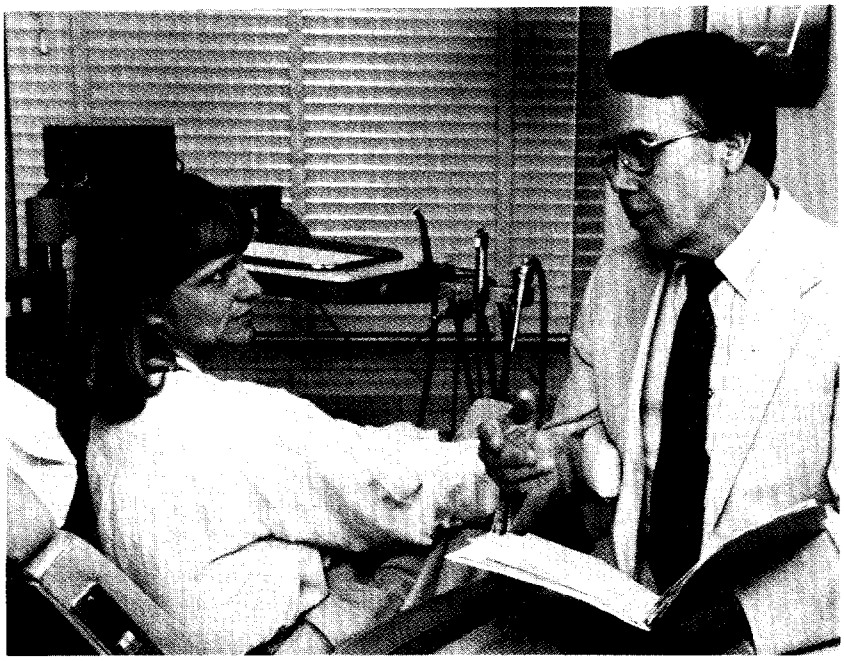
As the senior ADA research associate at the Bureau for much of the twentieth century, Paffenbarger was instrumental in strengthening ADA dental materials research. He promoted the use of national and international standards for dental materials and developed a method for testing standard consistency of dental cement.

Dr. Wilmer Souder (1884-1974).

Dr. George Paffenbarger (1902-1985).

World War II slowed progress in dental materials research, but by the 1950s American ingenuity produced remarkable advances. NIDR, which already had been supporting restorative dental research at several universities, started funding most of the ADA research associate investigations at the Bureau in the late 1950s. Both NBS and ADA researchers subsequently introduced better dental materials.

In 1958 Dr. Gerhard M. Brauer, a Bureau chemist in the dental materials group, reported that zinc oxide-eugenol cements could be improved by the addition of o-ethoxybenzoic acid (EBA). The inclusion of EBA enhanced the physical and mechanical properties of the cements and stimulated formation of reparative dentin. As a result of that research, which continued in the 1960s and 1970s, dentists started using these cements for a variety of repairs, including crowns, bridges, and root canal sealers.

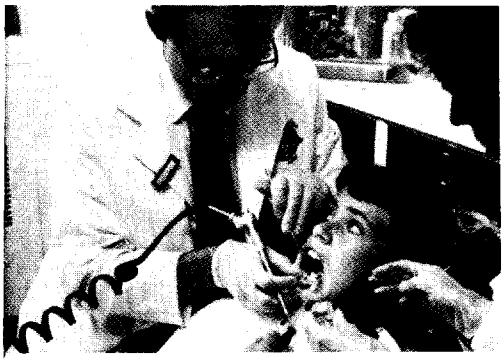


Dr. Rafael Bowen with a volunteer participant in a clinical trial of an adhesive material to bond composite restorations to dentin and enamel.

Because of the work by Dr. Duane F. Taylor, an ADA research associate at the Bureau and son of Dr. Norris Taylor, the first ADA research associate at NBS, the amount of mercury in amalgam has been reduced. In 1962 he and his colleagues announced the development of a spherical-particle alloy for amalgam, an advance that also allowed for low packing pressures in that substance.

By the early 1960s the fruits of studies by Dr. Rafael Bowen, an ADA research associate at the Bureau, became widely available to the nation's dentists. In research launched in the 1950s, Bowen synthesized an epoxy resin known as Bis-GMA, the first successful production of a composite resin for filling teeth since acrylic acid was discovered in 1843. The earlier acrylic fillings of the 1940s had proved unsatisfactory because they discolored, shrank, contributed to pulpal inflammation, and allowed extensive decay to recur. Bowen's product demonstrated more stable properties and better cosmetic qualities. Because Bis-GMA could be made to resemble the color of natural teeth, it proved especially useful for fillings in anterior teeth. Ten years after Bis-GMA became commercially available, an NIDR spokesman estimated that dentists used the material in at least 50 million restorations between 1962 and 1972. Later research showed that use of Bis-GMA also contributed toward preventing dental caries.

Another imaginative dental scientist, Dr. Michael Buonocore of the Eastman Dental Center in Rochester, New York, eventually combined Bowen's findings with his own outstanding, pioneering studies. He had conducted research concurrent with Bowen's that ultimately resulted in the



Dental researcher applies protective sealants to a child's teeth.

development of tooth sealants of pits and fissures to prevent new tooth decay. In the course of this work, he had developed an acid etching technique that prepared teeth for bonding. In the late 1960s Buonocore, an extramural grantee of NIDR, carried out clinical trials with children by painting a thin coating containing Bowen's Bis-GMA base on teeth in one-half of the mouth and then bonding this addition with ultraviolet light. In 1970 and 1971 he reported that this sealant technique resulted in a 99 percent reduction of new decay in permanent teeth while new caries formed on 84 of the 200 untreated teeth. His tests showed that the permanent teeth retained the Bis-GMA sealant at an 87 percent retention rate for one year.

In 1972 the ADA approved Buonocore's acid etching technique, and dentists began using sealants to curtail tooth decay, particularly in children and adolescents. ADA surveys showed that in 1974 slightly more than one-third of the dentists surveyed offered sealant treatment. By 1982 over 57 percent used this therapy.

DENTAL DEVICES

Yankee inventiveness also produced dental equipment that facilitated the skill of the dentist and alleviated the plight of the patient. One of the most revolutionary discoveries was the invention of the dental foot engine by James B. Morrison in 1872. Morrison's machine eased the drilling process considerably.

In the twentieth century Americans developed instruments that radically improved dental services around the world. In 1953 Dr. Robert Nelsen, an ADA research associate, and John W. Kumpula of the NBS introduced technology for the turbine contra-angle high-speed handpiece. Manufacturers adapted their results to produce the high-speed drill that eased cavity preparation for fillings, an advance that revolutionized dental practice.

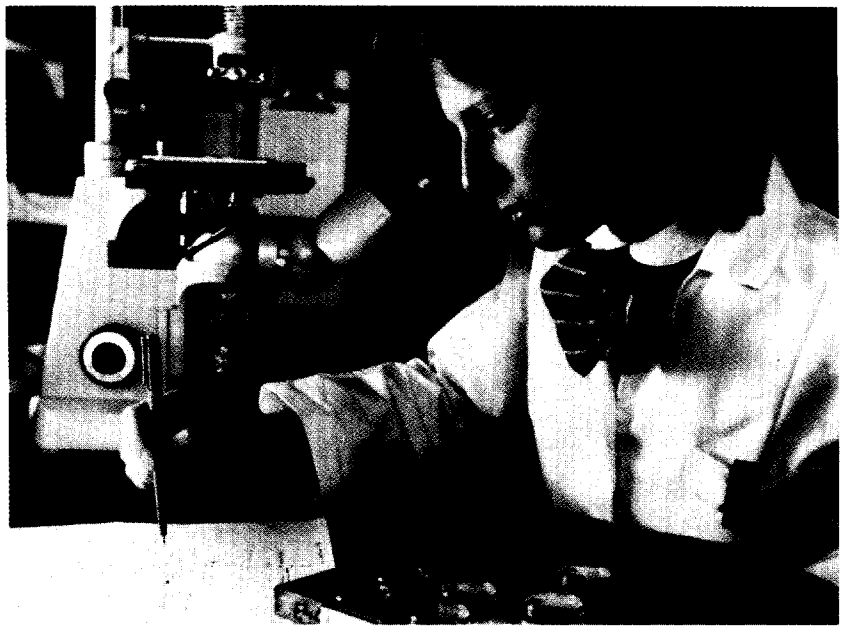
The U.S. Air Force funded research that led to the NBS creation by 1957 of a panoramic X ray machine. That instrument cut radiation exposure by two-thirds and took a picture of the complete dental arch in a few seconds with a film outside the mouth. By 1972 federal military clinics and induction centers were using the panoramic X ray extensively.

Dentists of the future will benefit from the computer age. A new computerized X ray process, developed by NIDR scientists, will enable practitioners to view details of teeth and supporting gum and bone tissues that are undetectable in conventional radiographs. Using minimal amounts of radiation, this system will make possible the early diagnosis of periodontal disease and dental caries. Computer-aided engineering, first developed in France, is also being applied to the field of restorative dentistry. NIDR grantees project that by the mid-1990s dentists will be able to custom design and produce precision crowns and bridges right in the office with a table-top computer system.

DEVELOPMENT OF HERPES SIMPLEX VIRUS VACCINE

At the National Institute of Dental Research in the late 1960s Dr. Abner Notkins and his team unraveled the complex operations of the herpes simplex virus type 1, which causes cold sores.

Later Notkins and Dr. Bernard Moss of the National Institute of Allergy and Infectious Diseases developed a vaccine against HSV type 1. They constructed the vaccine by using recombinant DNA techniques to insert the gene for an HSV protein into vaccinia virus, formerly utilized in smallpox immunization. In 1985 the researchers reported that mice injected with the vaccine produced antibodies to HSV type 1, and almost 100 percent of them survived a normally fatal dose of the virus. The vaccine also prevented development of a latent herpes infection in most of the animals. A year later the vaccine still protected the animals from HSV type 1.



A researcher examining virus cultures.

PAIN RESEARCH

A swig of whiskey or its counterpart prepared American patients for dental surgery until anesthesia was introduced after the mid-1800s. Whereas mainstream British and French physicians withheld approval of anesthesia during surgery, Americans experimented and proposed its use after "laughing gas demonstrations" became the rage at young people's parties in the United States during the 1840s.

After witnessing the effects of laughing gas at a party, Dr. Crawford W. Long, a Georgia physician, in 1842 administered ether to a patient and successfully removed a tumor. But Long, who continued to use ether in his practice, never publicized this treatment.

"A New Era in Tooth Pulling."
The first dental operation performed on Horace Wells under the influence of Nitrous Oxid Gas, December 11, 1844. The above remark is attributed to Dr. Wells on recovering consciousness following the extraction of one of his upper wisdom teeth by Dr. John Riggs. The spectators are Gardner Q. Colton, Sam Cooley and the third is unknown.

A depiction of the painless extraction of the wisdom tooth of Horace Wells using nitrous oxide anesthesia.

Faced with daily encounters of pain associated with dental treatment, American dentists promoted the use of anesthesia. In 1844 Dr. Horace Wells, a Hartford, Connecticut, dentist, used himself as a subject by inhaling nitrous oxide before a former pupil extracted Wells' aching tooth. Other American dentists adopted Wells' technique and publicized the use of anesthesia for tooth extraction.

Local anesthesia came into use several decades later. Europeans first administered novocaine to block dental pain, and in 1910 Guido Fischer introduced its use for dental practice in the United States. Novocaine quickly became the most widely used dental painkiller.

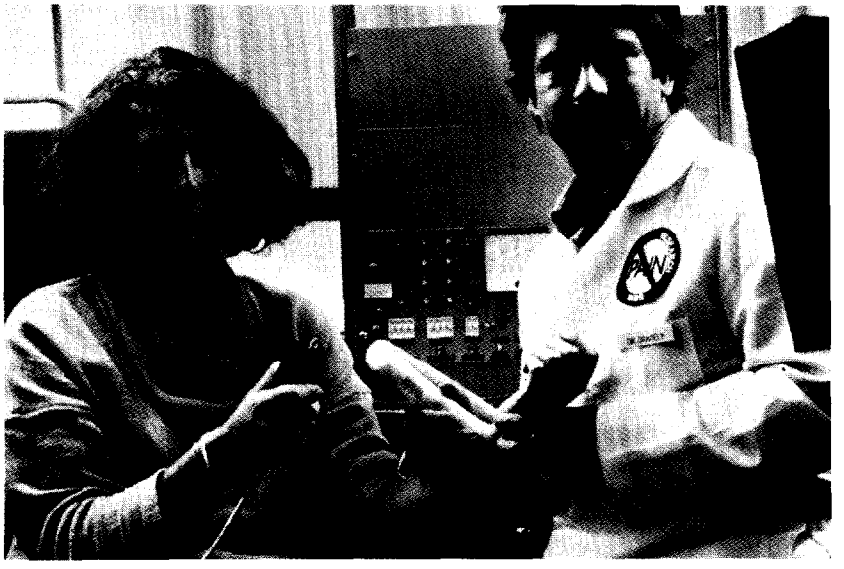
During the first three-quarters of the twentieth century the United States devoted minimal resources to pain research. A few universities, principally the University of Washington and Harvard University, conducted investigations. In 1975 American pain researchers helped found the International Association for the Study of Pain.

Although general anesthesia remained the method of choice for tooth extraction in the United States, American scientists experimented with other less potent means of reducing pain. During the 1970s NIDR researchers were the first to test the safety and efficacy of an intravenous administration of anesthesia that left patients conscious during surgery. Clinicians also tried a new technique known as TENS (transcutaneous electrical nerve stimulation) that suppressed some pain from certain kinds of nerve injuries.

In the 1980s NIDR investigators and grantees used an oral surgery model, the removal of impacted wisdom teeth, to find more effective combinations of drugs, such as flurbiprofen and etidocaine, to diminish postoperative pain.

Some of the most interesting discoveries about pain emerged from basic research after 1975. Investigations revealed that beta-endorphins, which are naturally occurring peptides in the brain, have opiate-like activity. Scientists at NIDR identified brain neurochemicals involved in pain transmission. They also found specialized receptors existing in skin that responded only to tissue damage and noxious stimuli.

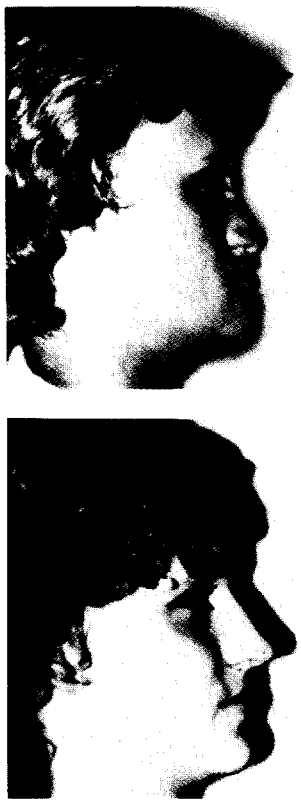
In 1983 the National Institutes of Health opened the nation's first pain clinic devoted entirely to research. The clinic, a multidisciplinary unit managed by NIDR, assumed responsibility for NIH research in the diagnosis, measurement, and pharmacological and non-pharmacological treatment of acute and chronic dental, cancer, arthritic, and diabetic pain. By 1987 NIH support of interdisciplinary pain studies had expanded to centers in seven universities located throughout the United States.



Thermal stimulation is being applied to a patient's arm in a study of pain perception at the NIH Pain Research Clinic.

CRANIOFACIAL ANOMALIES

Health experts estimated that during the twentieth century three-quarters of all Americans coped with dento-facial defects, ranging from faulty bite to cleft palate. In 1949 the most common facial abnormalities, cleft palate and/or cleft lip, appeared in 1 of approximately every 700 babies born in the United States. In cleft palate the roof of the mouth contains a break; this gap causes difficulties in chewing, drinking, swallowing, speaking, and hearing. The disfiguring cleft lip consists of a split in the upper lip.



Scientific progress has improved techniques for correction of structural and functional abnormalities of teeth and facial bones.

Until mid-century scientists concentrated on improving surgery and other treatment of the more serious craniofacial anomalies. Dr. Joseph Volker, dean of the University of Alabama School of Dentistry, and Dr. Seymour J. Kreshover, scientific director and later director of NIDR, promoted increased basic research on these abnormalities in the 1950s and 1960s.

American researchers suggested several possible causes of cleft anomalies. In the 1950s and 1960s scientists at the Henry Phipps Institute and NIDR found cleft palate in the offspring of laboratory animals with certain chemical substances in their systems during pregnancy. For example, pregnant rats injected with meclizine hydrochloride, an antihistamine taken for motion sickness, later bore progeny with cleft palate. By the 1970s laboratory tests indicated that a wide variety of chemical agents ingested at critical times during fetal development produced cleft palate in animals.

By the 1970s NIDR epidemiological studies had disclosed more information about the occurrence of cleft palate and cleft lip. These surveys produced no evidence that major environmental factors affected the prevalence of cleft lip and cleft palate, but results indicated that at least 25 percent of all clefts were related to hereditary factors.

American scientific progress by the 1980s also improved reparative techniques for victims with craniofacial abnormalities. Basic research on the relationships between natural and therapeutic stresses on facial bones enabled practitioners to create new orthodontic and orthopedic procedures. Studies at the University of Pittsburgh, for instance, showed that early surgery to correct cleft palate was safe and could prevent hearing loss if performed on infants at three months of age. Molecular biotechnology provided additional possibilities for facial and dental repairs with the discoveries of bone-inducing substances at the University of California at Los Angeles and NIDR. Indeed, with the flourishing of the biological sciences in the 1980s, the future looked brighter for the facially deformed and, for that matter, all those troubled with dental problems.

EPIDEMIOLOGY

Dentistry has benefited from the use of epidemiology, the study of diseases in large populations. Epidemiological studies of the incidence, prevalence and distribution of oral diseases were part of the early history of the National Institute of Dental Research when Dr. Albert A. L. Russell and his colleagues studied caries and periodontal diseases worldwide. Today the Institute and the National Center for Health Statistics sponsor national surveys to assess the nation's dental health. Epidemiology was instrumental in proving the value of fluoridation in controlling dental decay. Epidemiological work by NIDR dentists also helped determine the extent of periodontal diseases in children and adults and indicated the influence of heredity in cleft palate.

A 1980 caries prevalence survey conducted among the country's schoolchildren showed that new dental caries had decreased by more than 30 percent since 1973. In 1985 and 1986 NIDR undertook a dental census of 21,000 adults, a sample representing 105 million people. That survey revealed that toothlessness had declined dramatically from that measured in

a 1960 to 1962 survey. For example, in the earlier study 20 percent of persons from ages forty-five to fifty-four had no natural teeth; however, the 1980s survey showed only 9 percent in the same age group lacked teeth. NIDR conducted another survey of 40,000 American children from ages five through seventeen in 1986 to 1987. Representing the nation's schoolchildren, that study also showed another decline in dental decay among American youngsters, with 50 percent having no tooth decay at all.

BEHAVIORAL SCIENCES

In the 1970s the National Institute of Dental Research promoted behavioral science research to shed light on psychological, social, cultural and economic factors associated with oral diseases and disorders. Investigators studied the characteristics of preventive oral disease behaviors and strategies to promote oral health. Others studied means of overcoming dental fear and anxiety, particularly among children. Yet others directed efforts toward alleviating stress involved in certain dental conditions, such as bruxism, or teeth grinding.

Today a major effort is directed toward promoting health behaviors to avoid toothlessness among adults. Behavioral research focused on dental professionals' infection control practices and the public's behavior with regard to the prevention and management of oral manifestations of HIV infection is high on the list of priorities.

APPLICATIONS OF DENTAL RESEARCH TO NON-DENTAL PROBLEMS

As the volume of dental research grew after NIDR was established in 1948, scientists found that studies initiated to solve dental problems frequently contributed to knowledge in other scientific areas.

Basic research focusing on dental problems has contributed to the understanding of other biomedical problems.

In the 1950s NIDR launched genetics studies of interrelated families in Brandywine, Maryland, that eventually engaged six other institutes of NIH and public and private institutions in the Washington, D.C., area. These surveys provided valuable information on a variety of hereditary diseases and led to similar investigations elsewhere.

Law enforcement benefited also from the expertise NIDR scientists gained in using the electron microscope. Drs. David B. Scott and Marie U. Nylen, who became internationally recognized for their electron microscope tooth structure work, achieved fame as forensic dentists, sought by such agencies as the F.B.I. to assist in solving crimes.

Basic research, especially, contributed toward understanding other biomedical problems. Saliva studies of the 1960s and 1970s helped explain certain aspects of cystic fibrosis. Through 1960s investigations of collagen, a protein of connective tissue and bone, Drs. Jerome Gross of Harvard University and Karl Piez and George Martin of NIDR discovered how lathyrism, or poisoning from eating certain kinds of sweet pea legumes, caused victims to lose tensile strength. In the 1970s The Johns Hopkins University and NIDR scientists revealed defective or missing collagen in a number of connective tissue disorders, including Ehlers-Danlos IV Syndrome, a skin-stretching condition like that seen in circus rubbermen. Moreover, NIDR investigators working on tissue destruction, particularly chronic destructive periodontitis, found in the 1970s and 1980s that laboratory results could be applied to other chronic inflammatory diseases such as rheumatoid arthritis. In the 1980s NIDR scientists studying bone formation produced information relating to osteoporosis, a degenerative disease affecting primarily older women.

In the 1980s other fundamental investigations pertinent to dentistry also were related to various forms of diabetes. NIDR scientists studying the herpes simplex type 1 virus used that experience to shed light on the roles of a virus and heredity in juvenile diabetes. At the State University of New York at Buffalo, researchers found severe periodontal disease as a common complication of adult-onset diabetes.

Dental scientists also made major contributions to cancer research. NIDR investigators designed new, nontoxic drugs which, in experimental animal studies, block the ability of tumor cells to spread to healthy tissues. In addition, these scientists developed a laboratory test that can determine if a tumor is malignant and, if so, how quickly it is likely to spread. Further, this test can be used to screen the effectiveness of new anti-cancer drugs.

These far-reaching benefits of dental research reflected the integration of dental science into mainstream biomedical and behavioral research by the twentieth century.

SUGGESTIONS FOR SUPPLEMENTAL READING

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THE NATIONAL INSTITUTE OF DENTAL RESEARCH

Congress established the National Institute of Dental Research in 1948 to conduct, coordinate, and encourage research on dental diseases and disorders. Between 1948 and 1988 five directors and two acting directors have led the Institute: Dr. H. Trendley Dean, director from 1948 to 1953; Dr. Francis Arnold, director from 1953 to 1966; Dr. Seymour J. Kreshover, director from 1966 to 1975; Dr. Clair L. Gardner, acting director during 1975; Dr. David B. Scott, director from 1976 to 1981; Dr. John F. Goggins, acting director in 1982; and Dr. Harald Löe, the current director who came to Bethesda in 1983.

In its first year the Institute conducted important studies on fluoride and carried out epidemiological, biochemical, and histological research. NIDR supported intramural and extramural research on its initial budget of $465,000 with a staff of seventeen Civil Service employees, eight Public Health Service Commissioned Corps officers, and an ADA research associate and his assistant.

In January 1949 the National Advisory Dental Research Council, composed of dentists and scientists from outside NIDR, held its first meeting. The Council awarded eleven extramural research grants and ten dental research training fellowships during its first year.

Basic research at NIDR grew in the 1950s with the establishment of the laboratories of biochemistry, microbiology, and histology and pathology. In 1961 NIDR moved into its own laboratory building on the NIH campus. By 1964 NIDR had taken control of the dental care unit in the NIH Clinical Center.

Following a trend at NIH, the dental institute fostered fundamental studies in both the extramural and intramural sectors. In the late 1960s NIDR established and supported five regional academic dental research centers to encourage multidisciplinary approaches to dental problems. The NIDR staff also added new laboratories to increase basic research in soft tissues, biological development and anomalies, neurobiology and anesthesia, and immunology. In 1971 NIDR launched the National Caries Program, the first NIDR effort combining intramural and extramural research. Extramural periodontal research centers followed in the late 1970s.

NIDR also encouraged innovative means of research and increased clinical studies after the mid-1970s. The Institute introduced consensus development conferences in 1978 to bring experts together to exchange information and suggest future research. In 1980 the NIDR staff created a diagnostic systems branch to conduct research on noninvasive diagnostic methods. That same year it established a clinical investigations and patient care branch to facilitate the association between treatment and clinical research. In 1983 the Institute opened the first multidisciplinary pain clinic in the nation—combining the resources of basic researchers and clinicians to seek an understanding of pain and its mechanisms.

By 1987 NIDR had grown to a staff of over 350 with appropriations amounting to almost $118 million, including $24.5 million for 106 intramural research projects. Active extramural research grants numbered 727. Further, NIDR was sponsoring 54 active training grants, 67 fellowships, and 61 career awards to provide a well-trained dental research corps for the future.

Copies of this booklet may be obtained free of charge by writing to:

National Institute of Dental Research
Building 31, Room 2C35
9000 Rockville Pike
Bethesda, Maryland 20892

or

Chief, History of Medicine Division
National Library of Medicine
8600 Rockville Pike
Bethesda, Maryland 20894

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