Digital Revolution: Informatics for Oral Healthcare Profession

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Abstract: **- The science of informatics has transformed the healthcare profession by the extraordinary revolution in information technology, and continues to do so. Oral health profession is no exception to this and the discipline of dental informatics is influencing it in clinical care, education, and research. The scope of dental informatics has not yet been extended to the use of artificial intelligence expert systems in diagnosis and treatment plan, effective tutoring systems, and continuing dental education programmes and research. The exchange of information among different healthcare professionals through networked computing is bringing the world together as a true global village. This can help in improved communication among experts, besides forming an interdisciplinary collaboration. Dental teaching institutions need to reshape the dental curriculum encompassing the science of information technology (IT) and informatics to better equip students in their ability to use IT tools in their training as well as future clinical practice and research endeavours. Dental informatics is of enormous benefit to research in dentistry, which only indicates the tremendous changes it can impart to clinical care as well as educational research. Hence, it is inevitable to continue to embrace dental informatics effectively in all spheres of oral health education, research, and clinical care.**

Key words: dental informatics, information technology, artificial intelligence, clinical care, research, dental education.

I. INTRODUCTION

The progress in the field of information technology and scientific discoveries are paving the way to unraveling the mystery of the human body. The era of information and knowledge revolution is augmenting the skills to understand health and untangle the enormous knowledge being generated and recorded at an exponential rate. Human knowledge is doubling every 10 years (1). This development is continuous and dentistry has to cope with these technological advancements by adopting newer contemporary approaches. The approach of dentistry in understanding oral health and providing better clinical care should also be extended to research and dental education. The younger generation of dental students use the available tools and skills of information technology (IT) to mainly retrieve information because these developments in information technologies have not been effectively incorporated in dental training to guide them into the how and why of managing information by the dental teaching institutions. In simple words, the what, how and why of managing information technology is informatics, which is more crucial than mere use of technology (2). Hence, the science of informatics should be utilized effectively in providing better clinical care as well as in research and dental education. Incorporating informatics in the dental curriculum will help students to understand and use IT effectively in their future clinical care and research activities.

II. EVOLUTION OF INFORMATION REVOLUTION

Digital revolution is the third great revolution in the history of the world. First was the Neolithic Revolution in agriculture. Second was the Industrial Revolution of the nineteenth century, which saw the substitution of human muscles by mechanical processes.

The third major revolution is the so-called ***Digital or Information Revolution*** in which electronic circuits substitute human mental skills. The impact of IT on scholarly collaboration was responsible for this great revolution which progressed through three stages of connectivity: electrical connectivity, software and data connectivity, and *information connectivity*.

Information connectivity, through networked computing (Internet) is a robust and pervasive electronic infrastructure, coupled with software and data architectures. This advancement has been greatly utilized, especially by the newer generation (2, 4), and the dental faculty needs to adopt this contemporary technological advancements to understand how student training works in this age (2).

III. DENTAL INFORMATICS AS A DISCIPLINE

The world's first electromechanical digital computer was developed by Konrad Zuse in 1941 followed by Maichly and Eckert's Electronic Numerical Integrator and Calculator (ENIAC) of 1946, the invention of the transistor at the Bell Labs in 1948, and the development of the electronic core memory by An Wang in 1949. Concurrent with the development of computer hardware, information science,

computer science, and telecommunications evolving as core research fields contributed to the computer revolution (5, 6).

In the 1960s, ***"informatics"***emerged as a distinct concept. Aleksei Mikhailov, at the Moscow University, first defined the term as a discipline that *"studies the structure and general properties of scientific information and the laws of all processes of scientific communication"(7).*Concurrently, the evolution of dental informatics took place illustrating the growing potential of this field in dentistry (7). Individuals, who had been trained in dentistry and other disciplines such as engineering, collaborated with other professionals such as computer scientists to better apply the science of informatics in dentistry.

IV. DEFINING DENTAL INFORMATICS

According to Merriam-Webster's Collegiate Dictionary, informatics is derived from the term "information science", which is a collection, classification, storage, retrieval, and dissemination of recorded knowledge treated both as a pure and applied science. When applied to a specific domain, such as medicine, nursing, or dentistry, information science becomes "informatics".
The existing definition of medical informatics shares several common elements (7, 8):

Universality- Informatics is viewed as applicable to all activities in the domain, such as research, education, and patient care.

Goal- Most definitions cite the improvement of patient care as the goal of medical informatics.

Science- Informatics is a basic and an applied science, that is, a continuum spanning model formulation, system development, system installation, and the study of effects.

Multi-disciplinarity- Aside from domains such as medicine or dentistry, informatics is composed of several constituent disciplines, such as computer science, information science, cognitive science, and telecommunications. Dental informatics can be considered a specialty of biomedical informatics. These two disciplines can share, transfer a number of models, methods, and applications. For instance, in the National Library of Medicine, MEDLINE and GenBank are the biomedical literature databases and gene and protein databases, respectively. These databases are also applicable to dentistry, besides providing a portal for researchers from all disciplines to contribute (7).

V. APPLICATION OF DENTAL INFORMATICS

Oral healthcare professionals should understand and recognize the potential of dental informatics and IT in oral health education, patient care, and research settings. The following segments discuss the existing scenario of application of dental informatics and propose certain approaches to apply effectively informatics science to dentistry.

Clinical care
As the patterns of oral diseases are continuously changing, dental care has now become more complex and informatics is an effective science to rely on. A new paradigm for clinical care, embracing informatics includes: development and maintenance of computer-based patient records, full use of expert systems and artificial intelligence in diagnosis, treatment and prevention of oral diseases, and improved communication between various professional elements based on electronic links

Computer-based patient records
Computer- based patient records not only offer a theoretical construct for oral care, but also present complex obstacles in their implementation (9, 10). Yet, computer-based patient records have the potential to change the delivery of oral healthcare and will continue to do so in the future by intimately connecting doctors, patients, institutions, and systems. The definition of computer-based patient record (CPR) developed by the Institute of Medicine of The National Academy of Sciences shows why:
"The future patient record will be a computer-based, multimedia record capable of including free text, high-resolution images, sound (eg, auscultation), full-motion video, and elaborate coding schemes. CPR systems will offer access (availability, convenience, speed, reliability, and ease of use), quality, security, flexibility, connectivity, and efficiency. In addition, future patient records will provide new functions through links to other databases and decision support tools".
CPRs are not without limitations and design flaws in its application in private practice and dental teaching institutions. Landmark publications in medicine have articulated how electronic records could improve clinical care (11, 12, and 13). A recent report of the National Research Council (13) recommended, among other things, that electronic patient records should be designed for human and organization factors and should support the cognitive functions of all caregivers, including health professionals, patients, and their families. Clinicians and patients should seriously consider these recommendations to make better use of the electronic records.

Use of Expert Systems and Artificial Intelligence in Diagnosis, Treatment, and Prevention of Oral Diseases
Artificial Intelligence (AI) is the field of computer science that seeks to implement computer-based technology that can simulate the characteristics of human intelligence (14). This broad scope includes computer vision, expert systems, game playing, general problem solving, machine learning, natural language, pattern recognition, robotics, speech recognition and synthesis, and theorem proving. These diverse subjects have in common the premise that the computer assesses raw

information and makes some decision. Large amounts of specialized factual and empirical knowledge provide best solutions for the AI systems in diagnosis (15).

An expert system in the computer software attempts to act like a human expert on a particular subject area. It uses the knowledge base of human expertise for problem solving, or to clarify uncertainties where normally one or more human experts would need to be consulted (16). These computer programs attempt to incorporate skills or attributes usually thought of as intelligence when observed in humans, e.g., making a diagnosis (14). Their ultimate goal is to add value to information. These computer programs contain a knowledge base of expertise capable of reasoning at the level of an expert.

The central aim of the decision- support program is to improve the quality of patient care by assisting the clinician to make better decisions. It is a challenge for any clinician to keep abreast of the ever increasing generation of new information. Decision-support systems may provide a mechanism whereby this information is made functionally available to the general practitioner. If the decision-support systems are to be useful, they must provide generalist recommendations that have sensitivity and specificity accuracy rates equal to the expert (14). The cost of unnecessary tests and consultations and the duration of hospital stays may reduce considerably if such programs are successfully executed.

All decision-support systems contain a store of medical knowledge. The program also must contain a module to collect specific information regarding the signs and symptoms of the patient in question. This process may be passive (requiring the clinician to take the initiative to use the system) or it may be active (automatically using data from an electronic data record). Another important ingredient in the program is an inference engine, which matches what is known about the patient to the program's store of information to arrive at a diagnosis.

The most common means of data analysis used in decision-support systems to link patient information to the store of medical knowledge are: Algorithmic Systems, Statistical Systems, Rule-based Systems and Neural networks(15). Increasingly, large decision-support systems are using both probabilistic (statistical systems like Bayesian classification) and rule-based techniques.

Development of decision- support systems in dentistry has employed all major types of decision-support system designs. The fields of dentistry where these decision-support systems are commonly developed and used (15) are dental emergencies, orofacial pain [IMPATH:TMJ, RHINOS (Rule-based Headache and facial pain Information Organization System)], oral medicine (Diagnostic Aid Resource Tool, Differential Diagnostic Assistant for Soft Tissues, OralCDx), radiology [ORAD, CAREOP (Computer Assisted Radiographic Evaluation of Oral Pathology)], COMRADD (Computerized Radiographic Differential Diagnostic system), Logion Caries Detector Program, CADIA, Tuned Aperture Computed Tomography (TACT), orthodontics (Slavicek analysis), restorative dentistry (RaPiD, MacRPD, virtual articulator), impression taking, and surgical evaluation (stereolithographic methods, videofluorography, spiral CT, MRI).

Developing such useful programs help reduce the psychological barriers as well as logistical costs, which benefits dentistry by efficiently collaborating with other fields in the future. Effective use of information from interdisciplinary fields by artificial intelligence decision-support systems may lead to successful clinical practice.

Improved communication between various professional elements based on electronic links

Numerous opportunities for communication between various professional elements are possible because of the World Wide Web and networked computing (Internet). The Internet is an effective resource for accessing current and relevant information that will support patient care. Oral healthcare professionals are required to communicate regularly with other members of the healthcare professions, patients, and payers. The communication tools of Internet may help provide ways to reduce professional isolation, promote information exchange, increase the diffusion of innovations, strengthen individual skills and knowledge, and heighten standards of care (17). Service and requirements of Facebook is also explored for its usefulness in establishing scientific collaborations (18).

Research

Recent scientific and technological advances have combined with new information technologies to reveal the needs of dental research and patient care. During the past decade, advances in information technology have increased ~~the~~ computer speed. These accelerating advances in information technology are having a parallel impact on the technologies used to conduct dental research, and consequently, on the methods and materials used to provide oral healthcare to patients. The impact on dental research has helped increase our knowledge of dental caries, oral candidiasis, periodontal disease, and other oral health diseases, in addition to helping map the human genome (19, 20, 21, and 22).

Besides, traditional dental research, biomedical informatics is also advancing educational and clinical research. Biomedical informatics supports educational research through simulations of biological systems to improve the understanding of the roles and interactions of biological systems for students and practitioners. Robotic devices simulate sensing and manipulation for expert clinicians and new software has been developed for dental and professional education and assessment of competence (20). Biomedical informatics also supports research to improve diagnosis, patient care, and patient care management. Intra-oral cameras and digital radiography enable practitioners to store and retrieve, manipulate, and analyze visual patient information.

Biomedical informaticians help in creating databases and knowledge bases by means of working on diagnostic codes

and assessing outcome data for patients. Standard vocabularies and structured representations of data and knowledge are being created so that these can be exchanged person-to-person, person-to-computer, and computer-to-computer. Collections of information stored in databases are being developed along with the knowledge gained from these data (knowledge bases). These databases and knowledge bases are ~~being~~ used to assist other researchers, such as the caries research performed by a geneticist. The scope of informatics on research is tremendous, and hence, it begets a dental researcher to have adequate training in informatics to use effectively IT tools to stimulate research activities. There also exist challenges to use information technology in research, which require different approaches to simplify the complexity of research by using IT support (2).

Education

Computers and the Internet are revolutionizing the process of education at all levels. Besides, being a key tool in the educational process, computers are also making education available in places and at times in which it was previously inaccessible. Students in the health profession now dissect cadavers on the computer screen, prepare teeth with real time feedback from a computer, and practice surgical procedures on simulators (23). Distance education makes single courses and whole degree programmes available anywhere and at anytime.

The trends of dental informatics, which can reshape dental education and continuing education, have been explored in previous reports (24, 25, 26, and 27). Certain trends predicted (7, 29) were increasingly realistic in learning aids, intelligent tutoring systems, and the merging of learning systems with clinical decision support. For instance, in a virtual reality environment, the human heart can be observed not only statically, but also in function. Such realistic learning systems can make the content come alive and improve the students' comprehension.

Continuing dental education on the World Wide Web

Continuing dental education (CDE) is a requirement for dental practitioners and dental hygienists. These requirements can be fulfilled in various ways, including attending lectures, reading journal articles, listening to an audiotape, viewing a videotape, and completing a course on the World Wide Web. CDE courses offered on the Web have the advantage of being completed at the practitioner's convenience and paid for using an available computer and Internet connection, without the costs of closing the office and travel. Increased and convenient access combined with reduced costs may explain the growth in Web CDE (29, 30).

An important pioneering application in dental education is the emergence of E-textbooks. As biomedical and dental literature is inevitably generated and stored digitally, the move towards e-textbooks has become unavoidable. Many other technologies, such as intelligent tutoring applications (31), student response systems (32), and lecture recording and broadcasting (33) have reshaped the dental education landscape already and will continue to do so (2). Apart from using technological tools, it is imperative that dental teaching institutions adopt strategies to include information technology and informatics effectively into the dental curriculum. Such curricular reforms will help incorporate newer scientific advances to equip students with informatics skills to induce future research activities. Recommendations to restructure the curriculum to improve academic vitality have been proposed previously, which will help train the next generation of academicians and researchers (34, 35). New curricular models will need to address the in-terdisciplinary integration of new scientific advancements within the broad oral health environment (36, 37).

The limitations in implementing informatics in oral healthcare profession are several, which may best be perceived as challenges to overcome in the near future. The required investments in implementing informatics infrastructure in dental hospitals, teaching institutions, and private clinical practice are tremendous, in terms of money, training, operation, maintenance, and clinical and administrative changes. Adopting CPRs in dental hospitals is yet to be seen in its complete sense, especially in developing countries. Even in private clinical practice, dentists are constrained by limited financial resources as well as problems with staff training and compliance, and reliability problems with equipment and software. Another major setback is the perceived threats to privacy and confidentiality of personal health information. Personal health record systems are growing parallel to CPRs and increased efforts are made to address security issues regarding wireless transmission of patient medical data and its security, integrity, and confidentiality (38). Both, technological and ethical concerns of using information technology in dentistry are to be addressed for effective implementation in areas of education, research, and clinical care.

VI. CONCLUSION

Oral health profession should embrace informatics to fully realize the digital revolution of this era and engage actively in incorporating the science of informatics into clinical patient care, research, and education. The newer advancements in information technology coupled with complex computational problems will render the inclusion of such tools effectively into the dental profession, including curricular reforms in teaching institutions (2). Hence, the dental profession should effectively develop a conducive atmosphere, both in clinical care as well as in dental teaching institutions, to go beyond traditional methods of teaching and operational set-ups, to more contemporary methods using the expertise of dental informatics. Dental informatics, by its own nature, inevitably employs an interdisciplinary approach, which will profoundly help create the next generation of students to be better equipped to pursue their academic or research

interests as well as foster a capacity to excel in clinical care with robust technological knowledge and skills.

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