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The Role of Medicine and Technology in Shaping the Future of Oral Health

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Abstract

This commentary describes the changes taking place in dentistry and speculates on improvements that could happen soon. Advances in health care will have an impact on the integration and delivery of oral care; conversely, there is growing acceptance that oral health impacts systemic health. Technological innovations are changing the face of medical care and are quickly becoming integrated into dentistry. Advances in novel antimicrobials, genomics, robotics and artificial intelligence are transforming our ability to diagnose and manage disease.

More than 10,000 years ago, a Sumerian found a better way. He invented the wheel, perhaps the world's greatest single technological achievement. Since then, millions of individuals — some celebrated and some unknown, some by design and some by accident — have found a better way. Thomas Edison found a better way – the incandescent lamp; Henry Ford – the mass-produced automobile; Alexander Graham Bell – the telephone; Alan Turning – the computer; Bill Gates – Microsoft Windows; Steve Jobs – the iPhone and iPad. The desire and the motivation to find a better way are integral parts of human nature. We Americans are known for our "Yankee ingenuity." We are a nation constantly striving to find, and sometimes obsessed with finding, a better way to do our jobs, teach our children, refine our

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goods, sell our products, interact with people, maintain our health, test our skills and stretch our endurance.

The history of dentistry is as ancient as the history of humanity and civilization.[1] Dental treatment has come a long way from the earliest known evidence of dentistry in 7000 B.C. with the Indus Valley civilization to current approaches and diagnosis and treatment. Over the past seven decades, we've gone from ignorance to understanding because of the standards and quality of education, our clinical efforts and scientific research. From a primitive form of medicine, the incorporation of modern-age technologies into dentistry within the last 50 years has accelerated this transformation.

Oral health in the 21st century is not just a "drill-and-fill" routine. While earlier efforts in dentistry conformed to removal of diseased tissue and restoration of lost tooth structure, newer advances are emphasizing prediction and prevention of the disease process.

Within our lifetimes, a sea of change in the knowledge and perception of dental diseases has occurred. Historically, oral health has been separated, clinically and administratively, from the overall health care delivery system; in recent times, there has been a major effort to incorporate oral health in overall health care diagnosis.[2] This is due to the realization that oral care is the gateway to prevention and early detection of many nonoral systemic ailments. In 2000, "A National Call To Action To Promote Oral Health," published by the surgeon general, called for "changing the perception" of oral health as separate from overall health and charged oral health and other health professionals to partner in research, treatment and policy efforts.[3]

There is growing evidence that oral health plays a significant part in development of systemic diseases like cardiovascular disease, diabetes mellitus, various cancers and dementia.[4,5] The surgeon general's office will issue a 2020 report on oral health to show us how we're doing and challenge us to new action.[6]

Although we live in one of the most technologically, medically and scientifically advanced societies, we clearly still have much work to do if we are to live up to our full potential. In this country, we still have more than 28 million citizens without health care coverage,[7] two out of three adults without dental insurance,[8] 37,000 new cases of oral cancer each year[7] and a continuing crisis in oral health.

As we move forward into an exciting decade of promise and change, we would like to encourage you — our best and brightest — to take on new challenges, to take some risks and to challenge the status quo.

As a society, we are in a flux due to the sweeping changes occurring in all aspects of life, including the health care industry, which will impact oral health as well. The emergence of new technologies, be it robotics, artificial intelligence, tissue and organ transplants, use of novel antimicrobials or even application of genomics to create personalized oral care, will have a lasting impact on patient care. The integration of dental practices with comprehensive medical teams — embedding dentists within a team of physicians, pharmaceutical providers

along with geneticists — would be a first step toward providing comprehensive diagnosis and treatment for all patients.

An obvious area where medicine can influence delivery of oral care is in personalized dentistry. The increasing availability of genetic testing and genome sequencing data and their relative affordability have opened many possibilities for the identification of novel markers for oral diseases through genetic sequencing. The option exists for adapting preventive oral care targeting individuals with higher genetic susceptibility or predisposition to certain oral diseases. Because most oral conditions are a result of genetic and environmental factors, a risk profile combined with other tools could be a useful predictive tool, which could influence treatment procedures and preventive care. The American Dental Association announced general guidelines for the use of genetic testing in dental practice.[9] So far, 13 genes have been identified as involved in the caries process, while 11 are implicated in the periodontal disease process. The day is not far when patients, alerted by the results from genetic tests for susceptibility genes, will bring the genetic analysis for counseling or treatment by oral health professionals.

> The surgeon general's office will issue a 2020 report on oral health to show us how we're doing and challenge us to new action.

A promising development where genomics overlaps with other areas of dentistry is in the use of salivary imaging and diagnostics employing novel salivary proteins, nucleic acids, metabolites and other markers for the early detection of both oral and nonoral disease.[10–14] The potential for correlating the profile of the microbial community (the microbiota) in our saliva with susceptibility to oral or systemic disease is intriguing.[15–17] Due to the ever-evolving nature of microbes and the desire to avoid abuse of antibiotics, novel antimicrobial therapies are being developed that rely on the use of naturally occurring salivary antimicrobial proteins like histatins, immunoglobulins and defensins.[18] In addition, the targeted delivery of antimicrobial proteins using salivary gland gene transfers is being considered.[19]

Advances in bioengineering to replace lost tooth structure or entire teeth are being made at a rapid pace. In groundbreaking studies, researchers created 3D printed tooth buds that show many similarities to natural tooth structure.[20] Other researchers developed a strategy that allows autologous mesenchymal cells derived from bone marrow to supply nerves to bioengineered teeth.[21] These exciting developments point toward a future where damaged teeth could be restored completely and biologically without the use of crowns and fillings.

Robots Are Coming for Our Jobs

With artificial intelligence, we will have better personalized health care, more efficient shopping, improved transportation, enriched entertainment and, in general, more creative jobs and less mundane work.

Workplace automation through robotics has significant advantages, but there is also skepticism in dentistry attached to their use to treat patients.[22] While robotics is employed in many medical and surgical procedures, dentistry is still in the early stages of robotics

for routine dental procedures. Thus, robotics is now used routinely in many dental clinics for digital impressions and digital milling. Robots are also being integrated in dental clinics for other procedures.[23] A company announced last year that it obtained approval from the Food and Drug Administration (FDA) to market a first-of-its-kind robotically assisted dental surgical system called Yomi. A design for robot-assisted dental surgery for 3D surgical planning and guided placement of dental implants already exists. In China last year, a robot dentist replaced a dental implant for the first time. A human programmed the precise measurements in order to ensure the implants fit correctly, but the robot did the physical work.[24]

There is also potential for predictable surgical and dental outcomes using end-to-end digitization and reduction of postoperative symptoms as well as patient management by programming machines to recognize signs of stress like pupil dilation, elevated blood pressure and tachycardia. Deep learning systems have already shown clinically acceptable performance for detecting diabetic retinopathy in a population-based screening.[25]

Advances in digital technology have already introduced computer-assisted designing and milling in everyday use in dentistry. While a few years ago the concept of same-day digital dentistry was treated as a novel concept, this improvement is now increasingly viewed as a standard inpatient convenience of modern dental practice. Digitization of health records is also having a major impact on standardization of care in both oral health and medical settings.

Coming to Your Office: "Alexa, Show Me the Bitewings of No. 20"

While the use of digital radiographs is a standard of care now, incorporation of artificial intelligence (AI) could be the next milestone in better predicting patterns of caries and other diseases.[26] With the ability to learn from past data, AI has significant potential in detecting and predicting caries in often-overlooked areas of radiographs or at least stages of caries. For many dentists, routine eye fatigue sets in after observing 10 to 15 black-and-white X-rays. This is where AI-based software can help the dentist, by training the software with stored images and replicating predictions in a standardized pattern for caries detection.[27] There are the advantages of speed, availability and elimination of bias using AI-based technology for radiographic detection, eliminating the burden on radiologists to read and interpret simple images.

> With the ability to learn from past data, AI has significant potential in detecting and predicting caries in often-overlooked areas of radiographs.

Among the most innovative predictive uses of AI are the integration of smart toothbrushes, which could analyze teeth as the patient brushes, check with cloud-based AI software against a database of images and alert the subject of either present or emerging teeth caries and cracks.[28] Furthermore, the subject could schedule the next dentist visit while brushing their teeth with a smartphone assisted by AI again.

Potential uses of AI could be in smart patient scheduling and communication through machine learning and booking appointments with patients directly.

Technology: A Game Changer in Orthodontics

Recent innovations in orthodontics include cone beam computed tomography (CBCT) and 3D visualization, intraoral scanners, facial scanners, instant teeth modeling software capabilities and new appliance developments using robotics and 3D printing. Digital technology has dramatically changed and will continue to change the nature of clinical practice and orthodontic education.

3D printing is one of the fastest growing digital technologies and allows orthodontists to develop and produce their own appliances (customized brackets, orthopedic appliances and clear aligners) with nearly limitless potential applications. Sensor technology can also be integrated in monitoring patients' compliance and optimizing tooth movements and bone remolding. The sensor chips can be integrated in brackets in the fixed orthodontic appliances and clear aligners.[29]

What About Training of Future Dentists?

Advances in AI have the potential not only to affect patient behavior and treatment, but also recruitment and training of our future dentists.

With the use of customer resource management (CRM) for student success, [30] there is already the possibility for developing a comprehensive recruitment and assessment tool for prospective students in general higher-education institutions. CRM would enable educators to learn and predict what is working and what is not working for individual students in dental schools. The education could be more personalized, tailored around the students' experiences and abilities. We could follow a student's progress from the start, analyze and advise the growth, spot weaknesses and help them achieve success.

Are We Ready for the Future?

Amplification of the flood of new discoveries in technology requires dynamic collaborations between basic and clinical research that can lead to clinical application. It is not hard to imagine a future when the patient will walk into a clinic and be treated as a whole being, starting with genetic testing and consideration of environmental factors to identification of predisposing genetic risks and nutritional counseling. The patient will be provided with a comprehensive oral and medical treatment plan, using AI to learn from the patient's past behavior and help to predict and refine future behavior, interactions and treatment.

One of the most serious challenges for the leaders in our profession is the imperative to motivate the unconcerned, the uninformed and the uncommitted members among us. We, as a profession, must find a better way to reduce barriers to care; a better way to fund education and student aid; and a better way to increase dental health care awareness and improve the dental health of all our citizens. We need to enhance our technology; enrich our educational programs; elevate our innovation and research, which has been the source of our excellence; and heighten the standards and quality of care, which have made our profession, because of its value systems, the envy of the rest of the world. Our profession must not restrict tomorrow's range of choices, and we must not dilute our capacity to solve tomorrow's

problems. We have the talent, ability and determination to pay the price in dollars, time and leadership to find a better way.

The power to shape the future is earned through persistence. The future for dentistry is not uncertain. The future is what we choose to make it. The decades ahead will be exciting, awesome, challenging and inspiring, and they are ours to shape.

The dreamers of a decade ago are considered realists in the present, and the dreamers will now usher in the future ■

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