Advanced Engineering Informatics 28 (2014) 153–165

Contents lists available at ScienceDirect

Advanced Engineering Informatics

journal homepage: www.elsevier.com/locate/aei

A knowledge centric methodology for dental implant technology assessment using ontology based patent analysis and clinical meta-analysis

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ARTICLE INFO

Article history:
Received 19 September 2013
Received in revised form 23 February 2014
Accepted 5 March 2014
Available online 13 April 2014

Keywords:
Patent analysis
Ontology schema
Meta-analysis
Clinical trials

ABSTRACT

The medical equipment industry has been one of the fastest growing sectors of the decade with predicted global sales reaching US$ 430 billion in 2017 [22]. During the period from 1995 to 2008, the patent applications in medical technology increased rapidly worldwide (World Intellectual Property Organization, 2012). Patent analysis, although useful in forecasting technology development trends, has posed a challenging analysis task since the volume and diversity of new patent applications has surpassed the ability of regular firms and research teams to process and identify relevant information. Further, medical related technologies rely on clinical trials to validate and gain regulatory approval for patient treatment even though patents, protecting the intellectual property rights of inventors, have been granted. This research focuses on developing a knowledge centric methodology and system to analyze and assess viable medical technology innovations and trends considering both patents and clinical reports. Specifically, the design innovations of dental implant connections are used as a case study. A novel and generic methodology combining ontology based patent analysis and clinical meta-analysis is developed to analyze and identify the most effective patented techniques in the dental implant field. The research establishes and verifies a computer supported analytical approach and system for the strategic prediction of medical technology development trends.

1. Introduction

The World Health Organization [59] reported that about 30% of the population whose age is between 65 and 74 are likely to lose some of their natural teeth. Dental implants are a medical treatment with a range of products used to restore oral functions when losing teeth to caries, periodontitis, or accident. The global dental implant and prosthetics market was valued at US $ 6.8 billion dollars in 2011 and is expected to reach US $10.5 billion dollars in 2016 [5]. The surgical success and consumer acceptance have increased the global demand for implants and the prosthesis market. The demand for dental implants continues to attract companies and researchers to improve the design and development of dental implant components, devices, and techniques.

Modern dental implants have been used since the 1960s [1]. Since then, many improvements in dental implants have been introduced resulting in a variety of patents filed and granted. Fig. 1 depicts the number of patents related to dental implants in the United States Patent and Trademark Office (USPTO) from 1990 to 2012. Most dental implants consist of implant bodies (screws embedded in the jawbone), abutments (the platform for connection between the implant and crown), and crowns (the aesthetic and functional artificial replacement to the tooth). Many forms of dental implant connections have been developed as a critical part of dental implant R&D to improve torque transfer, gain stability between the implant body and the abutment, and subsequently minimize implant connection failure. Thus, this research focuses on the case study of dental implant connections to demonstrate the knowledge centric methodology of DS technology assessment and trend prediction.

The FDA [17] establishes regulations for dental implants abutments and enforces rigorous procedures of mechanical tests and clinical studies. However, there are still some implant designs in

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http://dx.doi.org/10.1016/j.aei.2014.03.001
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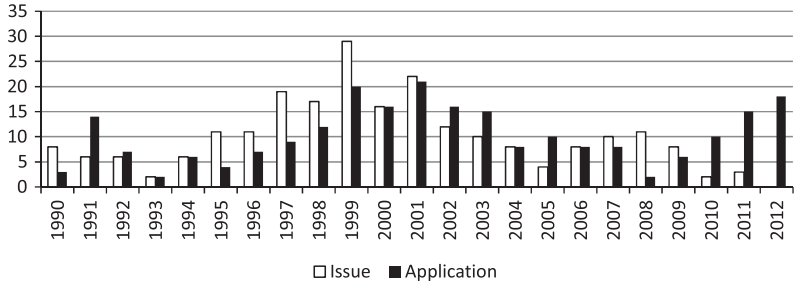

Fig. 1. US patents (1990 through 2012) filed and issued that are related to dental implants.

use with relatively high failure rates that pass the FDA regulations [46,2]. This research focuses on efficiently and accurately predicting medical technology trends with computer supported analyses of published patents and collective clinical trial literatures. Patent documents contain technical details of the innovations and inventions. In order to better understand the performance of new medical technologies and gain approval from regulatory agencies, reports of updated clinical trials on human subjects are also collectively analyzed. The objective of this research is to combine text mining, data mining, and meta-analysis within a specific domain, i.e., dental implant connections, including related patents and the corresponding clinical trials to better understand successful trends in medical technology innovation and adaptation.

2. Literature review

The literature related to dental implants, ontology, knowledge discovery, patent analysis and meta-analysis are discussed in this section. We first provide a brief background review of dental implants to provide a better understanding of the domain knowledge. The entire analytical procedure is based on domain specific (DS) ontology. The definition of ontology for knowledge representation and the ontology-based knowledge discovery applying text and data mining techniques are depicted in Sections 2.2 and 2.3. In Sections 2.4 and 2.5, macro- and micro-patent analyses and systematic meta-analysis of clinical literatures are described.

2.1. Dental implants

A dental implant is an artificial tooth root which is placed into a patient's jaw to hold a prosthesis replacing a missing tooth. Most dental implant systems consist of a crown, an abutment, and an implant body. Dental implant procedures are divided into two stages. First, the implant body is implanted into the jaw. Second, once the implant is stable inside the jaw bone, the abutment is connected to the implant body and the crown is attached to the abutment. The abutment is the component for connecting the implant body and the final outer crown or artificial tooth. The abutment usually connects to the implant body via a screw. One of the features which vary among dental implant systems is the type of connection that allows the abutments and prosthesis to be attached to the implant body. These connections include external connections, internal connections, or Morse taper connections [39] as shown in Fig. 2. Implant systems with external connections have a polygonal protrusion at the upper part of the implant body. For internal connections, the implant body has a notched polygonal cavity at the upper part which matches the polygonal protrusion at the abutment end. The internal hex connection combined with a Morse taper implant body is considered an alternative to the external hex implant [39]. Marginal bone loss (around the connection) is used as one of the most critical indicators of dental implant quality and long term stability (Papaspyridakos et al., 2012). New designs

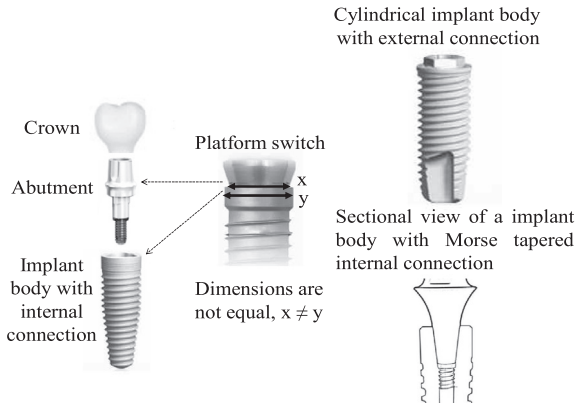

Fig. 2. Dental implant illustration and design variations.

of the implant-abutment interface, such as one-piece implants and platform switching (an implant body connected with a narrower abutment), have increased the success rate of implant technology [3]. However, the comparison of design effects has not been studied and there is no research demonstrating which design has a greater impact on implant quality and long term success.

2.2. Ontology

An ontology is an explicit specification of a knowledge domain and consists of a set of concepts, relations, objects and functions [24]. Another definition given by Grüninger and Fox [25] is the ontology is a formal description of a set of entities and their properties, behaviors and relations. Therefore, the ontology is considered to be a representational model of some portion of a real world knowledge domain [28] and is a set of objects and the relationships among these objects, which may be represented in the form of graphs and figures. The ontology types include terminology based ontologies, information ontologies, and knowledge modeling ontologies [26]. Domain ontologies focus on a specific field and describe the concepts of the domain entities as well as the attribute values and characteristics of the domain. Researchers focus on a specific domain through the visualization of knowledge, but there are no standard procedures to build specific ontology. Ding and Foo [15] define the methods used to construct an ontology as bottom-up, top-down and middle-off depending on how the ontology schema is initiated (e.g., bottom-up patching and synthesizing, top-down detailing and propagating, or working from both ends). The ontology reasoning technique is widely applied in the application of expert systems, artificial intelligence, and knowledge management in industry. Liou et al. [34] proposed a development procedure that includes planning, design, testing and modification, deployment, and integration to build an ontology based database. Trappey et al. [49] proposed a method for automatic patent document summarization which used ontology trees to