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ORIGINAL ARTICLE

Advancing oral medicine through informatics and information technology: a proposed framework and strategy

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The implementation of information technology in healthcare is a significant focus for many nations around the world. However, information technology support for clinical care, research and education in oral medicine is currently poorly developed. This situation hampers our ability to transform oral medicine into a 'learning healthcare discipline' in which the divide between clinical practice and research is diminished and, ultimately, eliminated. This paper reviews the needs of and requirements for information technology support of oral medicine and proposes an agenda designed to meet those needs. For oral medicine, this agenda includes analyzing and reviewing current clinical and documentation practices, working toward progressively standardizing clinical data, and helping define requirements for oral medicine systems. IT professionals can contribute by conducting baseline studies about the use of electronic systems, helping develop controlled vocabularies and ontologies, and designing, implementing, and evaluating novel systems centered on the needs of clinicians, researchers and educators. Successfully advancing IT support for oral medicine will require close coordination and collaboration among oral medicine professionals, information technology professionals, system vendors, and funding agencies. If current barriers and obstacles are overcome, practice and research in oral medicine stand ready to derive significant benefits from the application of information technology.

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> I have applied everywhere for information, but in scarcely an instance have I been able to obtain hospital records fit for any purpose of comparison […] If wisely used, these improved statistics would tell us more of the relative value of particular operations and modes of treatment than we have means of ascertaining at present. (Florence Nightingale, 1863, Nightingale, F. (1863), Notes on Hospitals (3rd ed), London: Longman, Green, Longman, Roberts, and Green.)

Introduction and motivation

The implementation of information technology in healthcare practice and research is a significant focus for many nations around the world (Duftschmid *et al*, 2004; Thompson and Brailer, 2004; Christensen and Grimsmo, 2005; Anderson *et al*, 2006). Judicious and appropriate use of information technology is expected not only to bring greater efficiency and efficacy to clinical practice, but also to our ability to generate knowledge from clinical observations (van der Lei, 2002; UK Clinical Research Collaboration and Wellcome Trust, 2007). However, there is a significant gap between the capabilities, adoption and use of health information technology (HIT) in practice, and our ability to generate meaningful insights from the data collected.

The experience in oral medicine (OM) illustrates this gap. In 2006, participants in the World Workshop in Oral Medicine IV (WWOM IV) in Puerto Rico evaluated different treatment strategies for common oral medicine conditions. Data necessary for providing evidence-based recommendations was often found to be missing and the systematic reviews conducted revealed the need for high quality research. It became evident that international collaborations, based on methodologies appropriate for systematic reviews, have

the potential to advance treatment modalities in the field of oral medicine. However, although the profession often advocates for collaborative efforts through multi-center research, studies which take full advantage of information technology are rare.

On the other hand, most oral medicine professionals (OMPs) have been using computers for clinical purposes for more than 20 years. Hospital information systems, dental practice management systems, electronic dental records and custom-written database applications provide functionality for documenting diagnoses, treatment and outcomes essential to the work of many clinicians. However, our ability to generate knowledge through the systematic standardization and analysis of clinical information obtained in daily routine practice is poorly developed. To help close this gap, the Institute of Medicine advocates:

> Efficiently generating medical evidence and translating it into practice implies a 'learning healthcare system' in which the divide between clinical practice and research is diminished and ultimately eliminated. (English et al, 2010)

The primary goal of this article is to stimulate collaboration between the fields of oral medicine and informatics/information technology to move toward this vision. To do so, we comprehensively review the current state of IT use in oral medicine, and propose strategies to leverage IT for advancing practice and research. We begin by reviewing the needs and requirements for electronic support of oral medicine practice and research. We consider these requirements both in the local context of the individual practitioner or practice setting, as well as in light of performing the multi-center activities suggested by initiatives such as the WWOM IV. We then propose needed solutions and suggested strategies to achieve them. We conclude the article with some recommendations for future steps.

To help readers of the various communities understand the major concepts we discuss, we first define oral medicine and its practitioners, informatics, information technology, and electronic patient records (EPR).

Oral medicine has been defined by the American Academy of Oral Medicine as follows: 'Oral Medicine is the specialty of dentistry concerned with the oral health care of medically complex patients and with the diagnosis and non-surgical management of medically-related disorders or conditions affecting the oral and maxillofacial region'. This article refers to any individual who is involved in patient care, research or education in oral medicine as an 'oral medicine professional (OMP)'.

Dental informatics has emerged as a separate discipline distinct from information technology in dentistry during the last several decades (Schleyer and Spallek, 2001). Dental informatics applies computer and information science to improve dental practice, research, education, and management. *Information technology*, on the other hand, is primarily focused on the implementation, application, and support of computer technology and telecommunications. Often, information technology applications result from dental informatics research. However, the distinction between these two concepts is not always clear cut (Friedman, 1995). For practical purposes, we will therefore use 'information technology' as the common term to refer to both concepts in this article. An 'information technology professional (ITP)' is an individual involved in any aspect of information technology application, development, or support.

Electronic patient records are computer-based tools designed to provide clinicians with access to complete, comprehensive, and accurate data about patients (Committee on Improving the Patient Record, Division of the Health Care Services, Institute of Medicine *et al*, 1991). Important objectives of EPRs include supporting patient care and improving its quality; enhancing the productivity of healthcare professionals; facilitating clinical and health services research; and improving population health. Electronic patient records are seen as key tools in supporting healthcare and generating knowledge.

In addressing the dual audience for this article, OMPs and ITPs, we have several objectives. It is important that OMPs understand how EPRs could improve the practice of OM better than is possible with current computer applications. Properly designed EPRs can help manage *all* information about individual patients, and facilitate diagnostic and therapeutic activities, as well as prognostic assessment. In addition, it is crucial for OMPs to understand how computerized entry, management and analysis of clinical data can support generating knowledge. Deeper insights into the capabilities of IT applications will allow OMPs to enter into productive discussions and meaningful collaborative relationships with ITPs. ITPs, on the other hand, should benefit from this article by understanding the needs and desires of the OM community for IT applications, specifically EPRs. In addition, this audience should gain an appreciation of the barriers and challenges to EPR use in the OM community, as well as the necessity for interoperability standards for data exchange in OM.

Needs of and requirements for information technology support of oral medicine

In discussing the needs of and requirements for information technology to support oral medicine, it is useful to begin with a brief review of the clinical care process for the benefit of ITPs. (OMPs, who are likely to be intimately familiar with this process, may want to skip ahead to the questions below). Figure 1 shows a generic clinical workflow, which we will illustrate with a concrete example. Patients typically see OMPs with a specific concern or complaint. To arrive at a diagnosis, the clinician obtains a detailed history and performs a thorough clinical examination. For instance, the clinician will ask a patient with an oral ulcer about the history of the chief complaint, which may include onset, duration, location and size of the lesion(s), acute/-chronic nature, associated extraoral manifestations, pain, response to previous treatment, and precipitating

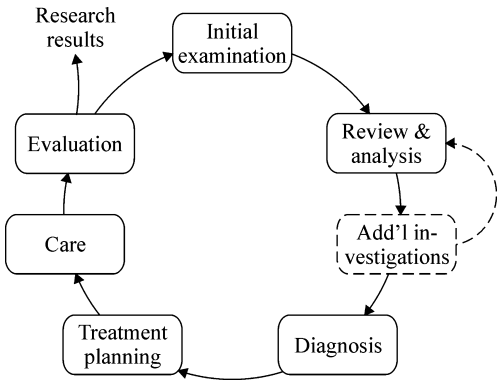

Figure 1 The workflow of clinical care begins with the initial examination of the patient, which is followed by review and analysis of findings, possibly requiring additional investigations. Based on the diagnosis/es, the clinician develops a treatment plan which is implemented during subsequent care. The results of the evaluation may require a further iteration of the described process or particular phases, and may be used to further research in oral medicine

factors. Demographics, medical history, and social history may also be part of this investigation.

During the examination, the clinician performs an extraoral and intraoral assessment. Characteristics of the lesion, such as singularity/multiplicity, location, size, borders, color, texture, and consistency are of primary interest. Review and analysis of findings result in an assessment or diagnosis, and determine a treatment plan and subsequent examinations. For instance, if the oral ulcer is affecting an otherwise healthy patient, diagnostic considerations will be quite different from an ulcer in a patient who is medically compromised.

When considering several differential diagnoses, the clinician may acquire adjunct data through laboratory studies or consultations. For instance, in the case of an ulcer, biopsies, bloodwork, radiological assessment, cytologic and microbiologic studies, and clinical imaging may be used to narrow the number of possible diagnoses.

Throughout this process, the clinician acquires, reviews, and analyzes various data. While these data are primarily employed in the care of the specific patient, they can also be used for research. In the following, we review salient questions for how information technology should support the clinical process and the secondary activities associated with it.

What clinical data should be collected and how should they be represented on the computer?

Data collected during a clinical encounter largely depend on the individual clinician. General conventions inform our data collection efforts, but, over time, each clinician tends to develop a personal 'style'. Experience provides clinicians with an intuitive sense of which findings in a case history, physical examination and investigation are critical to determining an accurate diagnosis or assessing a patient's prognosis. Relevant general questions for the oral medicine profession therefore include: What data are essential for making an accurate diagnosis? How do data collected affect further data acquisition and diagnostic activities? Can certain data be omitted without jeopardizing the validity and reliability of a diagnosis? How should the data we collect be updated in light of new research findings?

Once we have determined what data to collect, we need to consider how these data should be represented on the computer. The validity and reliability of a diagnosis is a reflection of the accuracy of the input data. It is therefore essential that data stored on the computer represent the source data accurately and without bias. As the case vignette described above shows that the clinical oral medicine record is a 'multimedia' document. It can contain text, numbers, standardized codes, and radiographic, histologic, and clinical images. Unambiguous data that can be acquired using reliable methods do not present a particular challenge for representation on the computer. However, these types of data are relatively rare in oral medicine practice.

The assessment of clinical data by practitioners can be subject to significant variability. For instance, when we describe a patient's gingiva, we may use terms such as 'pink', 'red', 'stippled', or 'edematous'. In the absence of standardized measurements for these attributes, it is left to the clinician to determine the difference and nuances. In addition, higher-level concepts, such as 'erythema' or 'inflammation' integrate many different attributes, further increasing the risk of inter- (and intra-) observer variation. While we can store such clinical data as text strings on the computer, we cannot easily capture the concepts that they represent. Younai and Messadi (2000), for instance, found that the absence of visual information lowered diagnostic accuracy in a pilot study of a text-based oral medicine consultation system.

How to translate clinical observations into data on the computer is, therefore, first and foremost a human and professional, rather than a technical, problem. Computerized acquisition of data can provide a solution, but only a partial one. For instance, computerized periodontal probes can help improve the reproducibility of pocket measurements (Alves *et al*, 2005). Images, which most individuals would consider as a reliable method of documentation, can be subject to variation due to differences in lighting, capture and other factors.

How should data be standardized?

It is obvious that clinical and histopathological terms used in oral medicine must be more clearly defined and validated than they are now. The continuous debate regarding leukoplakia is an example. van der Waal (2009) recently discussed the lack of consensus regarding diagnostic criteria and level of certainty for the diagnosis, identified the need for uniform reporting, and recommended the use of a global classification and staging system.

Information technology can assist oral medicine in acquiring standardized data, but only if the profession can agree on standards and definitions. Our objective, therefore, should be to convert the existing professional language into a formulation that can be understood and operated on by computers. 'White patch' and 'leukoplakia' may sometimes signify the same thing to

oral medicine clinicians but not to computers. Thus, one challenge is to develop well-defined international terms for the clinical descriptors to achieve semantic interoperability (Hayrinen *et al*, 2008).

Terminologies (Humphreys *et al*, 1997), controlled vocabularies and ontologies (Bodenreider, 2008) are well-developed biomedical informatics approaches that can help translate these standards into computer-based representations. Ontologies build on terminologies and controlled vocabularies, and represent the knowledge within a domain through concepts and the relationships between them (Stevens *et al*, 2000). Examples of such efforts include SNOMED (Systematized Nomenclature of Medicine), which has been used for several decades (Wells, 1972; Smith and Brochhausen, 2010); SNODENT, which is an effort by the American Dental Association (ADA) to develop a controlled terminology for dentistry (Torres-Urquidy and Schleyer, 2006); and the Ontology for Dental Research (Smith *et al*, 2010).

Clearly, the oral medicine community is unlikely to agree on a comprehensive set of standardized concepts in the near future. It is therefore reasonable to begin with narrow and focused domains in which consensus is likely to be reached quickly, and then broaden the effort to more ambiguous areas. Any standardization effort should allow for the use of localized and new concepts to allow oral medicine practice to evolve.

As a consequence, analyzing and learning from clinical information should be regarded as a continuous process. Electronic records for oral medicine should be flexible with regard to the data that they capture and how they represent them. New knowledge and scientific hypotheses require continuous adaptation and evolution of the clinical data collection process. Ideally, the end user should be able to perform this type of maintenance on the EPR without having to involve a programmer.

How can computers support the clinical workflow and efficient, effective and accurate decision making by the clinician?

Beyond data collection, computers must support the clinical workflow and efficient, effective and accurate decision making by the clinician. In this context, we need to consider the effects of technology on the clinical workflow; the cognitive and information needs of the clinician; the influence of information design on clinical decision making; the integration of external knowledge resources with the decision-making process; and the potential role and utility of decision support systems.

As previous studies have shown, the clinical workflow in dentistry tends to be highly collaborative, complex and non-linear (Irwin *et al*, 2009). Technology often results in breakdowns, which interrupt the workflow, cause rework and increase the number of steps in the work processes. Irwin *et al* concluded that current dental software could be significantly improved with regard to its support for communication and collaboration, workflow, information design and presentation, information content, and data entry (Irwin *et al*, 2009). This likely applies to the oral medicine arena as well.

Within the context of the workflow, the cognitive and information needs of the clinician deserve particular attention. Good system design often begins with an investigation of how clinicians review and process information (Nygren and Henriksson, 1992; Nygren, 1997; Jaspers *et al*, 2004). Methods such as cognitive task analysis and think aloud protocols can help determine cognitive processes during diagnosis and treatment planning. Without a good understanding of how clinicians review, analyze, and process clinical information, the design of effective computer-based tools to support these activities is severely handicapped.

Once workflow and cognitive requirements are known, we can leverage a significant advantage of computers compared with paper: the capability to arrange and display information in multiple and flexible ways. Previous studies indicate that the display of information on the computer can have significant effects on the performance of tasks by clinicians (Elting *et al*, 1999; Thyvalikakath *et al*, 2007). For instance, Elting *et al* (1999) found that study participants made correct decisions significantly more often with icon displays (82%) than with either pie charts or bar graphs (both 56%). It is therefore important to consider the influence of screen design and information presentation on clinical decision making.

External knowledge resources are important in helping clinicians make valid and reliable decisions. At this time, computers still appear to play only a minor role in this context. Coumou and Meijman (2006) concluded that primary care physicians, despite the availability of electronic information, still principally consulted colleagues and paper sources. In studying dentists' information needs, Song *et al* (2010) recently found that '*A major challenge in designing useful clinical information systems in dentistry is to incorporate clinical evidence based on dentists' information needs and then integrate the system seamlessly into the complex clinical workflow*'. As oral medicine evolves toward a more evidence-based mode of practice (Sackett *et al*, 1996), we must consider how to integrate evidence-based information with the work of the clinician, as well as how clinical practice can help in improving the evidence (as discussed below).

A final consideration with regard to decision making is the potential role and utility of clinical decision support systems (CDSS) (Lyman *et al*, 2010). CDSSs are designed to provide expert support for health professionals making clinical decisions (Mendonca, 2004). A recent review concluded that many medical CDSSs improved practitioner performance, but also that the effect of patient outcomes was understudied. When studied, the results were inconsistent (Garg *et al*, 2005). In dentistry, CDSS use is not widespread. Very few of the systems reviewed by White (1996), Mendonca (2004) and Khanna (2010) appear to be in routine use. The question of whether decision support systems would be beneficial in oral medicine is currently open. The development of CDSSs is complex, necessitating a close collaboration between clinicians and computer specialists over a long period. Rigorous evaluation studies need to determine whether CDSSs have clinical utility. At

present, the development of CDSSs in oral medicine appears to be neither pressing nor imminent.

How can clinical data be used to generate knowledge?
A direct implication of enhancing oral medicine's capability to collect and manage data in a standardized fashion during routine clinical encounters is the ability to generate knowledge and advance clinical practice in the process. At present, data generated by clinicians during clinical care are sometimes used for research, but this type of research is often of limited value when the data lack validity and reliability.

Typically, research studies are conducted as one-off projects in academia or industry. Two scenarios for the collection and analysis of data for research are common. In the first, the study is focused on a specific diagnosis or clinical question according to established criteria in a prospective manner. The form for registration of data is developed based on the particular questions and parameters of interest. The study can either be conducted locally or multi-center. In the second scenario, an aggregated database is used for testing various hypotheses. Doing so is enormously difficult using paper-based systems because hardcopy data cannot easily be rearranged and manipulated. Using a flexible, computerized database, however, researchers can perform various queries on the data to explore analyses and hypotheses. Saalman *et al* (2010) used this approach successfully to detect a novel type of long-standing oral mucosal lesion that shared some features with orofacial granulomatosis in children after solid organ transplantation. Similarly, Jontell *et al* (2005) have developed MedView, an analytical tool for oral medicine data. Using MedView, the distribution of a set of data, for example by age or gender, can easily be visualized. MedView provides 'drill-down' capability, which allows the user to navigate through the data to the level of individual patient data, such as clinical findings and images.

Once data are collected and represented in a standardized manner as described above, they become highly useful for research. Standardized data can be aggregated for specific clinical questions or studies in the local as well as in a multi-center context. Knaup *et al* (2007) describe an interesting example for conducting multi-center clinical trials in pediatric oncology in which EPRs have been used for cooperative care and research for more than a decade (Knaup *et al*, 2007). The system is currently used by 20 pediatric oncology centers in Germany, which all use their own local hospital information system. The overall aim of the project was to create an application which was strictly focused on the questions clinicians wanted to answer using the documentation system. The application developed was as independent of particular technologies and focused on adaptation to existing computer platforms, a defined terminology and an end-product which could provide answers to specific questions of interest. It is tempting to view the experiences from this very problem-oriented project in relation to contemporary research needs in oral medicine.

In addition, standardized collections of data can also help support other activities, such as quality assurance (Filker *et al*, 2009), monitoring of trends and outcomes assessment. For instance, using standardized data and reports clinicians can analyze individual patients, patient cohorts or whole practice populations. Public health officials can examine distribution and trends of disease, and treatment outcomes in oral medicine.

How should electronic patient records support clinical work in a multi-platform, multi-provider environment?
The majority of electronic dental records are commercial programs developed for general dentistry, rarely suitable for oral medicine purposes. Moreover, OMPs often work in institutional settings which mandate the use of specific health information systems, such as hospital-based Admissions-Discharge-Transfer or Picture Archiving and Communications Systems. As a result, oral medicine departments sometimes develop their own, proprietary applications to 'fill in' the gaps among the systems they use.

The resulting collection of systems is, most of the time, not interoperable (Di *et al*, 2006). In supporting clinical work, this situation brings significant disadvantages at two levels. First of all, data must be managed in separate 'silos' or databases, often forcing double registration or, at least, duplicate storage (Schleyer, 2004). Second, it is hard for clinicians to review patient data efficiently and effectively when they are spread over more than one system, and displayed on different screens and in different formats (Schleyer, 2004; Thyvalikakath *et al*, 2008). Obvious benefits result if aggregated data can be stored in a database where all participants can view and learn from obtained information (Bui *et al*, 2002; Afantenos *et al*, 2005; Chen *et al*, 2008).

To be useful for OMPs, EPRs for oral medicine must be designed to present the right information in the right format at the right time and place. There are currently only few examples within dentistry where attempts have been made to integrate medical and dental history, oral status, treatment planning, and progress notes into a database (Peterson *et al*, 1995; Wagner *et al*, 2008). In light of recent advances in understanding oral-systemic connections, the integration of medical and dental information for individual patients has been recommended (Din and Powell, 2008). However, few systems, notably the Veterans Administration and the Marshfield Clinic (Wisconsin) in the US, have implemented this integration in practice.

An additional challenge in supporting clinical practice in oral medicine adequately is the fact that much of the care is delivered collaboratively by multiple providers, such as physicians, OMPs, pathologists, dermatologists and others. Unless those providers are able to access the same electronic record systems, for instance by working in the same organization, meaningful exchange, shared review and management of information about a patient is difficult (Pratt *et al*, 2004). Electronic records for oral medicine must, therefore, support collaboration both in

local as well as multi-center settings. Beyond multi-center environments, collaborative care and consultation can also involve colleagues anywhere through the Internet (Younai and Messadi, 2000; Falkman *et al*, 2008).

One example of computer-based support for a multi-center activity is the Swedish Oral Medicine Network (SOMNet). The network started in the middle of the 1990s and involved four oral medicine clinics. Today the network has some 110 associated clinicians. All involved clinicians can submit cases for consultation or discussion to a central server. The clinical information for each entered case since 2006 is registered with an application called SOMWeb (Falkman *et al*, 2005, 2008). With this application, information is entered with formalized criteria in a similar manner as in MedView (Jontell *et al*, 2005), which means that all cases include information on general medical condition, drugs, symptoms, laboratory-results, performed treatment, and treatment outcomes. Clinical photographs of mucosal lesions are always included. Results and images from histopathological or radiological examinations, as well as references to relevant literature can also be included. All gathered information is visible to the members in the network but the identity of the patient is only known to the responsible clinician. The cases are then discussed via telephone conferences which are held on a monthly basis, and may concern both diagnostic and therapeutic aspects. New cases are continuously added to the database which is searchable according to any combination of included formalized information. SOMWeb was recently evaluated in a doctoral thesis (Gustafsson, 2009). One conclusion was that the collected knowledge of SOMNet had the possibility of having a large health impact, both by specific suggestions on the case and also by exposure to the reasoning of the senior members.

Figure 2 shows a global overview of how future IT support for oral medicine could be architected. This overview is partially based on the structure of the SOMWeb system. The EPR would be based on both a general system, which exists in many oral medicine settings, as well as an oral medicine system that meets the specific needs of OM. The OM system includes a toolbox with which developers and clinicians can create and maintain a variety of forms that are based on standard ontologies. In addition, analytical tools and decision support systems help support the work of the clinician. External clinical information is integrated into the system to provide the clinicians with evidence-based information and other decision aids. Aside from facilitating clinical care, the OM system can be used to support education and research.

Proposed solutions and strategies

Technology does not function on its own, but is embedded in a complex behavioral, social, professional and organizational context (Kaplan *et al*, 2001). Therefore, considering solutions for meeting the needs and desires of OM professionals described in Needs of and requirements for information technology support of oral medicine only from a technical perspective is almost guaranteed to fail.

As discussed in the introduction, the oral medicine and information technology domains must collaborate closely in a mutual understanding of each other's needs and expertise to produce appropriate solutions. This collaboration should be founded on the principles of

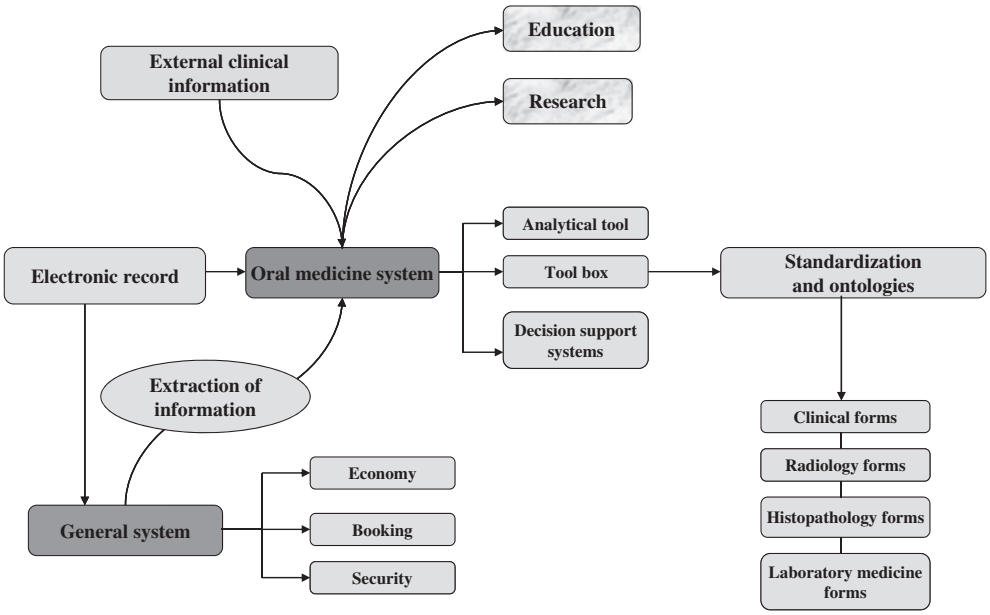

Figure 2 A global overview shows how information technology can help support clinical care, education and research in oral medicine. The electronic patient record would be based on both a general system as well as an oral medicine system that meets the specific needs of OM. The OM system includes a toolbox with which developers and clinicians can create and maintain a variety of forms that are based on standard ontologies. In addition, analytical tools and decision support systems help support the work of the clinician. External clinical information is integrated into the system to provide the clinicians with evidence-based information and other decision aids

user-centered design (UCD), which is an approach to designing computer systems and software applications that focuses on the user's needs, wants and abilities as central elements of the design process (Beyer and Holtzblatt, 1998; Christensen and Grimsmo, 2005; Schleyer *et al*, 2007). UCD does not assume that technologists and developers 'know better', but that users implicitly can guide a design process toward a product that is intuitive, easy to use and useful.

In the following, we propose an agenda for research and development for OM designed to pave the way toward more efficient and effective support of OM with information technology. This agenda should be matched by a corresponding one in IT, which we describe briefly.

A common recommendation for computerizing business processes is to analyze and possibly reengineer the workflow, regardless of the discipline. The OM community should evaluate current practices and determine which should be maintained in their current form, and which should be modified or abandoned. This review should not only focus on how data are entered, but also how they are managed and analyzed. Once consensus has been reached, IT can effectively document and propose solutions for supporting the resulting best practices.

As emphasized above, clinical and histopathological terms used in oral medicine have to be more clearly defined and validated. To date, standardization of data in clinical healthcare has had limited success. Any new initiatives must build on an intimate understanding of the reasons for these failures to avoid repeating past mistakes.

It is most likely naïve to assume that standards can be developed and adopted throughout the international oral medicine community in the foreseeable future, aside from the obvious linguistic barriers. Our recommendation is to begin the process on a small scale where a group of clinics and computer experts with genuine interest work together to define standards and harmonize criteria. Emphasis should be placed upon openness and shared input, focus on the user, and open software and sources. These development efforts should be accompanied by intensive educational efforts to promote adoption and subsequent evaluation. By setting good examples, the group may be widened over time. Once clinical and histopathological terms are more rigorously defined, they can be used to establish clinical diagnoses, treatment outcomes, and other variables of interest, with more consistency and reliability.

Concomitant with progressively standardizing clinical data, the OM community should consider examining its practice processes and protocols. Ideally, evidence-based reviews and approaches would help determine which diagnostic and treatment strategies are most likely to lead to success. In the process, treatment outcomes need to be defined and validated from both the clinician's and the patient's perspective. Standardized, agreed-upon protocols can then be supported by IT solutions to the benefit of the OM community.

As discussed above, it is currently uncertain where and under which circumstances computerized decision support would be useful and appropriate in OM. Here again expert panels could be used to lead the establishment of these CDSSs, and their potential implementation in clinical practice and education. An initial evaluation of areas where CDSSs may be of greatest benefit would provide a focus for the direction of these expert groups.

These initiatives could be facilitated by establishing small, focused expert panels, possibly combined with multi-center collaborations. Expert panels could provide the theoretical framework which could be tested and evaluated with actual patient cases in a small multi-center collaboration. Once proven in practice, such approaches could be scaled up to a larger number of centers and patients, thereby enabling more rigorous and scientifically valid clinical trials.

A corresponding agenda for informatics/information technology should first focus on determining the current use of, attitudes toward, opinions about and satisfaction with electronic systems currently in use by OM professionals. Such research could provide important baseline information, and insights into perceived strengths and weaknesses of current products, and threats to and opportunities for support of OM with IT.

With this information as background, detailed study of information needs of OM professionals, as well as the cognitive strategies they use during care, should be pursued. Once information and how it is used is well understood, the development of controlled vocabularies and ontologies can help the OM professional generate structured data. However, exclusively relying on controlled vocabularies as a means to represent data is too restrictive. Therefore, EPRs must provide a certain degree of flexibility to accommodate local, regional or national variation, and advances in clinical and scientific knowledge.

Results from these research activities can be used to develop application designs that support practice and research in OM more effectively and efficiently than current computer applications do. These application designs should integrate data from different systems during the care of a single patient by a single practitioner, and make available information from external sources for decision making. In addition, they should support collaborative, multidisciplinary care by teams of healthcare professionals.

Discussion

The use of electronic systems in healthcare is growing rapidly. If current barriers and obstacles are overcome, practice and research in oral medicine stand ready to derive significant benefits from the application of information technology. In this article, we have reviewed the needs of and requirements for information technology support of oral medicine, and proposed solutions and strategies to meet them. Our agenda is clearly ambitious and will require the concerted efforts of many stakeholders to succeed.

We see four groups of people as crucial in successfully pursuing the benefits that IT could provide in oral medicine: OMPs, ITPs, system vendors and funding agencies. As described, OMPs should work toward a more standardized and reproducible approach to practice. OMPs should to collaborate with ITPs to conceptualize, design and develop appropriate IT solutions for oral medicine practice and research. System vendors could help in implementing those solutions if they align with their business model and offer the prospect of a viable market. Lastly, funding agencies should provide the resources necessary for useful and valuable clinical trials that are performed using newly developed IT infrastructures. Correctly designed, these infrastructures can help conduct clinical investigations with greater efficiency and at a lower cost than currently possible.

To facilitate collaboration, OMPs need to gain a deeper understanding of informatics and information technology. Educational programs for informatics/information technology specific to dentistry exist, but are rare at the certificate, master's and doctoral level (Schleyer, 2000). In addition, not many practicing OMPs may have the option to complete a lengthy on-site program. For those, a growing number of distance education programs in health informatics may be useful.[1] Another option may be to integrate curricular content in informatics in oral medicine training programs.

While our proposed agenda may seem daunting, we do not consider it unachievable. We suggest starting with small, focused projects that are guided by a larger, comprehensive vision. One idea would be to try to integrate basic patient data from two or more commonly used commercial systems, or to expand oral medicine-specific systems, such as SOMWeb, to a larger, international audience. Future World Workshops in Oral Medicine may be an ideal venue to conceptualize and begin such projects. The process of developing electronic systems for oral medicine should not be considered a short-term project, but be supported by a long-term view of continuous evolution and enhancement.

In conclusion, we believe that information technology, when properly used, has a huge potential to benefit oral medicine. To achieve these benefits, we must think beyond the concept of the simple EPR as a ready tool to solve our problems. The task ahead is far more complex, and requires that we critically assess and improve data standardization, practice processes, existing and future systems, and interoperability in oral medicine. Further, we must articulate our problems and needs to informatics/information technology experts. If we can collaborate through a mutual understanding of each others' expertise, there is every reason to believe that dental informatics, information technology and oral medicine can develop a close and productive partnership for the benefit of patients, clinicians, and researchers.

[1]See https://www.amia.org/informatics-academic-training-programs

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Author contributions

T. Schleyer, U. Mattsson and M. Jontell have spent most time writing up the paper. The rest of the authors have contributed equally.

Conflict of interest

None.

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