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Capabilities of Computerized Clinical Decision Support Systems: The Implications for the Practicing Dental Professional

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Abstract

This article presents the use of captured data within the range of patient care activities of the dental practitioner with an emphasis on prosthodontic activities. It describes the use of computer technology in dentistry during a typical patient encounter in a dental care facility. The oral health record, the need for speech recognition technology, and existing documentation software are discussed. Ongoing development of the capabilities of Clinical Decision Support (CDS) systems is becoming an important part of the oral health setting; including systems applicable to prosthodontics. These systems all rely on a common standardized structure for the electronic (oral) health record (EHR/EOHR). Current developments in radiological technology and digital imaging are explained as well as fundamentals of decision support systems clarified. Recent developments in the representation of domain knowledge as well as the implementation of a dental nomenclature and metathesaurus are also presented. A quality matrix identifies target values for dental informatics while demonstrating an "importance-weighting" of dental characteristics.

Keywords: Computer technology, dental informatics, digital x-ray and imaging devices, computer-based oral health record, decision support systems

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Introduction

Dentistry is no longer a traditional discipline of healthcare where patients are treated using only dental instruments and devices. Computers are now integrated into the dental office and growing exponentially in number and frequency of use. Like medicine, a new field, "Dental Informatics," has emerged and continues to develop in dentistry. It combines computer technology with dentistry in order to create a basis for research and to solve real-world problems in oral healthcare using computer applications.

There is a difference between informatics and "information technology" (IT). The first focuses on the research and "making of" information models and computer applications, while the latter is related to the implementation and application of computed technology and telecommunications respectively.

The successful integration of electronic technology into dental healthcare practice, education, and research is comparable to the mission of medical informatics. Schleyer and Spallek reviewed this new field recently[1] and identified parallels to medical informatics as well as specific computer applications in clinical care, education, and research in dentistry.

There are several computer applications used in medicine to assist physicians in coping with their daily work. Although it is good to learn from the uses of information technology in medicine, most of the functionality is not transferable to dentistry. Dental practice differs significantly from medical practice; hence, dentistry needs to develop its own computerized solutions to effective information utilization.

This paper will describe the usage of captured data as it relates to the range of patient care activities in dental practice including prosthodontic practice. The ongoing development of Clinical Decision Support (CDS) systems as part of the Electronic Oral Health Record (EOHR) offers the corresponding support that can be provided using computer technology. Such a relationship depends on the utilization of a common standardized structure for the EOHR that has been established by the American Dental Association's (ADA) standard series 1000.[18]

The implementation of technology-independent concepts and thought processes will be examined, and some of the current technology that may benefit the practitioner's usage of those concepts in the patient care process will be noted in sections to follow. The intent is also to introduce the reader to the preliminary concepts of the work in progress on the development and basic ideas of the Markov Model for prosthodontic treatment[2] and its continuation of the probabilistic causal approach to the Dental Clinical Advisory System.[3]

Decision-Making Models

Modeling decisions and treatment options in dentistry are particularly difficult since they involve risk that is continuous over time, and timing in dental care is important. For instance, caries and periodontal diseases can both occur at a specific time in the past and 're-occur' at another time in the future. Additionally, these disease entities can happen more than once, and they can occur in multiple sites. Humans have more than one tooth that is vulnerable to disease, and teeth can be restored more than once. Under these 'real world' conditions, the use of conventional decision trees may require unrealistic simplifying assumptions.

Here, the Markov Model can be used to model prognoses for clinical problems with ongoing risk and changing transition probabilities over time.[4] In prosthodontic practice it is now possible to calculate the risk of a patient becoming edentulous based upon the patient's actual state within the prosthodontic cycle.[2] Algorithms adapted from Hollenberg enable analysts to determine cost-effectiveness as well as the financial cost of being in a certain state for a single or multiple cycle.[5] Since clinical data are needed to perform such calculations, the need to develop a large database becomes apparent. The probabilities for the resulting causal network are learned and adjusted from stored findings in a corresponding relational database. Initial versions of the Dental Clinical Advisory System, which is in progress, are described in a 2000 paper by Umar, et al.[3]

Expert Systems For Clinical Decision-Making

The integration of patient or personal data with large amounts of stored information is widely used to perform computations in order to aid in decision-making, not only in medicine but also in several other fields. Financial institutions use this strategy to check credit worthiness, or insurance companies use it to weigh their exposure to risk. Such computer programs are often referred to as decision-support systems or expert systems. The encapsulation of domain knowledge such as all known facts and treatment options on infectious diseases and antibiotics can be put together by a collection of implications. Based on programming rules such as "if-then" scenarios, probabilities can be forecast. In other words, if certain conditions exist, then a result can be defined. This represents a more flexible type of expert system and is called the rule-based system.[6] Today we know successful applications in medicine, such as the INTERNIST/QMR system in medical diagnosis[7] or the Pathfinder project in pathology.[8] They are based on causal or probabilistic reasoning and decision-theoretic schemes. Later they were refined using so-called Bayesian methods. These methods provide formalism for reasoning about partial beliefs under conditions of uncertainty. This means that propositions are given numerical parameters that signify the degree of belief accorded them under some body of knowledge. These parameters are then combined and manipulated according to the rules of probability.[9] The primary limitations of a rule-based approach are that logical rule sets usually make rigid, binary [yes or no] decisions as to whether to classify given findings as important and there is no sense of a continuous degree of confidence.

However, only a few expert systems or other types of mathematical models have been developed for general dentistry or prosthodontics. An example of such an expert system is the Oral Radiographic Differential Diagnosis (ORAD) software program that is designed to evaluate radiographic and clinical features of patients with intrabony lesions in order to assist in their identification using Bayes' theorem.[10] Following the recognition of a dental problem and invoking the program, patient-specific information is entered to characterize the lesion in question. ORAD's output provides a listing of each of the diseases in the program associated with the probability for that described condition. It also computes a pattern match estimating how closely the set of entered characteristics match the typical presentation of each of the considered program's conditions. This information is helpful to the clinician in the decision-making associated with arriving at a final diagnosis. An online version of this program is available at http://www.orad.org.

Another example of an expert system for dentistry is the development of a simulation model of the caries process. The model examines the influence of time relevant factors on health gain from restoring posterior approximal tooth surfaces. This simulation model is described by Downer and Moles who demonstrated there is no automatic benefit from restorative dental treatment.[11] An advantage of using this decision model is that it highlights clinically relevant data that dentists need in order to make treatment decisions conducive to achieve a health gain for the patient. They conclude substantially correct predicted outcomes, but within broad confidence limits and propose further investigation of cost-utility of restorative dental treatment.

These are only two examples of several tasks associated with diagnosis and treatment planning and represent only a fraction of dental skills needed to assess the patient's health status. A dentist is trained in systematic workflow in order to gain insight into the patient's health status from clinical, radiographic, and health history findings. Expert systems allow the dentist to offer maximum benefits to the patient in terms of time invested, dental specialty, and monetary outcome. For the sake of completeness, additional skills in communication, education, training, and research are explained below.

The EOHR and Capturing Patient Care Data

The administrative function of patient care and the exploration of the specifics of the patient history are comparable to other medical domains beyond the scope of this paper. Following the usual patient registration procedures, Figure 1 depicts the patient-dentist relationship in a typical care process. The process is multifaceted and complex. The interaction between the patient and dentist starts with the patient history being taken before diagnostic procedures are performed. In addition to the oral examination, diagnostic procedures include a radiological examination, lab tests, oral cancer screening, and other imaging modalities when applicable. Based upon the diagnostic findings, a treatment plan is formulated and discussed with the patient. Preliminary treatment is usually undertaken based on the requirements of subsequent major treatment. A quality assessment of the treatment plan including necessary prosthetic adjustments is carried out during the whole treatment process. In order to gain maximum benefit from the treatment rendered, the patient is checked on a regular recall basis.

As this care process unfolds, there are several issues that could be addressed using a dental informatics approach. These issues are discussed below. All of these are important from both a dental informatics and a dental professional's view.

Speech Recognition Technology

It is well known that a good infection control protocol precludes the use of gloved hands for taking notes during the oral examination. This is done in order to avoid contamination in the patient-dentist-chart triad. However, documentation of this valuable clinical information is necessary and cannot always depend on the dictation of information to the dental assistant since other chairside functions may require that person's attention. Speech recognition systems would be helpful in the hands-free documentation process, but such systems are not yet standardized. These systems allow the clinician to dictate clinical findings into a computer system that digitizes the voice input and creates a document or clinical record.

A recent study of speech technology for clinicians shows that it has advanced considerably in recent years and is now a serious contender to replace some or all of the increasingly expensive alternative methods of dictation with human transcription.[12] Although the technology is still evolving, many applications are already tendered for radiology.[13] A comparison of data from 5072 reports generated with a commercially implemented system and 4552 reports produced during the same period one year earlier shows that continuous speech recognition nonetheless markedly improved report turnaround time and proved to be cost-effective.[14]

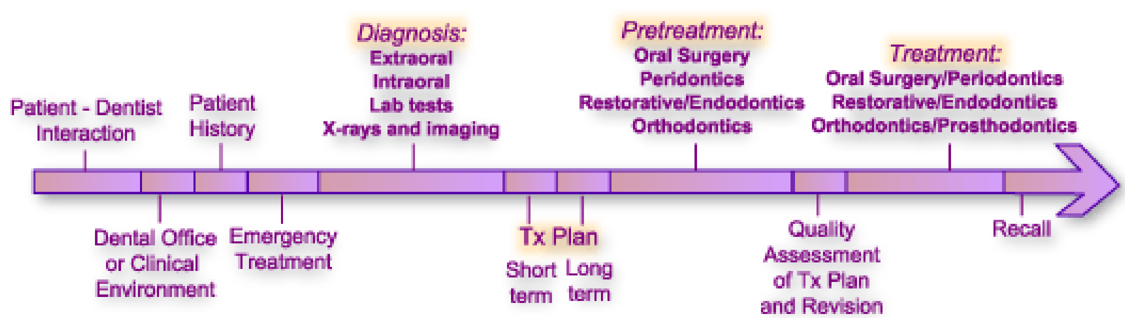


Figure 1. Breakdown of the patient-dentist interaction valid at many dental schools or hospitals and private offices. Depending on the complexity of the case, patients can remain or reenter each state for a consecutive number of times. See text for details.

Despite ongoing interest, there are no practical special dental speech recognition systems known for "hands-free" documentation of patient care. Furthermore, there is also a lack of speech recognition systems for "hands-free" positioning of dental equipment to avoid contamination during a dental procedure. One important issue arising with speech technology is the lack of standards for audio information retrieval on the Internet. Search engines like "Yahoo!" or "AltaVista" do not exist for audio data retrieval as of this writing.[15] Since the development of multimedia applications involve audio features, intelligent interfaces for navigating and browsing become necessary.

Standardized Dental Charting

Documentation in dentistry is as important as in medicine but differs in the dependence on the use of pictographic symbols, codes, and colors to record clinical information. Traditional paper dental records include an intraoral chart symbolizing all 32 teeth in location, size, shape, and orientation. Using colored pens and/or codes the dentist enters the intraoral and radiographic findings on the chart. Depending on the specific dental discipline, such as radiology or prosthodontics, additional symbols and classifications are being used and differ regionally. These charting conventions are often introduced to students by various dental schools. Unfortunately, there is a lack of a national or international chart standard. As a result, there is a variety of electronic chart systems available for dentistry on the market.

Incentives for a computer-based oral health record were developed by a collaboration of seven dental schools in the United States[16,17] describing features and concepts of basic data elements.[18] Today, this is administered by the ADA.

Despite the large number of existing proprietary computer systems, only few make the step for scientific documentation and publication such as the system developed and described by Benn et al.[19,20] Their April 2000 version represents a typical example of existing software and is described here to demonstrate common problems all documentation software products for dentistry have more or less in common. Like other systems, it has good but improvable features.

It is a large system offering several features including documentation of the medical and dental history, pictorial caries charting including radiographic classification, charting of periodontal findings, and an iconized representation for possible treatment. The developers of the system admit the new chart may appear complicated to use but shows an error rate at less than 3% after standardized testing with 24 users was demonstrated.[21] However, the system could be improved if it required less time to enter all findings. Familiarization with the system's new pictorial computer icons representing a myriad of clinical conditions is a challenge for users. Some icons represent different stages of lesion severity and activity for clinical caries classification as well as another set of icons for each radiographic classification, periodontal findings, and dynamic icon composition for implants and endodontic posts. This large set of different icons makes it difficult to memorize the particular meaning of an icon especially once the chart is printed on black & white and icon legends are no longer available to the clinician. The representation on the screen itself is packed with many diverse icons since a single tooth's possible findings consists of a minimum of four rows of information and, thus, lacks a quick overview and ease of use. Such 'symbolic' specialization might be a good adaptation to dental needs; however, many icons resemble one another in shape and color and exceed in their total number the amount of pictorial representation of traditional paper charts. Again, the points of concern mentioned here are valid for other dental software packages as well.

Standardized Reporting

Another attempt towards computerized reporting of aggregated data and development of telematic applications, i.e., the specific use of interactive multimedia technology (including voice in- and output, videoconferencing, and dynamic 2D and 3D visualization techniques) are linked to a dental software system known as the ORATEL project that can be found on the Internet at www.dis.uu.se/mdi/projects/oratel/index.html[22] It addresses the issue of quality assurance and provides chairside decision support and retrospective evaluation of performance for General Dental Practitioners (GDP). Findings so far have been approved by the European Commission for further development under a new project called ORQUEST. (www.dis.uu.se/mdi/projects/orquest/index.html) Reaching the step of data exchange it is important to note the need for compatible data, structuring trade-offs between unstructured text, and defined data structures. This is still an issue not fully resolved, but imminently needs to be solved in order to facilitate quality CDS.

Although further development of those systems is required, implementing standard findings known from instructional software design[23-25] and human-computer interaction[26,27] is vital in order for these systems to be accepted by dentists. Because dentists started to develop their own educational software packages and online courses using sophisticated software development tools, the quality of these products varies widely. Again, the establishment of standards is mandatory. Preliminary concepts on the development of standards for the design of educational software[28] as well as the analysis of instructional characteristics of online continuing education courses[29] are already accepted and used widely.

Diagnostic Technology

Clinical patient visits involving the extra- and intraoral examination, radiographic, and other imaging modalities are the most critical phases for planning a patient's future treatment. No attempt will be made here to review all aspects of dental diagnostics using computer technology. This discussion will focus on only recent major developments in this area.

All of the following diagnostic functions result in data usable in an EOHR. Only a few of them support applications that feed data to the EOHR, or to condition those data abstracted from the record for use in CDS. However, these data are suitable for use by the practitioner for decision-making purposes.

Computer technology is known for its fast turnover rate, and technologic aspects will evolve in other directions. But if the ideas presented here continue to be developed beyond the initiation phase, they will be useful to practitioners for a long time. Thus, the following technological capabilities can be used to emphasize a conceptual point.

Oral Cancer Screening

A non-invasive method for detection of precancerous and cancerous oral lesions uses computer-assisted analysis of the oral brush biopsy and is termed OralCDx.[30] It can aid in confirming the nature of apparently benign oral lesions and revealing apparently benign lesions that are in actuality either precancerous or cancerous. OralCDx appears to determine the significance of an oral lesion definitively and detects innocuous-appearing oral cancers at an early and curable stage. In October 2000, OralCDx received the ADA's "Seal of Acceptance."

Caries Detection

Caries detection is another major preventive task of a dentist. Here, a newly developed system named Logicon Caries Detector™ program (Logicon Inc., USA) is designed to assist dentists in the detection and characterization of proximal caries. However, an evaluation study of the program showed that the automated caries detection program was inconsistent and provided different opinions on the caries status in a tooth surface. In addition, the inter-observer agreement in caries diagnosis failed to improve while using the program.[31]

Techniques for Impression Taking

Since the process of impression taking can be difficult for maxillofacial prosthodontists and uncomfortable for dental patients, non-contact impression techniques are under development utilizing video scanning of the oral cavity.[32] One common problem encountered so far is inadequate spatial resolution.[33]

Interactive Communication

Video techniques are widely used in dentistry, including dental education and training[34,35], teleradiology[36], and prediction of orthodontic treatment.[37]

Oral Radiology and Dental Imaging

Clinical data and findings are mostly composed using computer technology in oral radiology[38] and with dental imaging techniques.[39] Here, technology advances very quickly and new costly systems become available almost on a monthly basis. It is very difficult to distinguish differences between various intraoral digital devices. Advantages and disadvantages of intraoral periapical and bitewing films as well as panoramic and cephalometric radiography are discussed today mainly based on technical issues.[40,41,42]

The comparison of digital systems with conventional X-ray films in terms of resolution has found a recent break with the development of new intraoral sensors (CCD) of small pixel size[43] and a spatial resolution that rivals direct-exposure intraoral X-ray films.[44]

Farman and Farman recently compared extraoral and panoramic systems and demonstrated the newest technologies available in dental radiographic hardware featuring new software concepts that is useful in the diagnosis and treatment of orthodontic and maxillofacial prosthetic cases.[45]

From the very beginning of Computed Tomography (CT), 3D imaging was carried out in the presurgical evaluation of dental implant sites. More advanced procedures include stereolithographic methods[46,47], magnetic resonance imaging (MRI)[48,49,] or the combination with other techniques such as videofluorography or spiral CT or the accuracy of 2D/3D CT data are currently under investigation.[50,51,52]

Artifacts and distortions in dental CT data were caused very often by metallic restorations. Depending on the size and location it was very difficult to use these images in 3D image reconstruction, which are needed for instance in diagnosis and treatment of dental implants, impacted teeth, or temporomandibular joints. Special algorithms to noise reduction in combination with multi directional interpolation resulted finally in clear three-dimensional images.[53] The first clinical model of limited cone-beam X-ray CT for dental use named "3DX multi-image micro CT" was developed by Befu et al. and is currently available only in Japan (3DX, J. Morita MFG Co. Kyoto, Japan).

Another method to produce three-dimensional images is termed Tuned Aperture Computed Tomography (TACT)[54] and has been licensed by Instrumentarium Imaging (Tuusala, Finland). The use of TACT for dental applications is work in progress for diagnostic efficacy in primary caries detection[55], diagnosis of external root resorption[56], the accuracy of depth discrimination[57], and to assess bone defects at implant sites.[58]

Despite these seriously ongoing projects and modifications for digital radiographs[59] potential for fraudulent use of digital radiographs have also been reported[60] and give implications to develop measures both to prevent manipulation of digital radiographic images as well as to facilitate its detection.

However, digital radiographic and imaging modalities offer more advantages that may be in the patient's best interest of fast transmission to consulting dentists, insurance companies, as well as off-hours interpretation. Once all data are transformed into a digital format, they will be more frequently transmitted urging teledentistry and teleradiology to become standards.[61,62]

Occlusion

A new development in the diagnostic field is the virtual articulator or the analysis of dysfunctions and the dysmorphology of dental occlusion. Kordass and Gaertner use results of a 3D scan of a single tooth and combine complete denture models and their centric relation with data from a jaw movement analyzer. This enables the virtual movement and diagnosis of dynamic occlusal contacts and tooth interferences.[63]

Treatment Planning, Pretreatment, Treatment

This step of 'clinical data mining' is significant and is based on the dentist's expertise. If the dentist considers implant treatment for example, effects of findings on bone condition, jaw site, and age are important parameters that affect the oral implant outcome.[64] Due to the broad context of prosthodontic options, there are no consensuses among professionals for treatment strategies.[65] The reason is quite simple and as demonstrated by Umar[2], the patient can remain or change different clinical states during dental treatment. For instance, the patient can have a crown treatment on a first maxillary premolar and two weeks later another crown treatment on a mandibular first molar; both procedures could occur independently from each other or as a result because of a 'bad outcome' of the first crown treatment due to occlusal problems. If we could predict a certain clinical result before initiating a myriad of dental therapy, the patient's future oral health would be much better off. Here is where probabilistic inference models can really show their strength. They have been already been developed for definitive surgical therapy of primary cutaneous melanoma.[66] Further on, graphical modeling techniques are refined and seem to be superior to classic statistical procedures of multivariate logistic analysis[67] and work fine with incomplete data (as a result of speedy daily routine work) for prediction as well.[68-70]

Basic Ideas of CDS and Its Beginning

Computer technology has been used in clinical decision making since the late '70s and early '80s in medicine. Since then transferring strategies have been identified by cognitive scientists.[71,72] Corey emphasized three dimensions of formal problem evaluation for primary care settings. These are accurate in terms of prediction, usefulness, and acceptability for clinicians.[73] Construction of these decision support systems were primarily focused and based upon statistically available and on knowledge-based data.[74,75]

Decision support systems in primary care settings improved further during the early '90s and in close conjunction with new strategies of judgment under uncertainty.[76,77] 'Guidelines' on how to construct decision support systems[78,79] with special emphasis on probability theory and Bayesian approach[80,81] are important points to improve these decision support tools.

Enhancement of Artificial Systems

Many evaluation studies were undertaken in order to determine whether an artificial system could distinguish novice and expert strategies during complex medical diagnostics. After training the system, artificial neural networks showed to have the ability to identify a small number of expert-like strategies.[82] Continuous user feedback can be collected and monitored during the routine use of the system to enhance the performance of the system.[83] The number of expert systems increased steadily as reviewed by Durkin.[84] However, errors and inconsistencies in the judgment of human experts building such artificial systems are apparent. The processes of decomposing and formalizing a decision problem into simpler components are today well defined and understood.[75,78,85]

Studies of testing and validation[86,] influence of expert systems on training[87,] guidelines to improve compliance with care standards[88,] implications for systems design[89,] and effects on physician performance and patient outcomes[90] show important findings that are also valid for tailoring systems for use in dentistry.

Dental Implications

Different modalities and requirements for dental decision-support systems are basically described in a 1993 paper by Feldman et al.[91,] 1995 by White[92,] and 1998 by Benn et al.[19] Primary dental systems progressed for instance in histopathologic diagnosis of salivary gland neoplasms[93,] orthodontic diagnosis[94,] caries diagnosis[20,] oral radiology[10,] oral surgery[95,] and partial denture design.[96]

Computer assisted design and computer assisted manufacturing (CAD/CAM) techniques are now routinely used to operate computer-assisted milling machines to produce dental restorations[97-100] and systems are available for use by dental practitioners.[101,102]

Further methods and applications using computer technology in dentistry include robotics to automate dental treatment[103,] neural interfaces to control computers[104,] or virtual reality (VR). The latter technique was reported in 1998 by Seipel et al. for simulations of dental implant planning.[105]

Internet resources are also used for medical and dental decision-making.[106,107] The World Wide Web is ideal to distribute developed applications from medical and dental domains such as knowledge bases[108,109] or dental records.[110] It is expected that healthcare professionals will use information services via the Internet and wide-band multimedia intranets more and more for instance of homecare telemedicine, patient education, and online clinical decision support.[111]

The last two sections described in detail the many components of practice information architecture. It should be noted the general practitioner could facilitate the management of practice information architecture more effectively over a long time, if consideration is given to the many different implementations available as independent 'add-ons' to a practice's information architecture. The conceptual basis and resulting implementation perspectives can be dealt independently.

Recall and Outlook

The use of relational databases for storage and retrieval of these large patient data is today successfully applied in a variety of medical domains in order to provide statistical analysis and documentation of care. Several commercial products are available for storing and retrieving patient data including billing software.[112] Effective EOHR data structures are needed to encounter attributes for the management of patient populations as well as for resource management within the practice. However, the extraction of relevant information to a specific clinical scenario can be tedious and time consuming because sources for clinical data relevant to a particular context may be obscure, or indexing information necessary to locate data may be absent; thus, complicating search and retrieval. One example of providing rapid access to medical facts, decision models, and commentary of specific use is DecisionNET that represents a unique model of medical knowledge bases.[113] Object-oriented databases are used to represent domain knowledge.[114] Unfortunately, similarly structured dental databases are rare to find, since a corresponding representation of thoughts, words, and things using the Unified Medical Language System (UMLS)[115] does not exist for dentistry. Dentistry contains a much larger set of knowledge than described in this paper, which needs to be structured and conceptualized like the Systematized Nomenclature of Medicine (SNOMED).[116-119]

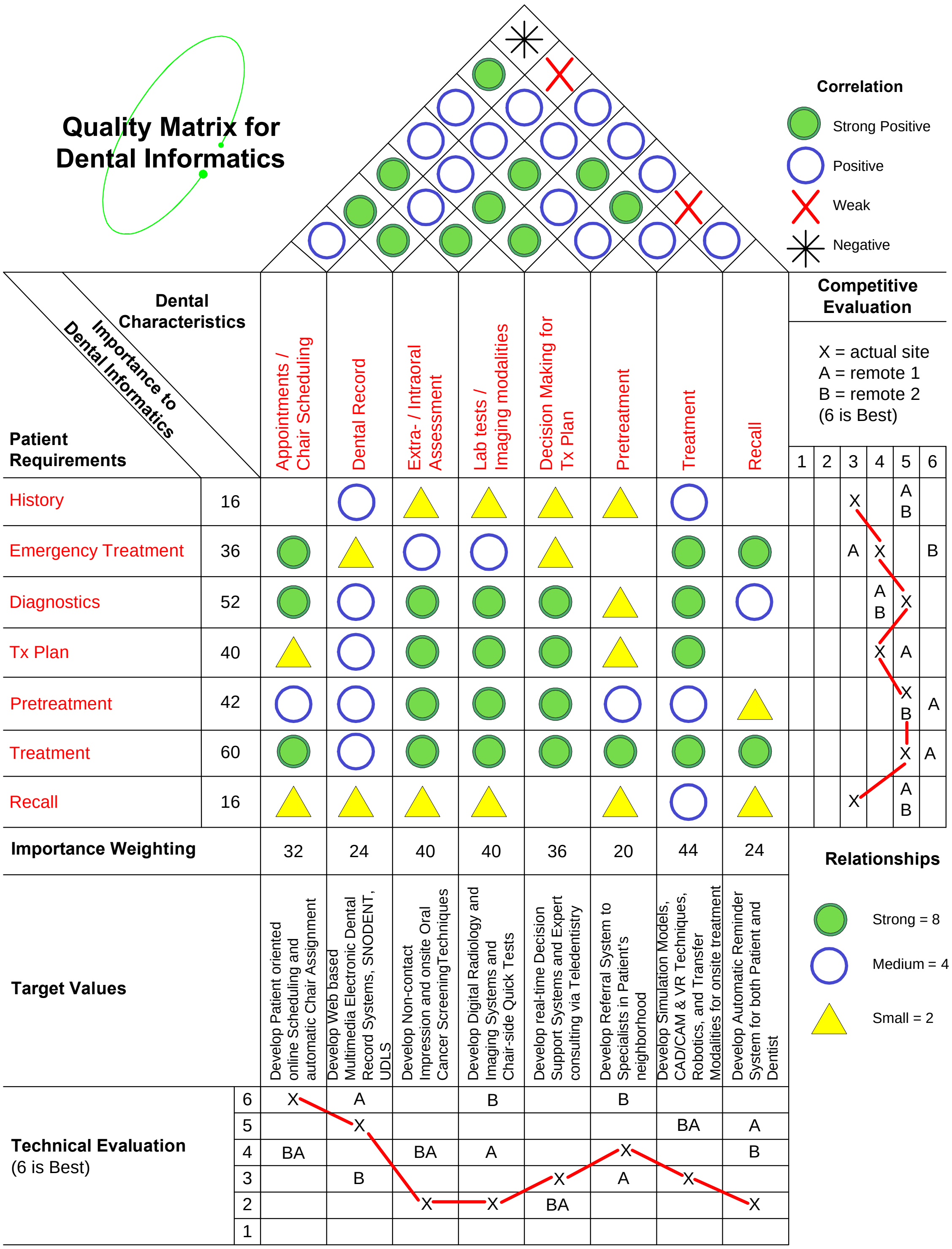
Fortunately, the ADA is counting on the belief that a systematized set of diagnostic and descriptive terms and codes will aid individual dentists and dentistry as a whole. Thus, they initiated a task force on the development of SNODENT. It includes standardized terms for defining dental disease in an electronic environment. These terms and codes, developed by the Council on Dental Benefit programs, will allow dentists to electronically document a full range of information about their patients including physical findings, risk factors, and functional status.[120] The development and implementation of a dental metathesaurus and its domain ontologies are as important for the design and implementation of an image management and communications system termed IMACS.[121,122] Once these concepts become reality, we can automate and go beyond the traditional dental recall system and use, for example, protocol-directed temporal-abstraction systems such as EON.[123]

As described so far, there are a number of different demands and tasks for dental informatics to solve ongoing and future problems in clinical dentistry. Figure 2 summarizes the different target values based on data presented in this paper and on relationships between patient requirements and dental characteristics in order to depict the importance to dental informatics. In addition, this quality matrix demonstrates an importance weighting of the dental characteristics and correlation between these target values and dental characteristics. Finally, results of competitive site and technical evaluations of dental schools are entered. They represent the author's subjectivist opinion across European and U.S. sites for the sake of completion of the final charts and, thus, these sites will remain anonymous.

Conclusion

As described in this paper, dental informatics is important in many ways to clinical practice. Since the number of computer systems and the

Figure 2.


Quality Matrix for Dental Informatics
Correlation
Strong Positive
Positive
Weak
Negative
Dental Characteristics
Importance to Dental Informatics
Patient Requirements
Appointments / Chair Scheduling
Dental Record
Extra- / Intraoral Assessment
Lab tests / Imaging modalities
Decision Making for Tx Plan
Pretreatment
Treatment
Recall
Competitive Evaluation
X = actual site
A = remote 1
B = remote 2
(6 is Best)
1 2 3 4 5 6
History 16
Emergency Treatment 36
Diagnostics 52
Tx Plan 40
Pretreatment 42
Treatment 60
Recall 16
Importance Weighting
32 24 40 40 36 20 44 24
Relationships
Strong = 8
Medium = 4
Small = 2
Target Values
Develop Patient oriented online Scheduling and automatic Chair Assignment
Develop Web based Multimedia Electronic Dental Record Systems, SNODENT, UDLS
Develop Non-contact Impression and onsite Oral Cancer ScreeningTechniques
Develop Digital Radiology and Imaging Systems and Chair-side Quick Tests
Develop real-time Decision Support Systems and Expert consulting via Teledentistry
Develop Referral System to Specialists in Patient's neighborhood
Develop Simulation Models, CAD/CAM & VR Techniques, Robotics, and Transfer Modalities for onsite treatment
Develop Automatic Reminder System for both Patient and Dentist
Technical Evaluation
(6 is Best)
6 5 4 3 2 1

frequency of their use increase constantly in a dental environment, it is getting more difficult to distinguish between basic and special purpose needs. Along the path of a dental patient entering and leaving the dental office, we have shown existing hardware solutions as well as software packages and identified current developments in diagnostics and treatment modalities. New systems can be purchased almost on a daily basis and only budgetary considerations limit the number of stand-alone systems in a dental office. The worst case could be that none of these systems can exchange any data or images. Challenges for the next few years for software developers will be to make sure that their system can 'talk' to another as well as issues of portability. The usefulness of their products in the newly evolving digital dental office will decide on recognition. Dental professionals, on the other hand, need to accept that purchasing alone is not a final step. Increased readiness to get training on the new system and purchasing costly solutions as teams of three and more dentists are major challenges to reach the break-even point of investment earlier. Here, dental informatics can help to find the right way to a digital clinical practice. However, significant efforts and investments are needed to transform theories and concepts into real-world solutions to improve dental practice. The ADA's coordination with other disciplines in the healthcare informatics activities ensures compatibility of the oral health and general health information domains; this coordination will help the dentist to be one of the earliest beneficiaries of interoperable systems and enterprise architectures that have a Life Cycle perspective. This perspective will greatly help achieve the economic benefits of the information architecture.

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