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Electronic Dentistry: An Essential Shift of the Future

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Abstract

Electronic Dentistry is an exciting and relatively new field of dentistry that fuses electronic health records, telecommunications technology, digital imaging, and the Internet to link health providers in rural or remote communities. For the patient located in underserved or remote areas, Electronic Dentistry improves ready access to preventive dental care and tele consultation with specialists. It allows the dentist in the nearby community to provide easier access to preventive care to a patient who, otherwise, probably will not seek care. Most dentists and dental educators are unaware that Electronic Dentistry can be used not only for increased access to dental care, but also for advanced dental education. This review discusses the history, scope, and applicability of electronic dentistry by considering the literature from various sources. This is an attempt to reinforce the awareness on electronic dentistry among the dental practitioners in developing countries.

Keywords: *Education; E-health; Tele consultation; Electronic dentistry; Tele Health*

Introduction

Dental care is being constantly transformed by the opportunities which are provided by technology and telecommunication. Dentistry, in a synergistic combination with telecommunications technology and the Internet, has yielded a relatively new and exciting field that has endless potential called "Electronic Dentistry" [1]. Due to the enormous growth of technological capabilities, electronic dentistry possesses the potential to fundamentally change the current practice and the face of the oral health care [2]. Electronic dentistry is a combination of Electronic communications and dentistry, involving the exchange of clinical information and images over remote distances for dental consultation and treatment planning. According to a review by Yashinaga, the term "Tele dentistry" was first used in 1997, when Cook defined it as "the practice of using videoconferencing technologies to diagnose and provide advice about treatment over a distance" [3]. It has the ability to improve access to oral healthcare, improve the delivery of oral healthcare, and lower its costs. It also has the potential to eliminate the disparities in oral health care between rural and urban communities. Many years ago, how telephones affected people, in the same way within next 10 or 20 years electronic dentistry will be a routine of life. What was considered relatively distant future some 20 years back is the reality today in dental clinics. Electronic dentistry is not scary and complicated. We can easily learn electronic dentistry, if we know how to turn on a television or how to make a phone call or how to fax a document [4]. The referring dentist logs into a secure web server and fills in the patient's details, the specific reasons for the consultation, the chief complaints, and the provisional diagnosis information and attaches the digital intraoral images and the scanned digital dental radiographs. The specialist subsequently logs into the secure web server, reviews the case and suggests his diagnosis and treatment plan within a limited period [5]. Electronic dentistry is implemented in some developed countries [6] and needs to be encouraged and implemented on a priority basis in India due to lack of specialist dental manpower and an extensive underserved population. This paper reviews the history, scope, and applicability of electronic dentistry. This is an attempt to reinforce the awareness on electronic dentistry among the dental practitioners in developing countries.

Method and Source of Information

Relevant research concerning Electronic Dentistry was identified by searching the biomedical databases for primary and secondary research.

Materials

The databases were searched for publications with key articles obtained primarily from MEDLINE. In order to ensure that relevant studies were not missed, the search terms remained broad. These were electronic dentistry, tele health, e-health, tele consultation, education anywhere in the title or abstract.

The literature reviewed in the present work is obtained from the following sources:-

a. Published articles
b. Unpublished literature
c. Internet news clippings
d. Online manuals and books
e. Thesis and
f. Government projects.

The literature from these sources was thoroughly scrutinized by the authors and relevant information from these sources was considered for discussion in this paper.

History of Electronic Dentistry

The initial concept of Electronic Dentistry developed as part of the blueprint for dental informatics, a new domain combining computer and information science, engineering and technology in all areas of oral health, which was drafted at a 1989 conference funded by the Westinghouse electronics system group in Baltimore. Its focus was a discussion on how to apply dental informatics in dental practice. Electronic dentistry was put into practice in US army in 1994 by doing dental consultations on persons located more than 100 miles apart. Since then, various institutes and organizations have practiced electronic dentistry with varying degree of success [6].

Types of Electronic Dentistry

Tele consultation through Electronic Dentistry can take place in either of the following ways-"Real-Time Consultation" and "Store-and Forward Method." Real-time consultation involves a videoconference in which dental professionals and their patients, at different locations, may see, hear, and communicate with one another. Store-and-forward method involves the exchange of clinical information and static images collected and stored by the dental practitioner, who forwards them for consultation and treatment planning. The patient is not present during the "consultation" [7]. Dentists can share patient information, radiographs, graphical representations of periodontal and hard tissues, therapies applied lab results, tests, remarks, photographs, and other information transportable through multiple providers. This data sharing can be of extreme importance for patients, especially those in need of specialist consultation. A third method has also been described, known as "Remote Monitoring Method," in which patients are monitored at a distance and can either be hospital-based or home-based. A "Near-Real-Time" consultation has also been mentioned in the literature, which involves low resolution, low frame rate product that looks like jittery television [8].

Requirements to practice Electronic Dentistry

For most dental applications, store-and-forward technology provides excellent results without excessive costs for equipment or connectivity. A typical store-and-forward electronic dentistry system consists of a computer with substantial hard drive memory, adequate RAM, and a speedy processor; an intraoral video camera and a digital camera for the capture of pictures; a modem and an Internet connection. A fax machine, a scanner, and a printer may also be required in some cases [9]. To enable live videoconferencing, one might employ a widely available standalone IP/ISDN videoconferencing solution or install a PCI codec board into the system. If a live group session is desired, a multipoint control unit that bridges three or more parties is required. The codec must be able to accommodate audio and visual functions [10].

Scope of Electronic Dentistry

Electronic Dentistry has the ability to improve access to oral healthcare, improve the delivery of oral healthcare, and lower its costs. It also has the potential to eliminate the disparities in oral healthcare between rural and urban communities. Dentistry may turn out to be expensive, as well as the fastest, way to bridge the rural-urban health divide and also can help to bring specialized healthcare to the remotest corners of the world [11]. Lienert., *et al*. [12] found that tele medical services were helpful for cases related to dental trauma in a Swiss Tele medical Center and provided valuable support for its cost-effective specialist dental consultations, where a specialty dentist was not available.

Inter professional communications will improve dentistry's integration into the larger healthcare delivery system. The use of electronic dentistry for specialist consultations, diagnosis, treatment planning and coordination, and continuity of care will provide aspects of decision support and facilitate a sharing of the contextual knowledge of the patient among dentists [13]. Second opinions, preauthorization, and other insurance requirements will be met almost instantaneously online, with the use of real images of dental problems rather than tooth charts and written descriptions. Electronic dentistry will also provide an opportunity to supplement traditional teaching methods in dental education and provide new opportunities for dental students and dentists [14].

Current Evidence on the Application of Electronic Dentistry

Application in Oral Medicine and Diagnosis

Bradley., *et al.* [15] in a study on application of electronic dentistry in oral medicine in a community dental service, Northern Ireland proved how electronic dentistry may be used successfully to offer specialist consultations. Patients with oral medicine conditions from all areas of Northern Ireland were referred by dentists and doctors to a small number of specialist services: predominantly, the Regional Oral Medicine Consultant at the School of Dentistry, Belfast. On receipt of the referral at the consultant places, the patient was put on a waiting list after making an initial assessment. Patients remained on the waiting list for long periods of time. Analysis of these patient profiles highlighted that many needed both multiple treatment and review appointments of their chronic conditions, and consequently remain in the hospital system for significant periods of time. This increased the waiting time for these services. The idea of using electronic dentistry to triage referrals, and its potential as a tool to support locally based treatment, provided an alternative approach to the management of oral medicine referrals. It was of particular interest to practitioners in rural locations where distance from the regional center was significant. In 2005, to test this theory, a prototype electronic dentistry system was set up as part of a service improvement scheme by the Community Dental Service of the Home first Legacy.

Trust now Northern Trust in partnership with the Oral Medicine Department at the School of Dentistry, Royal Group of Hospitals Legacy Trust now Belfast Trust. Electronic dentistry made it possible for dental hygienists to provide oral healthcare to underserved populations by digitally linking up with a distant oral health team. This reduced unnecessary waiting periods and saved resources by offering services at the local levels with specialist consultation. Pereira., *et al*. [16] assessed the feasibility of distance diagnosis of oral diseases, using transmission of digital images by email. The study involved documenting 25 cases of oral lesions over a period of 1 year in a primary care public health clinic in Parana in Southern Brazil. Clinical electronic charts and images were produced and sent by email to two oral medicine specialists with a median of 10 years experience in the field. The consultants provided a maximum of two clinical hypotheses for each case. The results revealed that distant diagnosis can be an effective alternative in the diagnosis of oral lesions and the use of two distant consultants improved diagnostic accuracy. The authors concluded that the primary care public health clinics may benefit from the use of email and digital cameras for tele health in remote areas where oral medicine specialists are not available. Summer felt., *et al*. [17] described an innovative oral health workforce model on electronic dentistry assisted, affiliated practice for dental hygienists. The 2010 U.S. Patient Protection and Affordable Care Act (PPACA) called for training programs to develop midlevel dental health care providers to work in areas with underserved populations. In 2004, legislation was passed in Arizona allowing qualified dental hygienists to enter into an affiliated practice relationship with a dentist to provide oral health care services for underserved populations without general or direct supervision in public health settings. In response, the Northern Arizona University Dental Hygiene Department developed an electronic dentistry-assisted, affiliated practice dental hygiene model that placed a dental hygienist in

the role of the midlevel practitioner as part of a digitally linked oral health care team. Utilizing current technologies, affiliated practice, dental hygienists could digitally acquire and transmit diagnostic data to a distant dentist for triage, diagnosis, and patient referral in addition to providing preventive services permitted within the dental hygiene scope of practice. The author concluded that electronic dentistry-assisted affiliated practice dental hygiene was one midlevel practice model that could answer the call of the PPACA to provide comprehensive preventive oral health care and diagnostic services for the growing population of underserved patients in both urban and remote areas. The electronic dentistry methodology described could be adapted to any model used for the emerging midlevel oral health practitioner and provides a way for the midlevel practitioner to participate as a digitally linked member of a complete oral health care team. Initial training endeavors proved that teaching the data acquisition technologies to dental hygiene students was easily and successfully accomplished: students, with only 6 h of training, showed their ability to set up, manage remote patient service facilities, and transmit digital diagnostic data from the remote locations that were statistically as diagnostically efficacious as diagnostic data obtained from an onsite dental hygiene clinical laboratory. These studies along with many others [18-20] clearly demonstrated the usefulness of electronic dentistry in offering specialist services to underserved population in remote areas.

Application in Oral and Maxillofacial Surgery

Duka., *et al*. [21] conducted a study to investigate practical usability of telemedicine approaches in everyday management of oral surgery patients in terms of reliability of established diagnosis and indications for oral surgery treatment of the third molars. The results obtained indicated an almost complete diagnostic agreement. They concluded that the diagnostic assessment of the clinical diagnosis of impacted or semi impacted third molars assisted by the telemedicine approach was equal to the real-time assessment of clinical diagnosis. Herce., *et al*. [22] in a pilot study on the management of impacted third molars using tele medicine described the preliminary results of a store-and-forward telemedicine system aimed at the pre surgical management of impacted third molar pathology. It was a multicenter, longitudinal, descriptive, evaluative pilot study conducted at the Oral and Maxillofacial Surgery Unit of Virgin Macarena University Hospital (Seville, Spain) and four primary care areas located between 15 and 95 km from the hospital. The results showed that over a period of 12 months, 97 patients were enrolled in the study, from 102 tele consultations received and evaluated within the same period. Patients managed through telemedicine were included on the surgical wait list on within a mean interval of 3.33 days since the visit to the primary care dentist, with only 1 visit to the hospital that was on the day of surgery. The mean waiting interval of patients managed through the conventional referral system was 28 days with at least 2 visits to the hospital before the final intervention. The on-the-day surgery cancellation rate of the series was 7.8%, because eight patients did not have surgery on the scheduled day. The cancellation rate in the sample of patients managed through the conventional system was 8.85%. The authors concluded that the practice of telemedicine was effective, accurate, and avoided unnecessary visits to the hospital and shortened waiting intervals. The advent of smart phones has made the practice of telemedicine and electronic dentistry more feasible. Aziz and Ziccardi [23] described telemedicine using smart phones for oral and maxillofacial surgery consultation, communication, and treatment planning. The authors concluded that the use of Smartphone telemedicine was an efficient and effective way for remote specialist consultation and recommended its consideration by the oral and maxillofacial surgeon. According to them, smart phone offered fast and clear access to electronically mailed digital images and allowed the oral/maxillofacial surgeon free mobility, not restricted by the constraints of a desktop personal computer. This in turn allowed for improved efficiency of the specialty consultation and improved triaging, ultimately providing improved care to the maxillofacial patient. The literature supports electronic dentistry could be effectively used in offering specialist services in oral surgery to the patients in remote locations [24,25].

Application in Restorative Dentistry and Endodontics

Brullmann., *et al*. [26] in their study on the remote recognition of root canal orifices tested the 50 images of endodontically accessed teeth acquired with an intraoral camera. The images were stored on a laptop computer and were presented to 20 observers who marked the visible canal orifices using software which stored the canal locations in standard files. The marked positions were verified on histological slices. In 87% of the cases, the canal locations were marked correctly. The results of the study revealed that the remote recognition of root canals by experienced dentists could help younger colleagues in the detection of root canal orifices. Baker., *et al*. [27] compared the interpretation of conventional radiographs transmitted by a video teleconferencing system to conventional view box

interpretation for both artificial and in vivo periapical bone lesions. Results of the study revealed no statistical difference between the ability of the evaluator to identify periapical bone lesions using conventional radiographs on a view box and his ability to interpret the same images transmitted on a monitor screen. The application of electronic dentistry in endodontics and restorative dentistry is proven in many other studies [28].

Application in Orthodontics

Berndt., *et al*. [29] assessed the feasibility of a general dental practitioner providing interceptive orthodontic services to disadvantaged children with real-time supervision from an orthodontist using electronic dentistry. Pretreatment and post treatment orthodontic study models of 30 children treated by a general dentist using electronic dentistry and 96 children treated by orthodontic residents directly supervised by orthodontic faculty were scored with the peer assessment rating index. The results revealed no significant differences between the groups before treatment or after interceptive orthodontic treatment. The study suggested that interceptive orthodontic treatments provided by sufficiently prepared general dentists and supervised remotely by orthodontic specialists through electronic dentistry were a viable approach in reducing the severity of malocclusions in disadvantaged children when referral to an orthodontist was not feasible. Stephans., *et al*. [30] in their review on orthodontic referrals via Teledent Southwest concluded that the project enabled dentists to offer a better service for their patients and use specialist services more appropriately. Mandall., *et al*. [31] evaluated General Dental Practitioner's (GDPs) opinion about a electronic dentistry system to screen new patient orthodontic referrals. Two hundred GDPs were approached from Stockport, Rochdale, Oldham, Bury, and Bolton in Greater Manchester, and High Peak in Derbyshire. A total of 71% of GDPs thought electronic dentistry for orthodontic referrals would be a good idea. Over half of GDPs agreed or strongly agreed that there would be implications on their surgery time, expense, and equipment security. The authors concluded that GDPs generally supported a electronic dentistry system for new patient orthodontic referrals. The use of electronic dentistry makes it possible for dental practitioners in remote locations to seek consultation from an orthodontist. These consultations will play a major role in diagnosis, treatment planning, and application of preventive and interceptive orthodontic procedures and use of helpful machines and facilities [32].

Application in Prosthodontics

Ignatius., *et al*. [33] conducted a study to investigate the use of videoconferencing for diagnosis and treatment planning for patients requiring prosthetic or oral rehabilitation treatment. The consultations took place between a specialist dental treatment unit in a central hospital and general dental practitioners in seven regional health centers. Videoconferencing was conducted using standard commercial units via an IP network, at bandwidths of 762 kbit/s^{-2} Mbit/s. In total, 24 patients and 25 professionals (18 dentists, 2 dental hygienists, and 5 nurses) took part. There were no technical problems. In 24 out of 27 tele consultations, a diagnosis or treatment plan could be made. All participating dentists were satisfied with the consultation process and indicated that the technology used was of sufficient quality for clinical purposes. A patient satisfaction questionnaire indicated that patients were also satisfied. The authors found that the video consultation in dentistry has potential to increase the total number of dental specialist services in sparsely populated areas, such as those in Finland.

Application in Periodontics

Rocca., *et al*. [34] described the evolution of a electronic dentistry system within the U S department of defense. Total dental access (TDA) was a electronic dentistry project within the Department of Defense that enabled referring dentists from the US Armed Forces to consult with specialists on the status of a patient. TDA focused on three areas of dentistry: patient care, continuing education, and dentist-laboratory communications. One of the goals of this project was to increase patient access to quality dental care. The other goal was to establish a cost effective electronic medicine system.

In the first study of electronic dentistry at Fort Gordon, Georgia, a dental image management system in conjunction with an intraoral camera was used to capture color images of a patient's mouth. These images were then transmitted over a 9600 baud modem from the dental clinic in Fort McPherson, Georgia to Fort Gordon, a distance of 120 miles. Fifteen periodontal patients were referred to Fort Gordon for surgery. One week after their surgery, each patient reported to Fort McPherson for suture removal and intraoral

imaging. At the time of suture removal, color still images were obtained of the surgical sites and these images were transmitted to Fort Gordon for examination by the periodontist who performed the surgery. The results revealed that 14 of the 15 patients saved the return trip to Fort Gordon. The patients uniformly felt that they had received better care than they normally received and were especially pleased at the elimination of the long trip to Fort Gordon. The dentists were also comfortable in their ability to make proper decisions and diagnoses using the equipment.

In the web-based electronic dentistry systems, the referring dentist logs into a secure server using a Web browser. He chooses a specialty (orthodontics, oral medicine, oral and maxillofacial surgery, endodontics, oral pathology, periodontics, prosthodontics or pediatric dentistry). He then sends the patient demographics, complaint, images, and radiographs to the specialist of his choice. The data get sent to the database and an electronic mail notifies the specialist of the pending consult, which he will access via the Internet. The specialist reviews the consult and writes his diagnosis and treatment. The completed consult is now stored on the database server. The referring dentist receives an email indicating that his consult has been answered. The results revealed that the data collected on the Web-based electronic dentistry referrals showed an average of 40 consults per month. The referrals to oral surgery had the highest number of consults, followed by prosthodontics and periodontics. Advantages of a Web-based electronic dentistry consultation system were low cost, expandable to a wide range of locations, more complete information for data analysis.

The economic analysis of the electronic dentistry demonstrated a return on investment for the current electronic dentistry system within 1 year of deployment and a return on investment Within 6 months for future deployments.

Role in Pediatric and Preventive Dentistry

Kedzierawski and Billings assessed dental caries prevalence and dental care utilization in preschool children enrolled in urban childcare centers in a comparative effectiveness study. Caries prevalence was determined in a cohort of children 12-60 months of age. Eligible children were randomized into two groups: group one received a traditional visual/tactile oral examination and group two received a electronic dentistry examination. The authors concluded that electronic dentistry was as good as visual/tactile examinations for dental caries screening in Young children and offered a potentially efficient means of screening high-risk preschool children for signs of early childhood caries. The study demonstrated that the use of intraoral camera was a feasible and potentially cost-effective alternative to a visual oral examination for caries screening, especially early childhood caries, in preschool children attending childcare centers.

Another study by Kedzierawski., *et al*. [36] assessed caries prevalence by means of electronic dentistry in 12- to 60-month old children enrolled in Early Head Start inner-city child care centers. Images of the primary dentition were obtained by trained tele health assistants using on Intra oral camera. Images were entered into a Web-based storage and retrieval program. They were transmitted to a secure, remote-site computer, and evaluated by a calibrated pediatric dentist. The results of the study revealed that almost half of the preschoolers enrolled in the study were affected by dental caries, only a few children had ever visited a dentist; and electronic dentistry offered a potentially efficient means of screening high-risk preschool children for signs of early childhood caries. These studies along with others [37] demonstrate the usefulness of electronic dentistry in assessing the prevalence of dental caries and other disorders among children where a pediatric dentist's consultation may be obtained in a cost-effective manner.

Concerns in Application of Electronic Dentistry, Feasibility, and Scope for its Application in Developing Countries

Legal issues

Largely still untested by law and with significant variation among countries, issues such as accountability, jurisdiction, liability, privacy, consent, and malpractice is crucial to consider, when attempting to establish sound foundations for tele health practice. Licensure of electronic dentistry practice largely depends upon the country definition of electronic dentistry. The most significant barrier to a nationwide electronic dentistry practice even in developed countries is the traditional system of state-by-state licensing.

Confidentiality

Patients should be made aware that their information is to be transmitted electronically and the possibility exists that the information will be intercepted, despite maximum efforts to maintain security. The form should contain the name of both the referring and consulting practitioners to ensure adequate coverage for malpractice, and the consulting doctor should acquire a copy of the informed consent before any form of patient contact is established.

Liability

Electronic dentistry raises concerns about liability. There is no law to clarify the role of the teledoctor and their liability. In most developing countries like India, a majority of population lives in rural areas, where healthcare facilities are insufficient. Electronic dentistry can have a significant contribution in bridging the gap between the demand and the supply. The various issues in healthcare delivery system such as inadequate health infrastructure and clinical services, paucity of qualified doctors, the almost non availability of specialist care, the late discovery of the ailment, the delay in the delivery of the treatment due to the greater time which is required for the transport of the patients to urban healthcare facilities and the provision of healthcare by inexperienced primary healthcare service providers may be addressed with telemedicine and electronic dentistry.

Conclusion

Health care is being changed dramatically by the marriage of computers and machines and devices telecommunications. Implications for hospitals and physicians already have received extensive media attention, but comparatively little has been said about the impact of information technology on dentistry. Currently, electronic dentistry has not yet become an integral part of mainstream oral health care. In the near future, electronic dentistry will be just another way to access an oral health care, especially encouraging for isolated populations who may have difficulty accessing the oral health care system due to distance, inability to travel, or lack of oral health care providers in their area. Future advances in technology will enable electronic dentistry to be used in many more ways, such as clinical decision support, quality and safety assessment, consumer home use, medication e-prescribing, and simulation training. In spite of some issues which need to be resolved, the potential of electronic dentistry is tremendous in developing countries, which needs to be explored.

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