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Shared decision support system on dental restoration

Seon Gyu Park [a], Sungin Lee [b], Myeng-Ki Kim [a], Hong-Gee Kim [b,c,*]

[a] School of Dentistry, Seoul National University, 28 Yongon-Dong, Choong-gu, Seoul 110-749, South Korea
[b] Biomedical Knowledge Engineering Laboratory, Seoul National University, 28 Yongon-Dong, Choong-gu, Seoul 110-749, South Korea
[c] Dental Research Institute, Seoul National University, 28 Yongon-Dong, Choong-gu, Seoul 110-749, South Korea

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ABSTRACT

Shared decision making (SDM) is an approach in which doctor–patient communication regarding available evidence and patient preferences is facilitated to enable the patient to participate in treatment decisions. SDM affords not only the inclusion of the ethical diversities involved in patient-centered care, but also the quality improvements in decision-making process. Though SDM has been studied extensively, there have been few practical implementations in real clinical environments. In this paper, we propose a shared decision-making system with its focus on dental restorative treatment planning. In our system, restorative treatment alternatives for SDM were generated by employing an ontology that had captured the clinical knowledge required for treatments. We considered patient preferences for treatment as an important support for mutual agreements between the patient and the doctor on healthcare decisions. We constructed a consistent and robust hierarchy of preferences using the analytic hierarchy process (AHP) method, to help determine treatment priorities. On the basis of our proposed system, we developed a Web-based application for the visualization of evidence-based treatment recommendations with preference-based weights. We tested our system using a scenario to illustrate how doctors and patients can make shared decisions. The application is of high value in supporting SDM between doctors and patients, and expedites effective treatments and enhanced patient satisfaction.

1. Introduction

A clinical decision support system (CDSS) is an application designed to assist health professionals in decision-making tasks as in regard to diagnosis and treatment planning (Shortliffe, Perreault, Wiederhold, & Fagan, 2001). Focusing on dentistry, there are only a few relevant studies exploring the potentials of CDSS. For instance, Brickley et al. (Brickley & Shepherd, 1996) developed a neural network application to provide decision support for lower third molar treatment-planning. Other CDSS examples for dentistry are caries management (Benn, 2002) and intelligent dental treatment planning (Finkeissen et al., 2003). However, none of these CDSSs were designed to consider patient preferences for enhancing the quality of patient-centred, or personalized, services and thereby improving patient satisfaction.

Restorative treatment decision making by dentists and patients often exhibit wide variations (Bader & Shugars, 1995). This appears to be due to differences between patient preferences and clinical judgments. Typically, dentists and patients exhibit differences in their preferences for dental restorative materials. For example, dentists tend to choose one with high longevity, while young patients are sensitive to aesthetics (Espelid et al., 2006). According to (Vidnes-Kopperud, Tveit, Gaarden, Sandvik, & Espelid, 2009), dentists use tooth-coloured restorative materials more often than dental amalgams for restorations in stress-bearing areas in young patients. In general, it is recommended that dentists consider patient preferences for dental restorative treatment alternatives prior to making a treatment decision, if the physical characteristics of the materials are not critical. Patients also tend to participate actively in the restorative treatment planning process when options abound and when they have material preferences (Oates, Fitzgerald, & Alexander, 1995). Furthermore, increased levels of patient participation tend to promote their satisfaction with treatment outcomes.

Shared decision making (SDM) is an alternative to the paternalistic care model (Charles, Gafni, & Whelan, 1997). It enables both patients and clinicians to reach mutual agreements on appropriate health care and treatment decisions (Frosch & Kaplan, 1999). In SDM, the patient is provided with all available evidences and information about a given medical problem, and the suitability of each alternative treatment plan is measured in relation to the patient preferences. SDM is a relatively new concept with a few implementations in health care settings. Implementation obstacles of SDM

* Corresponding author at: Dental Research Institute, Seoul National University, 28 Yongon-Dong, Choong-gu, Seoul 110-749, South Korea.
E-mail addresses: iontiger@gmail.com (S.G. Park), sunginlee@gmail.com (S. Lee), meeree@snu.ac.kr (M.-K. Kim), hgkim@snu.ac.kr (H.-G. Kim).

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include the task complexity, lack of time (Gravel, Légaré, & Graham, 2006), and missing information (Elwyn, Edwards, Gwyn, & Grol, 1999). In dentistry, Johnson et al. (Johnson, Schwartz, Goldberg, & Koerber, 2006) devised the Endodontic Decision Board (EndoDB) as a decision aid, a popular SDM approach. Though EndoDB facilitates the communication between patients and clinicians through the articulation of alternatives between dental treatment processes, it does not effectively identify or discuss preferences from patients' perspectives and is not suitable for complex, busy clinical settings. The analytic hierarchy process (AHP) is one of the most well-known and widely used multi-criteria decision making (MCDM) methods. It is specifically designed for dealing with complex decisions that require the integration of quantitative data and qualitative considerations. AHP has been successfully applied to decision making processes across a wide variety of fields including health care (Liberatore & Nydick, 2008), resource allocation, and quality management. It provides both a patient and a doctor with a simple and robust mathematical method for measuring or visualizing preferences in the form of a psychological hierarchy tree with pairwise comparisons (Dolan, 2000), and patients find AHP as a suitable tool for sharing their preferences with their doctors (Singpurwalla, Forman, & Zalkind, 1999).

A knowledge-based system that supports CDSSs in SDM requires a considerable amount of domain knowledge (Musen, 2001). A reusable and application-independent domain ontology, or structural framework, would be able to minimize the efforts required for knowledge attainment (GRUBER, 1993). Though CDSSs are developed using ontologies, few are applied to dental restorative treatment planning systems. In our previous study (Park, Lee, Kim, & Kim, 2010), we developed an ontology to represent the concepts related to the decision-making processes involving the choice of restoration types. The ontology specified the tacit knowledge of doctors participating in SDM, thereby facilitating communication and knowledge sharing between the doctors and the patients.

The paper proposes a shared dental restorative treatment decision support system that manages the knowledge required for problem-solving and converts it into a machine-understandable form, an ontology. The system computes priorities for treatment alternatives based on patient preferences for AHP methodologies. It offers doctors and patients common understanding on which shared decisions are reached based on patient preferences and accumulated clinical knowledge. The remainder of the paper will describe the system designs and illustrate a practical usage scenario.

2. Proposed approach

Our system (Fig. 1) collects the patient's dental information, such as the disease and affected location, through an oral examination. This information is entered into the ontology, which was first created and populated with knowledge gained both from journals and textbooks, and from consultations with dental experts. Evidence-based restorative treatment candidates are automatically obtained by querying the ontology that contains information about the patient's problem. In addition, the system quantitatively evaluates the preferences of the patient, such as convenience, price, aesthetics, and longevity of dental treatments. A priority for each of the previously gathered evidence-based treatment options is calculated using pairwise comparisons. Employing the AHP methodology, the preferences and evidence-based treatment options are arranged in order of priority. The dentist is now in a position to communicate the resulting decision aids with the patient and can make a definitive treatment plan.

2.1. Ontology design

When designing an ontology for dental restorative treatment plan formulation, we consider three main factors: tooth anatomy including spatial relationships, classification of diseases and findings, and restorative treatment options. We build the ontology, called TPSS (Treatment Planning Support System) ontology, which includes concepts and properties from ICD-10 (for diseases and findings) and the Foundational Model of Anatomy (FMA) ontology (for tooth anatomy). TPSS ontology is represented in the Web Ontology Language (OWL2) format. Its major classes and properties are described in the following. Properties are denoted in lowercase letters and bold, and classes in uppercase letters and italics.

ICD-10 acted as the basis for treatment options, which were further refined to represent restorative treatment options by combining diseases/findings with tooth anatomy concepts from the FMA. Juxtaposing the disease (and/or findings) with its location such as a tooth or jaw (i.e., mandible or maxilla) has led to more accurate treatment options as opposed to when dentists made restorative treatment decisions solely based on their beliefs or knowledge.

The FMA ontology is a reference ontology considered to be the most suitable template for aligning existing ontologies in the medical domain (Rosse & Mejino, 2003). Only those tooth-related concept classes were imported and converted to the OWL2 format while the original part-whole structure was kept. FMA uses frame-based formalism, and as such, if we carelessly convert it to description logic-based formalism, unintended conclusions or missing concepts may have resulted (Golbreich, Zhang, & Bodenreider, 2006). Therefore, we constructed a partonomic hierarchy by manually implementing **part_of** and **has_part** properties. In addition, we converted the tooth names into tooth numbers for convenience.

In regard to treatment alternatives, however, no comprehensive ontology exists that represents treatment alternatives. Furthermore, to our best knowledge, the existence of a relatively complete classification system or ontology on restorative treatment alternatives is very unlikely. Therefore, we manually created treatment alternatives using the concepts from the Unified Medical Language System (UMLS) metathesaurus.

The three bodies of knowledge—tooth anatomy, disease, and treatment—are semantically linked by the OBO Relation Ontology (RO) (Smith et al., 2005) and some application-specific properties. Three relationships such as **part_of**, **located_in** and **has_participant** are taken from the RO. The spatial relation **part_of** is to represent part-whole relationships. The **located_in** property is defined to be sufficiently broad to enable its use as a medium for spatial relationships. For example, each tooth has different functions, and this necessitates different treatment options for each function. The metal color of amalgam dictates that amalgam restorations cannot be used in esthetic zones, and hence, its location is restricted to posterior teeth. Therefore, we connected a treatment class (amalgam filling) to a tooth anatomy class (posterior tooth) using the **located_in** property as shown in Fig. 2. The **located_in** property not only represents a spatial relationship between biological objects, but also a rather broad connection between occurrents and biological objects, thereby effectively contributing to the development of a concise ontology (Schulz, Marko, & Hahn, 2007). A property in the RO that can link treatment (occurrents) and diseases (dependent continuants) is **has_participant**. Therefore, this property can be used to link diseases and findings with a certain treatment process. However, in order to make the property name more appropriate for our domain, we designed a new application-specific property **has_Indication** on the basis of the **has_participant** property.