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Decision support systems for adoption in dental clinics: A survey

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ABSTRACT

While most dental clinicians use some sort of information system, they are involved with administrative functions, despite the advisory potential of some of these systems. This paper outlines some current decision support systems (DSS) and the common barriers facing dentists in adopting them within their workflow. These barriers include lack of perceived usefulness, complicated social and economic factors, and the difficulty for users to interpret the advice given by the system. A survey of current systems found that although there are systems that suggest treatment options, there is no real-time integration with other knowledge bases. Additionally, advice on drug prescription at point-of-care is absent from such systems, which is a significant omission, in consideration of the fact that disease management and drug prescription are common in the workflow of a dentist. This paper also addresses future trends in the research and development of dental clinical DSS, with specific emphasis on big data, standards and privacy issues to fulfil the vision of a robust, user-friendly and scalable personalised DSS for dentists. The findings of this study will offer strategies in design, research and development of a DSS with sufficient perceived usefulness to attract adoption and integration by dentists within their routine clinical workflow, thus resulting in better health outcomes for patients and increased productivity for the clinic.

1. Introduction

The number of dental clinics using information technology has been increasing. Over a decade ago, information systems (IS) in dental clinics were already relatively matured in providing logistic and administrative support [67]. These systems were usually "designed primarily to facilitate administrative functions" centred on billing or at most, automating functions such as appointment alerts and reminders [1]. Though these functions bring about a positive change in the diagnostic behaviour of clinicians, there was still a prominent lack of advisory features such as decision support for clinical functions. This explains the increase in international research interest in the efficient design and adoption of IS and information technology in a typical dental practice [66].

With the potential benefits associated with DSS, it will be exciting to see more research carried out to enable a robust system that can fit within the clinical workflow of the dentist to be used as a diagnostic tool at point-of-care. With this motivation in mind, this paper explores the various barriers that hinder the adoption of clinical decision support by dentists and the key features that dentists desire in a clinical DSS.

There is general consensus that the use of clinical DSS will have potential to improve treatment outcomes [31]. Thus, to fully utilise the computational power of technology within the clinical environment, the use of IS should extend beyond administrative and alert functions to provide advisory functions tailored to the individual patient's medical and dental condition.

This study has observed that for dentists to adopt a clinical DSS within their workflow, the system should have a reasonably fast response time, be easy to use, and provide information on treatment planning as well as assistance on drug prescription based on individual patient profiles. In order to facilitate drug prescription effectively, a dataset which integrates all available sources is needed. However, besides the work done in [3], no attempt has been made so far in combining all the available drug information into a single dataset [3]. Hence, a system that conforms to our recommendations of a personalised system will contribute to the productivity and efficiency of dental treatment, as well as significantly reducing the occurrence of errors in drug prescriptions. This is crucial as medical negligence can lead to expensive legal suits. With timely and accurate diagnostic treatment planning from such a clinical DSS, more comprehensive treatment options can be made available to patients and practitioners, thus contributing to improved health outcomes for the patient and job satisfaction for the dentist.

This survey will also benefit vendors designing and developing practice management software for dentists. Awareness of the

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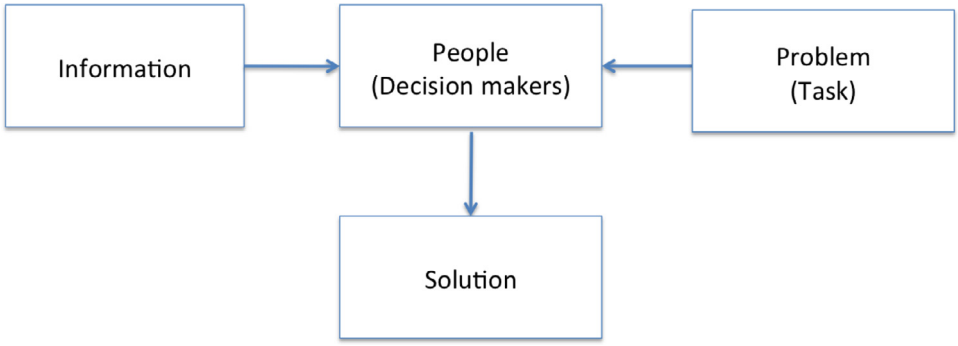

Fig. 1. Design of a typical decision support system.

barriers against adoption of an IS in a dental clinic, the expectations and requirements of dentists for such a system, and important factors such as perceived usefulness, sociocultural and economic factors, and ease of interpretation, will aid vendors in customising a more relevant and efficient system. Providing comprehensive and consistent knowledge through a DSS will result in increased demand for such systems [54].

Besides the contribution to the efficient treatment planning of dentists and assisting vendors in their design of systems for clinical implementation, this paper also has high value for the research community. Understanding the requirements of a clinical DSS that matches the expectations and requirements of dentists will help provide strategies in research agenda and priorities such as methodologies for knowledge reasoning and inference in the context of a dental clinic, thus further enhancing the potential for a seamless integration of a robust, user-friendly and scalable diagnostic tool within the clinical workflow of a dental clinic.

Section 2 continues with a description of the basic structure of a DSS with examples of some recent applications, followed by a brief description of clinical DSS in terms of the basic technology underlying their designs, classifications and benefits in Section 3. Section 4 then highlights some of the barriers facing the user with Section 5 giving a broad survey of current DSS that attempt to overcome these by improvements in interface design, as well as integration of disparate knowledge bases. The paper concludes by discussing future trends in the design of DSS in terms of big data, personalisation and standards, and privacy issues.

2. Decision support systems

Although the focus of this paper is clinical DSS, it is important to understand that these systems belong to the larger group of DSS, where the purpose is to provide decision makers a means to make decisions. Such an understanding from the perspective of general DSS will help support awareness of the functions and features expected of clinical DSS. Fig. 1 illustrates a design structure of a typical decision support system.

When there are more than one decision maker, the process can be complicated, all the more when the information available can be subjective, objective, a combination of both, or even fuzzy. The problem and solution in a dental clinic refers to the treatment that best suits the patient. As shown in Fig. 1, the decision made by the decision maker will depend on the problem itself which would influence the criteria adopted by the decision maker as well as relevant information pertaining to the problem. Such an approach is reflected in the popular PICO model [64] used by doctors in clinical assessment within an evidence-based practice. This framework guides the practitioner in gathering information by asking questions related to information on the Patient (P), Intervention process (I), Comparison with other alternatives (C) and the Outcome to be achieved (O) which is the clinical problem the practitioner is trying to solve or diagnose. In most clinical situations, the patient can also act as the decision maker where information in terms of financial cost and aesthetic demands can influence the final outcome of the decision.

Therefore, a decision making process would normally be influenced by the individual's role as the decision maker, their preferences and the criteria used to make the decision [37,39].

Generally, such complex decision making structure is determined by classical decision theories such as classical formal and empirical-cognitive decision theory, the theory of multi-criteria and/or multi-objectives decision making and the theory of group decision making. Interested readers may refer to [38] for more in-depth discussions.

Applications exist to put such theories into practice especially in the growing area of multi-criteria group DSS. For example, the "Decider" system, a fuzzy multi-criteria group DSS [41], takes into account the nature of information which in reality is usually expressed in linguistic terms, and the hierarchic structure of the problem and the decision makers.

Other areas of application where group decision making is based on multiple criteria include new product development such as for garments [40] and digital scales [86] where preferences regarding the product have to be considered, and the car manufacturing industry where budget and time constraints are critical [35]. Another interesting application of DSS is to support a group of users in the choice of vacation packages [45]. Besides commercial applications, DSS are also found in areas that require long-term planning for sustainable development, for example, energy policy planning [62] and forest management [52].

Similar to the system established by Lu et al. [39] where fuzzy numbers are used to handle the uncertainties in the role of decision makers and the criteria used to arrive at the solution, a recent system in [59] uses fuzzy logic to construct a clinical DSS based on information input in the form of probability distributions. The unique aspect of this system is that the outcome given is not the single most desired solution, but rather, a set of solutions. By expressing the conclusion in this way, patients are more likely to accept the diagnostic decision from the health practitioner [23] (Table 1).

In terms of DSS for dentists, the information needed before the final treatment is decided will include the preferences of the patient in terms of cost and quality. For example, a fuzzy cognitive map is used to help the dentist decide on a suitable implant abutment for patients [34], combining expert knowledge from dentists and suppliers in the decision making process. Similarly, fuzzy logic is used by the system proposed by Ma et al. [42] to identify symptoms from patients, which are usually vague, making it difficult for the dentist to reach a detailed and definitive diagnosis.