

## SCIENTIFIC BASIS OF DENTISTRY

### *Diş Hekimliğinin Bilimsel Temeli*

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#### ABSTRACT

Technological and scientific innovations have increased exponentially over the past years in the dentistry profession. In this article, these developments are evaluated both in terms of clinical practice and their place in the educational program. The effect of the biologic and digital revolutions on dental education and daily clinical practice are also reviewed. Biomimetics, personalized dental medicine regenerative dentistry, nanotechnology, high-end simulations providing virtual reality, genomic information, and stem cell studies will gain more importance in the coming years, moving dentistry to a different dimension.

**Keywords:** Science; technology; clinical practice; dental education; biomimetics

#### ÖZ

Diş hekimliği mesleğinde son yıllarda teknolojik ve bilimsel yenilikler katlanarak artmıştır. Bu makalede, bu gelişmeler hem klinik uygulama hem de eğitim programındaki yerleri açısından değerlendirilmiş ve biyolojik ve dijital devrimlerin dişhekimliği eğitimi ve günlük klinik uygulama üzerindeki etkisi gözden geçirilmiştir. Biyomimetik, kişiye özgü diş hekimliği rejeneratif dişhekimliği, nanoteknoloji, sanal gerçeklik sağlayan üst düzey simülasyonlar, genetik bilgi ve kök hücre çalışmaları önümüzdeki yıllarda daha da önem kazanarak diş hekimliğini farklı boyutlara taşıyacaktır.

**Anahtar kelimeler:** Bilim; teknoloji; klinik uygulama; diş hekimliği eğitimi; biyomimetik



## Introduction

Dentistry, with its master-apprentice relationship, is a powerful art, and a profession that has a solid scientific and technological background. Dental profession has a long history which goes back to ancient times (1).

## History of dentistry timeline

Some dental studies were written before the beginning of the modern Gregorian calendar, or before Christ (BC). Hesy-Re, an Egyptian scribe, is accepted as being the first “dentist” (2600 BC). An Egyptian text, the Ebers Papyrus dated 1700-1550 BC, shows teeth and toothache. Between 500 BC and 300 BC, Hippocrates and Aristotle wrote about teeth, eruption, decay, and gum disease. Dentistry was first accepted as a profession in the middle ages. Barbers had undertaken this task before dentistry became a profession. A Guild of Barbers was established in France in 1210, and barber-surgeons performed routine hygienic services including shaving, bleeding, and tooth extraction. In 1530, first dental book for barbers was published by Artzney Buchlein in Germany. It was written for barbers who treated the mouth and contained practical topics including tooth extraction, drilling, and teeth filling. Professional dentistry began to develop in the eighteenth century and there were many advances in dental science in the nineteenth century. The first dental journal, the American Journal of Dental Science, began publication in 1839. The world’s first dental school, the Baltimore College of Dental Surgery, was founded by Horace Hayden and Chapin Harris in 1840, and its graduates was given the “Doctor of Dental Surgery” (DDS) degree. The school joined to Maryland University in 1923. The first professional organization of dentists in the United States of America (USA), the American Dental Association, was formed by 26 dentists in 1859. Harvard University Dental School, the first university-affiliated dental institution, was founded in 1867. The school calls its degree the Dentariae Medicinae Doctorae (DMD). There is continuing controversy with respect to the DDS and DMD. Dr. Robert Tanner Freeman graduated from Harvard University Dental School in 1869 as the first African-American to earn a dental degree, and Ida Gray, the first African-American woman to earn a dental degree, graduated from University of Michigan School of Dentistry in 1890. The first female dental assistant was employed in a dental office in 1885,

and the American Dental Assistants Association was founded in 1924 by Juliette Southard and her female colleagues. Although tubed tooth paste started to be manufactured in the 1880s, the widespread use of toothbrushing took place 10 years later. In 1890, Willoughby Miller, an American dentist in Germany, wrote a book entitled “Micro-Organisms of the Human Mouth” and explained the microbial basis of dental decay. From then, regular toothbrushing and flossing began.

After the discovery X-rays by the German physicist Wilhelm Roentgen in 1895, New Orleans dentist C. Edmond Kellstook the first dental X-rays of a living person in the USA in 1896. In 1899, Edward Hartley Angle began the first orthodontic studies in dentistry. In twentieth century, many innovations in techniques and technology were achieved. The scientific and technological developments in clinical dentistry increased with turning of the twenty-first century. Developments related to dentistry in the new century are now closely related with medicine (Table 1).

## Impact of biotechnology on research and clinical practice

Research in dentistry must be conducted according to the oral health needs of communities. This is ensured by biotechnological advances. As biomedical techniques evolve, the biomedical knowledge on vaccines, cloning, drugs, DNA, tissues, microorganisms, viruses, and complex proteins are rapidly increasing and contribute to improving human health (2). One of the most revolutionary techniques regarding nucleic acid analysis is the polymerase chain reaction (PCR), which is used to boost specific DNA fragments in order to detect particular proteins. Measurements can also be made quantitatively using real-time PCR. Gene expression analysis or microarrays can be used to estimate mRNA. PCR has become a standard diagnostic and research tool in dentistry. PCR is used in medicine to detect microorganisms and identify chromosomal disorders and hereditary diseases, for analysis of mutations in oncogenes and tumour suppressor genes, and in the detection and quantification of transcripts of tumour-associated translocations. The applications of PCR in dentistry include the detection of periodontal cariogenic pathogens, microorganisms in endodontic infections, viruses present in host cells, useful markers in the diagnosis and prognosis of some types of oral cancer, and the quantitative estimation of different microorganisms (3).

**Table 1.** Major innovations in 20<sup>th</sup> century and most promising fields of research in 21<sup>st</sup> century so far.

<b>Major developments in 20th century</b>	<b>Promising fields of research in 21st century so far</b>
New local anesthetics	Impact of biotechnology on research and clinical practice
Porcelain jacket crowns	The effect of advances in genetics on dentistry
First formal training for dental nurses	Studies related with dental pulp stem cells
Opening of oral hygiene schools	Biochemical developments in dental research
Development of the first successful biocompatible implant metal	Biomimetics in dentistry
Marketing of the nylon toothbrush	Personalized dental medicine
Water fluoridation	
The National Institute of Dental Research was established in the USA	
Development of the first system for bonding acrylic resin to dentin	
Development of laser use in the treatment of periodontal disease	
Development of composite resin restorative materials	
Branemark technique described for the osseointegration of dental implants	
Marketing of commercial home tooth bleaching products	
Approval of the erbium YAG laser by the Food and Drug Administration for treating tooth decay	

Many advances in oral bioscience stem from the “Human Genome Project,” which began in 1990 and was completed in 2003, and in 2007, when the salivary proteome was mapped (4). Along with the development of bioinformatics and in parallel with biotechnology, research about genomics (structure, function, evolution, and mapping of genomes), transcriptomics (the study of transcriptomes: the complete set of RNA molecules in one cell or a population of cells), proteomics (the study of proteomes: a set of proteins produced in an organism, system, or biological context), and metabolomics (the study of the set of metabolites present within an organism, cell, or tissue) have increased exponentially (2). Two important diseases that dentists encounter throughout their professional lives are periodontal disease and tooth decay. Bacterial, genetic, and environmental factors play a role in these complex diseases. Understanding these conditions at the molecular level using molecular techniques is necessary for their appropriate treatment. Some salivary tests have been developed to measure genetic susceptibility to periodontal diseases. Although various therapeutic approaches, including the use of recombinant growth factors, complete regeneration of lost periodontium has not yet been achieved (5).

#### **The effect of advances in genetics on dentistry**

Important progress in human molecular genetics has been reflected in dental treatments. Advances in oral bioscience from passive immunization for dental caries, induction of new bone and cartilage tissue, and regeneration of periodontal tissues, to the artificial synthesis of saliva for patients with xerostomia also came about courtesy of the Human Genome Project (6). These remarkable advances provide the basis for gene-based diagnostics and drug developments for the management of condition ranging from chronic facial pain, to osteoarthritis as related with temporomandibular joint disease, and osteoporosis associated with periodontal diseases (7). Genetic bioengineering will be more impactful on dentistry in the next few decades in ways that encourage the body to repair itself, rather than artificially placing extrinsic materials. Seeding genetically-developed pulpal tissue into the canal to grow and fill the chamber, triggering epithelial cells to form dentin and enamel, thus completing the biologic restoration of teeth will be enabled through genetic engineering techniques in the future.

### **Studies related with dental pulp stem cells (DPSCs)**

At the beginning of the twenty-first century, in the same way that stem cells can be used for the treatment of diseases from muscular dystrophy to the regeneration of brain tissue, the most important dental studies are those related with dental pulp stem cells. After the first discovery of DPSCs in 2000, many studies have been performed (8, 9, 10). The first human trial for cornea replacement in a rabbit model with human immature dental pulp stem cells (hIDPSCs) was conducted in 2010. Although various studies with hIDPSCs showed promising results in animal models, effective results have yet to be obtained in humans. The most important aim of scientists working in the dental field is to obtain good results, to heal periodontal tissue using stem cells, and to replace lost teeth using scaffold technology (11).

### **Biochemical developments in dental research**

Recently, biochemical studies have become an area of increasing importance in dental research, from dental pulp stem cells to synovial fluid analyses, in order to understand the etiology and pathology of temporomandibular joint disorders. Saliva is now an important biofluid for the early detection of diseases; rapid and sensitive analyses of saliva and crevicular fluid are used as important diagnostic tools (12, 13, 14) In fact, the recent development of saliva as a diagnostic tool has placed dentistry at the forefront of monitoring systemic health and disease. The use of gingival crevicular fluid is an important biochemical tool in the diagnosis of diabetes and other inflammatory conditions (15). Advances in the science and technology of miniaturization (nanotechnology) now enables a biochemistry laboratory on a miniature chip and these types of microfluidic chips have been widely used to analyze small-volume fluids. This “lab-on-a-chip” technology allows oral fluids to be used for diagnostic and prognostic purposes (16).

### **Biomimetics in dentistry**

Biomimetics is a field in which some chemical, biologic, and engineering principles are applied to the synthesis of materials that mimic biochemical processes. Some biomimetic products can be used in regenerative dentistry such as shallow dentin defects, bone substitutes, remineralization of the

tooth surface, and biofilm destruction. In contrast to traditional treatment principles, biomimetics align with the biology, function, and mechanics of natural teeth. Biomimetic dentistry is an emphasis of modern dental education (17).

### **Personalized dental medicine**

The concept of “personalized medicine” (PM) necessarily emerged because an individual’s response to treatment of disease depends on their genetic factors and individual behavior. PM facilitates the selection of optimal therapy with the highest safety margin, thereby reducing trial-and-error prescribing and increased adherence to treatment by patients (7). Genomic information plays an important role in PM and can be used in the practice of dentistry (2) by taking into account ethical and legal obligations. Genome-derived information of a patient can help physicians understand the disease etiology and permit earlier diagnosis. Applying preventive dentistry rather than treating disease is made possible by using genomic tests. Also in orthodontics treatment, genetic and environmental (including treatment) factors (nature and nurture together) should be considered to ensure better results. “Regenerative dentistry” has progressed through the innovations in new diagnostics (17). In the future, analyzing “personal genetics” may determine the most effective treatment options in dental practice; for example, filling materials may be able to regenerate decayed teeth.

### **The effects of scientific developments on dental education**

#### *History of dental education*

Changes and innovations parallel to technological developments have occurred in dental education. After the second half of the 16<sup>th</sup> century and at the beginning the 17<sup>th</sup> century, there were many advances in dental education (1). The publication of the first textbook on dentistry in Leipzig (1530), and identification of microorganisms in material scraped from teeth by van Leeuwenhoek (1683) both occurred during this period. Later, the first American dental school was founded in Baltimore by four physicians (1840), and institutional dental education began in the USA after the medical department of the University of Maryland refused a request to include dental education in its curriculum (18).

After Harvard started the first university-based dental department in close association with medical department in 1867, much research was performed related with dentistry. Data were published indicating the infectious basis of tooth decay (1891). In 1926, the tenth in the series of Carnegie reports on dental education was written and published by William Gies, a Columbia University biochemistry professor with a particular interest in dental research. It was the first comprehensive report for dental education that took five years to research and write, and consisted of 250 pages of text plus more than 400 pages of appendixes. Gies, forcefully supported a strong basic science education and almost certainly encouraged dental schools to strengthen this aspect of their curriculum.

It was proposed in Gies's report that dentistry should be an independent part of health services in universities, and it should receive the same quality of consideration and support as medicine (18). Additionally, Gies supported hospital internships and a broad array of graduate specialty programs. The suggestion of Gies that predoctoral education should emphasize general practice and early specialization still maintains its validity today. Twenty-five years after Gies's report, recognized specialties in dentistry included dental public health (1950), endodontics (1963), oral and maxillofacial surgery (1947), oral pathology (1949), orthodontics (1947), pediatric dentistry (1947), periodontics (1947), and prosthodontics (1947). Dental school accreditation standards were published by the American Dental Association (ADA) council in 1941. In 1980, the Kellogg report on advanced dental education was published. The Dentist Scientist Award, founded in 1984, sponsored individuals in a five-year dental education and research training program that went on to doctoral degrees in basic sciences. In Turkey, developments in dental education closely followed those in the world. The first dental manuscript book in Turkey was published (19) by Dr. Musa Bin Hamun (1490-1554) before the first American book on dentistry (1801). The first Turkish dental school was founded in Istanbul in 1908, later becoming Istanbul University, Faculty of Dentistry. In Europe, the origins of formal dental education were more diverse. Dental schools were founded as separate schools, especially in northern Europe, whereas in southern Europe they were a discipline in medical schools.

### **Scientific and technological developments in dental education**

Dentistry is unique in that undergraduate dental students require competence-based clinical skills that can only be acquired through specialized laboratory training and direct patient care. The necessity of patient care in the undergraduate period requires that all students have professional and scientific knowledge, which is supported by "new science" that forms the clinical skills. Scientific advances in molecular biology, biomolecular sciences, stem cell technology, regenerative technology, genomics, proteomics, and tissue engineering all provide the basis for new technologies in dentistry (20). Scientific and technological developments in dentistry should be evaluated for the educational program as well as for the clinical program. Research-based education is realized by including biomedicine and biotechnology in the dental curriculum. Research outcomes should also be included in patient care. Supporting student research projects is one way of achieving this goal (21). The encouragement of student involvement in research projects is fundamental for dental education. Iacopino *et al.* (22) supported students' research projects and emphasized its importance for the future of academic dentistry. Some dental faculties have arranged "Student Scientific Days" when they present their research projects. These meetings have been arranged regularly since 1993 in Istanbul University, Faculty of Dentistry. In the study of Guven and Uysal (23), students also believed that their participation in this activity positively affected both personal development and academic success. Students' research projects, by developing these skills, are an integral part of dental education (24-26). According to the study of Henzi *et al.* (27), teaching and testing that focused on memorization was found to be a weakness of a dental faculty. Activities such as research projects in which students are actively involved replaced memorization methods and provided opportunities to them to use their knowledge in practice. Working on problems using an evidence-based dentistry approach also developed students' analytical skills. Lantz and Chaves (28) reported that biotechnological developments must be included in the dental curriculum and be taught to students at the highest level such that they can use this information in connection with health-related issues throughout their professional lives. Students should learn the concepts of science and use scientific methods such as critical thinking skills and clinical

judicial development tools. Students need to have sufficient knowledge in epidemiology, bioinformatics, molecular medicine, dentistry, and bioengineering to adopt new evidence-based preventive strategies, and diagnosis and therapy methods (29). Over the last 80 years, biomedical science evolved from a single discipline to a multidisciplinary approach in biological, digital, and nanotechnology fields in health science education (30). Biomedical sciences are necessary to understand different subjects, from human genes and functions, to communities and health differences.

In order for students to gain the competencies related to diagnosis, treatment, and prevention of oral diseases, the traditional approach must be changed and molecular biosciences and technologies should be embedded into curricula. These include biotechnology (gene therapy, drug delivery, transport dynamics), molecular engineering (macromolecular structure, protein structure, and molecular therapies), informatics (patient management/record systems, data mining/management applications, and simulation/computer-assisted learning environments), and biomaterials (biocompatibility, bioengineering applications of polymers, biomimetics, implant materials, and nanotechnology of dental materials) and named as "New science" (20). The oral health of an individual is now considered to be closely related to overall health. Dental students must therefore be equipped with information about human genetics and the current principles of molecular medicine. Dental curricula and faculty development programs have to be restructured in such a way as to compensate for the lack of genetic training. The future dentist has to be highly equipped with technology, have the ability to use social media, be able to solve problems through evidence-based dentistry and more as oral physicians. Most dental patients have some medical problems and they expect their care to be up to present standards of science (31). Dentists may be the first physicians to reveal the general health problems of patients. On the other hand, the attention of dentists to the medical problems of patients as well their dental treatment positively affects the patients' viewpoint towards dentists and increase their confidence. Educational systems change (32). Dental schools needed to strengthen the culture of a scientific approach to education and health care provision. The modern dental education model is learning-based, problem-oriented, and independent from disciplines, a vertically and horizontally integrated subject. As well as in learning and teaching,

there should be an integrated approach to patient care. The success of this type of educational model is in the acquisition of competencies, which are reflected in attitudes and behaviors as well as deep knowledge. This helps in the long-term retention of knowledge for future application. In contemporary dental education, high-end simulations that provide virtual reality, haptic trainers, 3D atlases, e-textbooks, learning management systems and student response systems, and Information and Communication Technology (ICT) are used effectively. Use of ICT will be the key for success of dental institutions in the future enabling reuse of clinical data and application of advanced methods in dental research. Graduates should be equipped with tools to evaluate the literature and scientific innovations. Research should be considered a part of experimental learning. The results of research in dental faculties should be reflected in dental education (29, 33, 34). Evaluation methods such as objective structured clinical examinations and portfolios will enhance students' future problem solving and critical thinking skills. The accreditation of dental schools plays a role in increasing the quality of dental education and is required in order to produce future leaders (35). In the USA, accreditation standards for dental education were revised in 2016 and published by the Commission of Dental Accreditation of ADA (36). Accreditation criteria were created for European dental schools by the Association for Dental Education in Europe (ADEE). These foundations are independent organizations representing academic dentistry. Their aim is to foster convergence and to promote excellence in dental education. The ADEE, by forming the DentEd Project, detected strengths, weaknesses, and identified best practices of dental schools. School visit programs by the ADEE prepare dental faculties for accreditation (37).

### Conclusion

As a result, it can be stated that world scale innovations in educational models have caused systemic changes contributing to the advancement of dental education. Since characteristics of scientific and technological developments, as well as their repercussions on dental education, will always be of utmost importance in modern dentistry, rapid integration of innovations into the dental curriculum plays a key role in reaching higher standards in patient treatment and disease prevention.

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**Conflict of interest**

None declared.

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