Enhancing Trust in Dental Care Recommendation Systems:

Using Trust-enhanced Information from Social Networks to Improve the Matching between Patients and Dentists

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CERTIFICATE OF ORIGINAL AUTHORSHIP

This thesis is the result of a research candidature conducted jointly with another research organisation as part of a collaborative Doctoral degree. I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as part of the collaborative doctoral degree and/or fully acknowledged within the text.

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Signature of Student:

Date:

To my parents
(my father the late Indra Prasad Dev Pradhan
and
my mother Kamala Pradhan)
for their support and inspiration.

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I have been tutoring IT subjects at the University on a part time basis while working full time in the industry. In 2010, I wanted to continue my studies and start my PhD degree. My wife also encouraged me to fulfil my dream to obtain a PhD degree. Due to the explosive growth in social networking sites, I decided to explore social trust that can be derived from these sites. So, I decided to work in trust models for recommendation systems with great help from my supervisors.

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Published Papers

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2. Pradhan, S., Gay, V. and Nepal, S. "Analysing and using subjective criteria to improve dental care recommendation systems", The 19th Pacific Asia Conference on Information Systems (**PACIS 2015**), Singapore, 6-9 July 2015. <Online: http://aisel.aisnet.org/pacis2015/99>. (**nominated for the Best Paper**) – ERA 2010 'A' Conference

3. Pradhan, S. "Use of Design thinking: a step towards fostering creativity and innovation in a teaching environment" case history submission to The Innovation & Entrepreneurship Teaching Excellence Awards, 10th European Conference on Innovation and Entrepreneurhip (**ECIE 2015**), Genoa, Italy, 14-18 September 2015.

4. Hawryskiewycz, I, Pradhan, S. and Agarwal, R., "Design thinking as a framework for fostering creativity in Management and Information Systems Teaching Programs", The 19th Pacific Asia Conference on Information Systems (**PACIS 2015**), Singapore, 6-9 July 2015. <Online: http://aisel.aisnet.org/pacis2015/97>. – ERA 2010 'A' Conference

5. Pradhan S. and Bajracharya, G. "Socio-economic impacts on the adoption of mobile phones in the major indigenous nationalities in Nepal", in Dyson, E.L. Grant, S. and Hendriks, M. (eds.), 'Indigenous People and Mobile Technologies', Routledge, New York, 2015

6. Pradhan, S., Gay, V and Nepal, S., "Improving dental care recommendation systems using patient and dentist profiling", The 25th Australasian Conference on Information Systems (**ACIS 2014**), Auckland, New Zealand, December 8-10 2014. <Online: http://hdl.handle.net/10292/8053> – ERA 2010 'A' Conference

7. Pradhan, S., Gay, V and Nepal, S., "Improving the matching process of dental care recommendation systems by using subjectivity criteria for both patients and dentists", The 18th Pacific Asia Conference on Information Systems (**PACIS 2014**), Chengdu, China, June 24-28 2014 <Online: http://aisel.aisnet.org/pacis2014/296> – ERA 2010 'A' Conference

8. Pradhan, S. and Gay, V., "Introducing patient and dentist profiling and crowdsourcing to improve trust in dental care recommendation systems", The 8th IFIP WG 11.11 International Conference on Trust Management VIII (**IFIPTM 2014**), Singapore, 7-10 July 2014, pp. 221-228. – ERA 2010 'C' Conference

9. Pradhan, S., Gay, V and Nepal, S., "Improving dental care recommendation systems using trust and social networks", The IEEE International conference on communications (**ICC 2014**), Sydney, Australia, 10-14 June 2014 pp.4264-4269. DOI: 10.1109/ICC.2014.6883990. – ERA 2010 'B' Conference

10. Pradhan, S., Gay, V and Nepal, S., "Social Networking and Dental Care: State of the Art and Analysis of the Impact on Dentists, Dental Practices and their Patients", The 26th Bled eConference, Challenges and Impacts for Individuals, Organisations and Society (**Bled 2013**), Slovenia, 9-13 June 2013. <Online: http://aisel.aisnet.org/bled2013/22>. – ERA 2010 'B' Conference

11. Pradhan, S. and Gay, V., "Towards a New Trust Model for Health Social Networks", The 8th International Conference on Internet and Web Applications and Services (**ICIW 2013**), Rome, Italy, 23-28 June 2013. ISBN: 978-1-61208-280-6 – ERA 2010 'C' Conference

12. Litchfield, A., Dyson, L.E., Wright M., Pradhan, S., and Courtille, B., "Student-Produced Vodcasts as Active Metacognitve Learning", 10th IEEE International Conference on Advanced Learning Technologies (**ICALT 2010**), Tunisia, 5-7 July 2010, DOI: 10.1109/ICALT.2010.160. – ERA 2010 'B' Conference

13. Lawrence, E., Zmijewska A. and Pradhan, S., "Mobile Payments: Partner or Perish?" The 3rd International Conference on Innovative Applications for Developing World, Asian Applied Computing Conference (**AACC 2005**), Kathmandu, Nepal, 10-12 December 2005.

14. Pradhan, S., Lawrence, E. and Zmijewska, A., "Bluetooth as an enabling technology in Mobile Transactions", The International Conference on Information Technology: Coding and Computing (**ITCC 2005**), Las Vegas, USA, April 4-6, 2005, pp.53-58. DOI: 10.1109/ITCC.2005.98. – ERA 2010 'C' Conference

15. Pradhan, S., Lawrence, E., Das, J. and Newton, S., "Bluetooth Potential in the M-Enterprise: A Feasibility Study", The International Conference on Information Technology: Coding and

Computing (**ITCC 2004**), Las Vegas, Nevada, USA, 5-7 April 2004, pp. 746 – 751. DOI: 10.1109/ITCC.2004.1286746. – ERA 2010 'C' Conference

16. Pradhan, S., "Mobile Commerce in Financial Services", The International Business Information Management (**IBIMA 2003**), Cairo, Egypt, 16-18 December, 2003. – ERA 2010 'B' Conference

17. Pradhan, S., "Mobile Commerce for Online Investors", The International Conference on Information Technology: Prospects and Challenges in the 21st Century (**ITPC 2003),** Kathmandu, Nepal, 23-26 May 2003.

18. Pradhan, S., "Mobile Commerce in Automobile industry", The International Conference on Information Technology: Coding and Computing (**ITCC 2003),** Las Vegas, Nevada, USA. April 28 -30, 2003, pp. 276-280. DOI: 10.1109/ITCC.2003.1197540. – ERA 2010 'C' Conference.

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Abstract

The recent growth in social media has impacted the way users are searching and sharing health information online. Crowdsources, such as review and rating websites, provide an outlet for consumers to share their opinions on healthcare professionals. Yet, faced with the enormity and diversity of information across multiple online sources, finding the right information can be a challenge for users, particularly when there is no consistency in the evaluation criteria across various sources. This difficulty is manifested when existing review and rating websites do not take patient information into consideration. Extremely biased views – positive or negative – are capable of skewing recommendations and thereby compounding the situation. This makes it important to filter trustworthy information from health social networks and dental crowdsources. In the case of dental care, the invasive nature of many dental treatments highlights the importance of selecting a suitable trustworthy provider for many patients, who may be anxious or reluctant to visit a new dentist.

By analysing, from multiple perspectives, the trustworthiness of information available to patients, this study proposes a new trust-enhanced information model for dental care recommendation systems. In this model, dentists are profiled based on subjective information extracted from dental crowdsources. Subjective qualities are also used to profile patients. Currently, online social network data cannot be used for profiling purposes due to privacy and identification concerns. Instead, one of the popular personality tests, the DISC personality test, is used in this study. The importance and suitability of subjective qualities for recommendations is explored. Two matching algorithms are evaluated based on the responses to an online survey. When the patients are classified based on their levels of fear, preferred search methods and other attributes, their list of recommended dentists changes. The subjective characteristics of both patients and dentists are important factors which need to be incorporated to improve the matching capability of dental care recommendation systems.

Including the subjective qualities of users could change the way that recommendations are provided in the future, especially in the health sector where the wrong information can lead to adverse impacts on health. Although patients' discussions about their health are sensitive and private, they can benefit from more accurate recommendations in relation to health care providers.

Keywords: health social networks, social media, review and rating sites, reputation, trust, profiling, matching, recommendation system

Chapter 1

1. Introduction

The healthcare industry has been impacted by the development in information and communication technologies (ICTs). With the recent massive growth of social media, an abundant amount of health information has become available online. Like other internet users, dental patients have come to rely on opinions provided by former consumers to identify the right service providers. Review and rating sites are re-shaping the way the users make their decisions, but finding the most suitable dentist is still not an easy task. Actually, more information does not make it easier to find a dentist, but adds complexities due to the wide variety of information. Moreover, the sensitive nature of health information makes it even more difficult to comprehend the available online information. Accordingly, this study proposes a new trust-enhanced information model to improve the matching process between patients and dentists within various types of social networks.

This chapter introduces the topic of this study by outlining the research background in recommendation systems for dental care. This is followed by research motivations, research gaps and topics which are explored in this study. Based on the research gaps, research questions are then outlined for this thesis. Next, theoretical and practical research contributions are identified and listed. The terminologies used in this thesis are defined to provide consistency throughout this document. Research significance is also discussed to show the importance of this study. Finally, a road map of this study is provided to outline the structure of this thesis.

1.1. Research Background

Nowadays, not all patients automatically accept the doctors' or dentists' recommendations without doing their own online research (Ratzan 2011). If patients fail to have their questions adequately addressed, through direct communication with health professionals, they may become frustrated and experience increasing uncertainty and anxiety about their illness. This may lead them to search the internet, as an alternate source of information (Li et al. 2014; Hou & Shim 2010; Tustin 2010). Unsatisfactory interpersonal interactions with doctors and dentists have been significant catalysts for potential patients to visit online channels such as health social networking sites (HSNs) and review and rating sites. The increasing trend of using online sources to obtain health information is not only as a result of the current habit of using social media but also because of its relative convenience. For some internet savvy patients, the HSNs have become better sources of information than physical consultations with healthcare providers (Volkman et al. 2014; Hou & Shim 2010). This phenomenon is gradually altering patients' behaviour and there is a noticeable shift towards patients being empowered by the information (Pickard & Swan 2014; Moick & Terlutter 2012). The HSNs provide an opportunity for users to be able to connect and relate with each other (Swan 2012; Lober & Flowers 2011). Up to a certain point, online sources have been recognised as trusted media for health information.

Pew Research Center (Fox & Duggan 2013) reported a rising number of e-patients stating that 77% of internet users in the US got their health information through online sources. Moturu & Liu (2010) found that 81% of adult users have used the internet for health information, and argued that the internet is the most widely used source for health information ahead of doctors, friends and families. However, in the context of health, most people are more concerned about their privacy and the security of health information (Libert 2015; Campos-Castillo & Anthony 2014). These concerns can be reduced by creating specific social networks where many aspects of trust (Pickard & Swan 2014) concerning dental care information can be incorporated such as filtering information from only trusted users. While searching for a dentist, or providing more information about dentists which has originated from their patients, etc. Thus, for this study, trust is evaluated in the context of the ability of enhancing the recommendation system to provide the most suitable health professional in dental care.

1.2. Research Motivation

The invasive nature of dental treatment is one of the main concerns which deters patients from visiting dentists. Therefore, issues such as anxiety about dental procedures, dental implants, dentures, gum disease etc., have been discussed in HSNs. Moreover, dental fear is the number one issue in oral health and the dental patients are generally anxious to visit dentists due to pain and uncomfortable feelings during treatment. Not only does it result in patients not showing up to their appointments but the news concerning deaths caused by an overdose or mishandling of an anaesthetic product (Malamed 2015) does not help patients to reduce their respective dental anxiety.

The research shows that friends and family are the major sources of referrals for dentists, as they are usually the most trusted people in a person's life. Thus, trust plays an important role when deciding which dentist is the most suitable for a user's individual needs. Dental care recommendation systems need to include this trust factor so that dental patients can be assured that they have been provided with high quality recommendations. An individual perception of quality of recommendation information is influenced by their judgement of its credibility. If the user believes that the recommendation information is genuine and credible, they would likely use to make decision of choosing or not choosing the particular dentist, recommended by the system.

No specific studies on the impact of trust on recommendation systems have been conducted in the area of dental care recommendations. However, there are many studies in relation to health recommendations in general. One of the studies conducted by Emmert et al. (2013) carried out a systematic review on 'physician rating websites' which identified major issues with recommendations on the websites (e.g. only a small number of physicians have been rated in practice, there is no standard way to evaluate the physicians, there is the potential for various forms of abuse). However, in another study, patient satisfaction was considered as a core measure through which policy makers could evaluate hospitals and practices (Tsai et al. 2015). Review and rating sites are gaining popularity for use in recommending health professionals but the above issues hinder the ability to identify the best match. Kim (2014) conducted a systematic review on 'trust in health information websites' to identify the antecedents of trust. However, the study suggested the need for a further longitudinal study to evaluate trust in health websites due to the dynamic nature of trust. Johnson et al. (2015) identified key criteria to assess the trustworthiness of health information through judgements of usefulness and credibility.

So, key motivating points for this study include:

- scanty research in recommendation systems in general, and the lack of prior studies about the trust impacting on dental care recommendation systems in particular;

- the lack of information collected on websites rating health professionals, especially dentists, even though a growing number of websites have rating on particular health practitioners, especially general physicians;
- the challenge of properly identifying patients who rated these dentists in practice;
- the challenge of some ratings being for group practice vs individual practitioners;
- the lack of rating standards in the evaluation as provided by the various crowdsources;
- the changing quality of rating that can be found, for example, the potential for various forms of abuse in/among these ratings (such as shilling attack).

Social networks may help patients to find trustworthy information about dentist. The following topics are explored to enhance trust in dental care recommendation systems:

- A need for a dedicated recommendation system for dental care so that patients can find the most suitable dentist,
- The use of social networks to analyse and profile patients based on their preferences and characteristics, attitudes and behaviours by analying their respective interactions within these social networks,
- Categorising and profiling dentists from subjective qualities extracted from online reviews which are publicly available, and
- Construction of novel matching algorithms based on the subjective qualities of both dentists and patients.

1.3. Research Questions

The following research questions and sub-questions are answered by this research work:

- **Can information from diverse sources improve the matching process of dental care recommendation systems?** (Diverse sources refer to the patients' *preferences*, *online reviews & ratings*, *the strength of relationships in social networks*, etc.)
    - Both dentists and patients can be classified based on subjective criteria. What would be the best criteria to classify the subjective qualities of both dentists and patients?
    - Do a dentist's qualities matter in order to determine the trustworthiness of the dentist? If yes, how many types of subjective qualities are important for patients and what are they? What will be the best matching configurations for patients?
    - Do the subjective qualities of patients matter in the matching? Will the subjective qualities of patients change the matching process in filtering the subjective qualities of dentists?

- **Can the subjective qualities of dentists be extracted from dental care review and rating sites?** The ratings of dentists represent a type of trust, referred to as reputation trust. How is that related to the subjective qualities of dentists? Can the dentists' qualities be used to profile dentists?
    - Besides the subjective qualities of dentists, what else is important to classify dentists to improve the matching for patients?

- **Is it possible to classify patients based on implicit information learnt from social networks about their attitudes and behaviour?**
    - What type of information contributes to subjective information about the dental patient from the social network?

1.4. Research Contributions

In this research, the information which influences the choice of dentist from various social networks is investigated. The subjective qualities of both dentists and patients serve as important information to match the most suitable dentist for patients. The importance of their subjective qualities has not been explored for dental care recommendation systems specifically. Trust related information from online social networks (OSNs) is investigated in this study in order to propose a new trust-enhanced information model for dental care recommendation systems.

There are dedicated dental review sites available online, mainly in the US and some other countries but the criteria for rating dentists is inconsistent. An effective way of matching a type of patient with a specific type of dentist by incorporating their subjective qualities, is investigated. Additional investigation is made to see how the subjective qualities impacts the match. The matching rules are prepared based on results analysed from one of the surveys conducted in this study. The matching rules are prepared to improve the quality of the recommendations.

The quality and accuracy of recommendations are improved by incorporating the subjective qualities of both patients and dentists in the matching process.

This thesis makes the following contributions:

- Develop a trust-enhanced information model to improve the matching of patients with dentists
- Identify subjective information as the preferred criteria to enhance trust in dental care recommendations. Subjective qualities were used for matching algorithms in this study.
- Extract and analyse the subjective information of both dentists and patients in social networks.
- Evaluate trust factors to improve the matching between patients and dentists.
- Cluster the subjective qualities of dentists to profile them.
- Construct patients' profiles from subjective information such as personality traits, level of dental fear, etc.
- Compare the use of subjective qualities with two different matching algorithms.

1.5. Research Terminology

This research work focuses on the ***dental care social network.*** It is a virtual community that facilitates and encourages its users to create and share dental related information such as dental symptoms, treatments, and experiences during their dental visits. Most of all, recommending an appropriate dentist is a major focus of the network in this study. ***Ratings*** and ***reviews*** for dentists have profound roles in the recommendations. A rating is a form of evaluation on products or services received by the consumer to show the level of his/her satisfaction. Overall, the rating shows how good or popular someone or something is (Cambridge Dictionary). Reviews are another form of evaluation but are usually written in text by the consumers as feedback to the providers of services or products. The reviewers may point out specific issues that they have experienced.

This research contributes to the improvement of the matching of patients and dentists in ***Dental care recommendation systems***. Dental care recommendation systems filter a list of dentists when a dental patient searches for a dentist based on location and other criteria such as: type of treatment, age groups, specialty, type of insurance covered, rankings etc. The criteria used may vary with different recommendation systems. For example, DrOogle.com, (a dedicated dentist guide in the US), ranks dentists in a local area, based on patients' ratings and reviews. 1800dentist.com, on the other hand, recommends dentists based on location, age group, and type of treatments. The generic business review site Yelp.com lists dentists based on either the 'highest rated' or 'most reviewed' dentist in a given location in several countries around the world. Most of the dental care recommendation systems rank dentists based on the reviews and ratings by the dental patients.

In this research, a ***matching*** is the process of finding the suitability between entities of different ontologies (Euzenat & Shvaiko 2007) such as a dentist for a patient. The matching process in the recommendation system takes place when the most suitable dentist is recommended to a patient who is searching for a dentist. The suitability of a dentist to the patient is investigated by incorporating trust-related information in both patients and dentists' profiles.

This research work makes use of ***Crowdsources.*** Crowdsourcing is defined as the process of obtaining needed services, ideas or content by soliciting contributions from a large group of people, usually from the web (Howe 2006). This term is a combination of 'crowd' and 'outsourcing'. In the context of this thesis, we use the term ***Dental care crowdsources*** to refer to online dental patients' rating and review sites where patients rate and write reviews after their dental treatments. Examples of Dental care crowdsources are Yelp.com, DrOogle.com, RateMDs.com, Healthgrades.com, whitecoat.com.au etc. where dental patients provide ratings and feedback to the dentist for the service they received from their recent dental visit.

One of the contributions of this thesis is the proposition of a new ***algorithm*** that extracts explicit and implicit information from the patient, the dentist and information from dental care crowdsources and takes into account both objective and subjective parameters in the most appropriate order. An algorithm is a set of rules and procedures which takes a set of value as input and produces a set of value as output for solving a problem in a finite number steps (Enggpedia.com). In the context of this thesis, this term is used to refer to a step-by-step set of operations, written in C# to match dental patients with dentists in the recommendation system. This term appears as ***matching algorithm*** in this document.

The overall objective of this thesis is to enhance ***trust*** in the dental care recommendation system matching process. Trust is defined as 'firm belief in the reliability, truth or ability of someone or something' (Oxford Dictionary). This term is also defined by many researchers as "*one's willingness to be vulnerable to another based on the confidence that the other is benevolent, honest, open, reliable, and competent*" (Tschannen-Moran 2014). The ultimate goal of this research work is to give the dental patient the best chance to trust the dentist s/he has been matched with by the recommendation system since the matching is based on trust-related information from both dentists and patients' profiles.

We also investigate trust in the Dental Care recommendation system itself by different ***stakeholders***. A stakeholder is a person with an interest or concern in something, especially a business (Oxford Dictionary). The major stakeholders of the dental care recommendation system identified in this thesis are dentists and patients. Other stakeholders are dental nurses, dental care practice staff, dental tools manufacturers, pharmaceutical industries, dental insurance providers, etc.

Another contribution of this thesis is to refine the existing ***matching model*** to include the use of ***trust*** for dental care recommendation systems. ***Model*** is simply defined as a thing used as an example to follow or imitate (Oxford Dictionary). ***Trust-enhanced model*** in the context of this thesis is described as a new model using social trust to improve the filtering and matching process while recommending dentists to patients. The model integrates trust-related information directly from patients and indirectly from social networks for both dentists and patients to match between them. The information for dentists is publicly available from dental crowdsources but patients' information can be somewhat challenging due to privacy and the anonymous nature of identifications (IDs) in social networks. The model is described using standard UML (Unified Modelling Language) diagrams.

In this research, elements of trust are put together to form ***Trust components*** which are integrated in the profiles of major stakeholders to improve the efficiency and effectiveness of the dental care recommendation system. A 'component' is defined as a part or element of a larger whole, especially a part of machine or vehicle (Oxford Dictionary). In the context of the recommendation system in this thesis, ***trust components*** are various elements of trust which help dental patients to make decisions on finding a trusted dentist. What does a trusted dentist mean to dental patients? Different trust components

are introduced in this research to help dental patients to filter a list of dentists available. For example, a trusted dentist is someone the patient knows for a long time or someone who is recommended by their very good friend. For some patients, a trusted dentist could also be someone who has received many awards or positive reviews whereas for others, it could be who has been recommended.

In this thesis, both patients and dentists are classified by their subjective qualities. Dentists are described with certain characteristics in the reviews and feedback written by their patients. The characteristics are analysed by web-crawling information from dental care crowdsources. The characteristics for the dentists are referred to as ***dentists' qualities*** in this research. As patients' subjective qualities are not available online, personality tests have been used.

1.6. Research Significance

Dental care recommendation systems are gradually replacing traditional channels used to find a suitable dentist such as newspaper, television, radio advertisements, friends and families. Defining the types of patients and dentists from their subjective qualities to match between them is an important development for dental care recommendation systems. Trust plays an important role to determine the credibility of recommendations provided by the dental care recommendation systems. For example, a level of trust can be derived from the patients who have been to a particular dentist and have provided a rating and account of their experience in the form of reviews.

This research has the following significant features:

- Subjective information about dentist from readily available online information such as dental care crowdsources, is extracted.
- The subjective qualities of both patients and dentists are analysed to improve the matching provided by dental care recommendation systems.
- Integrating the subjective qualities of patients and dentists in their profiling enhances the suitability of the match.

1.7. Thesis Structure

This chapter introduced the concept and topic of this study with clear references to research background, motivations, contributions, research terminology and the significance of this research. Research gaps and research questions are also summarised. This thesis document is outlined below in Figure 1.1.

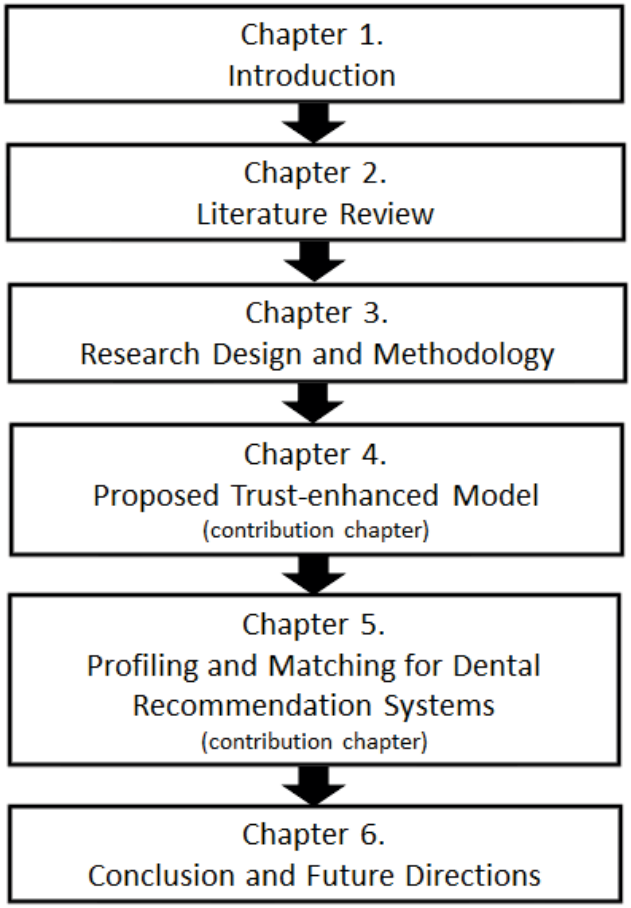

Figure 1.1: Structure of Thesis

In chapter 2, a literature review on dental care recommendation systems is presented. This describes their functionalities and usage in the online world. The popularity of dental care recommendation systems and their growing trend is reviewed with existing examples. This chapter then focuses on the matching techniques used in existing dental care recommendation systems. In an attempt to improve the quality of recommendations, trust of the recommendation systems and that of the users are studied. Therefore, the importance of trust factors while matching a patient with a dentist is reviewed. As user profiling is the key source for quality recommendations, existing techniques have been reviewed together with possible ways to improve the quality of recommendations by using different methods to profile. Subjective qualities are investigated as possible enhancements to include in the profiling of major stakeholders. This chapter concludes by reinforcing the research gaps stated in this chapter.

Chapter 3 presents the research design and methodology used in this study. It describes how research methods from different disciplines are combined in this study. From information systems (IS) methodology, pertinent information for the proposed trust-enhanced information model is analysed. However, the information is analysed and portrayed to include in profiling by using web content mining and prototyping as the computer systems (CS) research method. Briefly, social and behavioural science (SBS) research methodology is used to determine subjective qualities such as attitudes and behaviour of major stakeholders in the dental care recommendation systems and construct matching rules. The model is also examined using the reference model of open distributed processing (ODP) viewpoints to reinforce different aspects of the model. The chapter then summarises the methods used in collecting data from online surveys and interviews. Finally, the chapter describes how a prototype of the proposed model is set up to show a final result from this study.

Chapter 4 is one of the contribution chapters in this thesis. In this chapter, trust is introduced by investigating the main concerns of major stakeholders involved in dental care recommendation systems. Trust is extracted from the emerging rating and ranking system to filter a list of dentists in the dental crowdsources. Trust is then analysed from multiple perspectives for dental care recommendation systems. Thus, various trust components are integrated in the proposed information model to enhance the quality of recommendations in dental care recommendation systems. Towards the end of this chapter, a demonstration of prototype is briefly discussed to show how the proposed model would be used to improve the quality of recommendations.

In chapter 5, a complete picture of the proposed trust-enhanced information model for the dental care recommendation system is described and supported by the results from different methods used in this study. Major stakeholders, patients and dentists are profiled based on their subjective qualities. The detailed process and results of the subjective qualities and classifications of patients and dentists are described. Certain types of dentists and patients are analysed to create matching rules by analysing data from the survey. Patients are categorised not only from personality traits but also by including other variables from the survey to fine tune matching rules. The most suitable dentists are filtered by including more variables of patients to improve the quality of recommendations. This chapter concludes with a summary of results analysed from the data collected from the surveys and other methods.

Finally, a conclusion is drawn based on the results in chapter 5 and future work and directions are canvassed.

Chapter 2

2. Literature Review

This chapter provides an overview of previous research on dental care recommendation systems by examining the status of dental care related health social networking sites. It introduces standard recommendation systems and outlines their role within contemporary society where information sharing is rapidly increasing through the continuous evolution of social media.

The main purpose of this chapter is to review previous studies on dental care recommendation systems. It focuses on the systems used in the dental care area to see how the new trend of using social media has changed the way dental patients find their dentists for dental treatments. Usually dental patients go through decision making process to choose a dentist for their dental treatments either through online or offline social networks. In order to understand why dental patients choose particular dentists, it is a vital to ask what makes them choose a specific dentist over other dentists? Certainly, a level of trust may be due to many factors such as the source of referral, the suitability of the location, the way information is provided etc. The concept of trust which influences a patient's decision to choose a particular dentist is discussed in this chapter. Trust variables are identified from multiple dimensions to help the matching process in the recommendation systems. Several studies have been reviewed and discussed with up-to-date information in relation to trust in recommendation systems. The trust components that can be integrated in user profiling, are discuseed to improve quality of recommendations in dental care recommendation systems. Finally, this chapter concludes with a summary which explains how research gaps were formulated in this study.

2.1. Dental care and Health Social Networks (HSNs)

As the growth of social media is influencing the way we find information on the web, dental patients are turning to digital media such as blogs, search engines or social networking sites (SNSs) for any kind of dental information including symptoms, diseases, drugs, treatments and even how to find dentists. These sites are replacing traditional media such as face to face communication, television, magazines etc. (Ngai et al. 2015; Kwan & Ramachandran 2009). Before the internet age, if people needed to make a decision about a dentist, they asked for opinions from good friends, family, general practitioners (GPs) etc. But in recent years due to the rapid growth of social media, people are feeling more comfortable to use online reviews and rankings (Pickard & Swan 2014; Vayena et al. 2012) to choose particular dentists. Owing to the popularity of sites like Facebook (the largest social network with more than 1.55 billion members) (Statista 2015), users have developed the confidence to share health information and their particular health practitioner experiences online (Pickard & Swan 2014; Bhuiyan et al. 2009). Indeed, one of the most popular topics for people to participate in and discuss online is health related information. Health information is shared with other users even though personal health information is considered to be sensitive. Thus, the use of SNSs has made a substantial impact on the revolution of health care digital communication.

Health information is generally sourced from health care professionals but an increasing number of healthcare consumers turn to websites and SNSs nowadays for this information or for second opinions. Due to both the pervasive and ubiquitous nature of information and communication technologies (ICTs), the number of people sharing health information online and the number of SNSs for health related information are increasing (Webster et al. 2011; Williams 2010; Swan 2009). Online health information providers are known as 'health social networks' (HSNs) which provide unbiased health information. These platforms are used to search, self-track, discuss health, lifestyle or fitness related information by users (Gay & Leijdekkers 2011; Webster et al. 2011). For example, public views on oral health such as dental implants, dentures, teeth whitening, etc. are discussed in different social media platforms. The information shared in HSNs is very useful and has proved to be a great source of knowledge in the healthcare domain. That's why, if a dental patient wants to choose a dentist, there is plenty of information available including reviews from other dental patients about dentists and their ratings, which can help the patient to make a more informed decision in terms of choosing a dentist.

Since the term 'Web 2.0' has been introduced, the direction of information flow has absolutely reversed from 'providers to consumers' to 'consumers to providers' and this has resulted in creating a massive amount of user generated content (UGCs) on the web, which includes the sharing of opinions, experiences and acquired knowledge (Kim & Ahmad 2013; Moturu & Liu 2010) about specific health topics. Victor et al. (2011) stated that web 2.0 provides opportunities for information sharing, collaboration and interaction but there is a chance that users can potentially abuse the system by

providing incorrect information. One of the most popular features of the web is 'peer reviews' and 'ratings'. These reviews and ratings not only shape and influence public views on dental issues but also play a major role in the filtering of a suitable dentist for patients.

2.1.1. Dental care Search and Review sites

There are many sites where the dental patients can search for dentists or dental practices and read online reviews from previous patients of the dentists or dental practices. These sites help any patients who are looking for a new dentist for specific dental treatments. Some sites exist to alleviate dental anxiety and provide confidence to patients, but others exist to create new business venture opportunities by helping patients find dentists by collecting opinions about dentists from their previous patients. These sites either display dentist advertisements or request users to pay to access information (Dentistreviews 2015). Thus, there are many different types of dental crowdsources. Some of the sites are created to recommend dentists while other sites provide the means for users to voice their opinions or rank the dentists in particular locations based on various criteria and ratings. Some of them allow reviewers to be anonymous but others require the provision of correct names and IDs. A few sites require users to pay to access specific information while others are free to use (Dentistreviews 2015)

A website dedicated to dentist reviews quoted, "*About 60% of population has some fear of dentist… and the best way to find a dentist is through unbiased patient reviews of dentists*." (Dentistreviews 2012). This site also provides a list of other dentist reviews and rating sites, such as DentistDig, DentalFearCentral, RateADentist, NationalDentalReviews, DrOogle etc. Since dental professionals fall under the category of health, dental professionals have been also listed under other health professionals rating sites such as RateMDs and HealthGrades. In addition, the generic review site Yelp has been gaining popularity in the US for dentist reviews, which allows patients to post reviews/comments about their visits to their dentists. The DentistReviews site uses reviews from Yelp to rank the dentist in any given location within the US. Amongst them all, DrOogle is one of the most dedicated review sites for dental professionals in the US as it provides rankings on dentists in specific location based on positive reviews of patients (DrOogle 2015).

Some of the dental crowdsources have only basic functionalities while others have a host of user friendly features. Table 2.1 below shows some of the dental review sites, their established year, average monthly visitors and membership fees, if applicable. The table is sub-categorised into dentistry, healthcare and business sectors because the review sites for dentists are also spread across both healthcare and general business reviews as well.

Table 2.1: Review or ratings sites (Source: Dentistreviews 2015)

Review Site Address	Established Year	Monthly visitors	Membership fee
Dentistry			
doctoroogle.com	2004	106,155	US$18 (one off)
dentalfearcentral.org	2005	51,404	free
dentalcenter.com	1996	8,834	free
dentistdig.com	2009	15,026	free
dentistreviewsonline.com	2008	N/A	free
dentist-ratings.net	2008	N/A	free
nationaldentalreviews.org	2011	N/A	free
1800dentist.com	1997	N/A	free
Healthcare – the following sites also allow patients to review on dentists			
ratemds.com	2003	612,235	free
healthgrades.com	1999	9,352,220	free
Business – the site below is popular for reviews on dentists among other local businesses.			
yelp.com	2003	36,177,527	free

DrOogle: This site allows dental patients to write reviews and provide personal feedbacks on their dentists. Based on positive reviews, the dentists are rated within particular locations/suburbs of the US. This site provides a paid service (US$18 to become a member from the US only) and is regulated so that the users can only post one review per dentist. This site also monitors shilling attacks (biased behaviour and the creation of positive reviews for one's own or one's friends' practices) to provide fair ratings to the users (DrOogle 2012). At the time of writing, there are 194,843 reviews available from patients (DrOogle 2015). In addition to the reviews about their dental visits, the patients can also rate the dental practice with a likert scale between 1 to 4 for criteria such as 'first class service', 'like a health spa', 'painless procedures', 'superb results' and 'expensive'.

Dental Fear Central: This is a non-commercial site which provides awareness to the public about dental anxiety/fear. This site originated from the UK but has gradually increased its visibility globally. The dentist reviews and recommendations forum is now available to Australia, Europe, New Zealand etc. This site provides services such as the dental phobia support forum, commons fears in dental procedures and tips to deal with them, step by step guides to search for a dentist, psychological ways of tackling dental phobia, tips for dentists and dental FAQ. All dental patients, dental university students and professionals from around the world are welcome to use this this site. The main motive is to spread awareness in regards to dental anxiety. This site has put quotes from its users such as, " *So much of it is about having the right dentist, one who will stop when you tell them to stop and who you trust 100%. ….. and who understood my fears*." and "*Just want to say a big thank you – I had a very bad fear of the dentist ….. I now have a beautiful mouthful of teeth …thank you for information you supplied me*." (DentalFearCentral 2012).

Other Dental Search, Reviews sites: There are many other dental search and reviews sites emerging in dental care area. Most of them allow users to find the dentist based on the location (post code), and their own criteria and patients' reviews. For example, national dental reviews site has rating criteria: 'office cleanliness', 'affordability', 'staff friendliness', 'wait time', 'chairside manner', 'convenient hours' and 'pleasant office environment' for patients to rate between 1 to 5 stars. (NationalDentalReviews 2015)

RateMDs: It is a dedicated site to find and rate doctors and dentists. The patients can rate them on the criteria such as 'staff friendliness', punctuality', 'helpfulness' and 'knowledge'. (RateMDs 2015). This site allows users to search the doctors or dentists within a location and provides a list with aggregated rating scores. It also allows for adding doctors or dentists if they are not already in the list.

HealthGrades: This is another online database in the healthcare sector which helps to find doctors, dentists and hospitals based on location. This site has recently upgraded additional features. As shown in the Figure 2.1, patients are able to rank the list of dentists based on their speciality, distance, gender, insurance, patient satisfaction, experience, etc.

Figure 2.1: Healthgrades Website (Source: Healthgrades 2015)

Reviews are not free text but there is a short survey with star ratings and a sliding scale which provides quantifiable results from the survey. The patients' satisfaction is measured in major areas such as 'Office & staff', 'Experience with doctor/dentist' and overall rating. In the office & staff section, the patients are allocated to rate on 'total wait time', 'staff friendliness and courteousness' and 'office environment, cleanliness, comfort'. In terms of experience with the dentist, patients can rate on 'level of trust in provider's decisions', 'how well provider explains medical conditions', ' how well provider listens and answers questions' and 'spends appropriate amount of time with patients'. In addition, it exclusively asks to rate overall 'likelihood of recommending this dentist to family and friends?' From the patients, age group, gender and 'number of visits in last 2 years' are collected in the site. (Healthgrades 2015)

Yelp: This is a general business review site which helps people to find great local businesses including dentists or dental practices based on reviews provided by the users. Yelp claims that in the fourth quarter of 2014, there were approximately 135 million unique visitors monthly. This site is becoming an increasingly popular website to find dentists in local areas in the US. It allows users to give an overall rating out of 5 stars and to write reviews. Yelp allows users to filter the list of dentists based on 'highest rated' or 'most reviewed'. Recently the site has also added another criteria to filter the list of dentists based on 'best match' with more criteria listed such as variety of cost (inexpensive to ultra-high-end), open now, offering a deal, sells gift certificates, type of dentistry etc. Figure 2.2 below shows the filters Yelp has introduced recently to help patients to find the most suitable dentists. This site also allows the readers of the patients' reviews to mark whether the feedback was 'useful', 'funny' or 'cool'. (Yelp 2015)

Figure 2.2: Filters in Yelp (Source: Yelp 2015)

2.1.2. Comparison of Functionalities across Dental Crowdsources

Among different types of dental crowdsources, some are used to recommend the right dentist and others to collect opinions or reviews on dentists or dental care information. Table 2.2 below provides a summary of how some of the dental crowdsources mentioned in the above section differ in the functionalities and services they provide.

Table 2.2: Comparison of the services provided by the sites (√ - Yes and × - No)

Sites	Search	Reviews	Rate	Rank	Recommendation
DrOogle	√	√	√	√	√
Dental Fear Central	√	√	×	×	×
National Dental Reviews	√	√	√	×	×
RateMDs	√	√	√	√	√
Health Grade	√	×	√	×	√
Yelp	√	√	√	×	√

Clearly, when the intentions of the sites are different, their features will vary as well. Not all of the sites listed in the table above recommend a dentist.

2.1.3. Usage Trend of Dental Crowdsources

There is an upward trend in terms of using dental care related websites for searching and reviewing dentists online. Table 2.3 shows average monthly visitors to the reviews sites in the years 2009 and 2014. There is a significant increase of visitors to the dentist reviews site. For example, DrOogle had a substantial growth of monthly visitors from 60,000 in 2009 to 106,155 in 2014. The monthly visitors escalated from 6.5 million to more than 36 million for Yelp. One of the reasons is that Yelp allows people to review any business without permission from the business owner (FutureDontics 2014) and it attracts younger users (DentistReviews 2015). Another reason is that usernames can be created by users thereby keeping their identity anonymous.

Table 2.3: Average monthly visitors (source: Dentistreviews 2015)

Sites	Year 2009	Year 2014
DrOogle.com	60,000	106,155
Dentalfearcentral.org	19,500	51,404
Dentistdig.com	5,200	15,026
Healthgrades.com	2,000,000	9,352,220
Yelp.com	6,500,000	36,177,527

Figure 2.3 below shows the rise of the monthly visitors to the site DrOogle and Yelp based on the number from the table above.

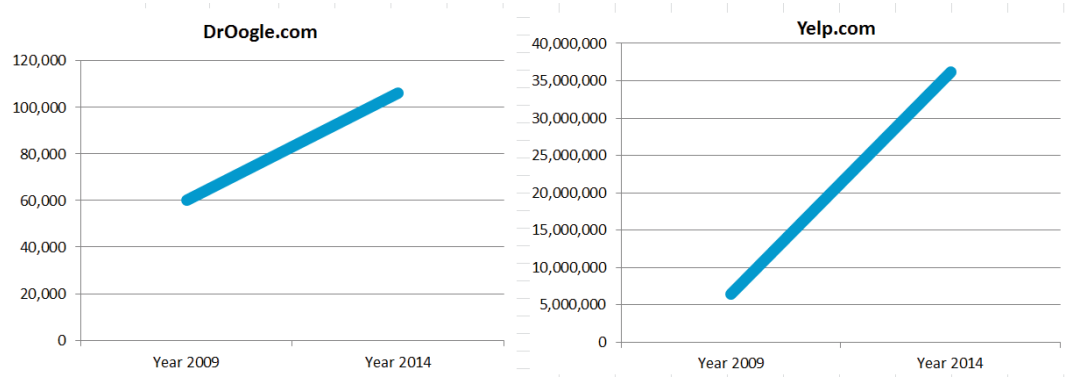

Figure 2.3: Monthly visitors to DrOogle and Yelp sites (2009 vs 2014) [Y – axis – number of users]

An increasing surge was seen across other sites as well. Healthgrades had 2 million monthly visitors in 2009 and it went up to 17 million in 2014, according to American Internet Analytics company, comScore. There was also an increased use of the reviews and recommendation sites before decisions were made to visit a dentist.

2.2. Recommendation Systems in Dental Care

'Information overload' is a phenomenon of our society in this information age. This has added an extra burden to internet users in terms of finding the right information which includes dental patients seeking a suitable dentist. Recommendation systems have become a critical function on the web to ease the burden and to support the patients' decision making. Recommendation techniques have been integrated in SNSs such as the social media giant Facebook uses to recommend possible friends. There are many types of social networks and they vary according to the purposes of their use (Mezgar & Grabner-Krauter 2015; Ickman et al 2014). HSNs are emerging to create, retrieve and share health related information (Swan 2012) including specific dental care. Dental crowdsources are arranging information about dentists and dental practices to provide related information to dental patients.

In the past, the recommendation system was described as 'information filtering and retrieval' technology because it only used document content and item descriptions (Tselenti & Danas 2014; Belkin & Croft 1992). Later on, personalisation through user preferences and opinions was included (Chung et al. 2015; Boutet et al. 2014) in the technology, to filter the information efficiently and effectively and the term 'recommendation system' or 'recommender' became popular. Because of the massive growth and expansion of social networks and information, recommendation systems have become one of the major areas of research. In this research, we explore dental crowdsources which have been used as recommendation systems to help find a suitable dentist for patients. This section briefly introduces some common recommendation techniques and shows how these techniques are used in dental crowdsources. Specific challenges and issues in dental care recommendation systems are discussed, which helps to formulate the research gaps in this study.

2.2.1. Recommendation Techniques and Challenges

Recommendation systems are gaining popularity as they are able to support and improve the decisions the users have to make (Xiao & Benbasat 2013). Traditionally two popular algorithms **content-based filtering** (CB) and **collaborative filtering** (CF) have been used in recommendation systems. CB analyses descriptions of items or individuals that have been rated by the users and descriptions of items or individuals to be recommended. A good example of this method is matchmaking sites, whereby a list of potential dates is suggested based on the preferences chosen in the user profile. However, recommendation systems like Amazon not only use simple CB methods but also analyse the users' other features such as similarity based on ratings and their profiles (i.e. demographic information and other available information). For example, if a user buys a book from Amazon, it recommends other books based on the user's behaviour and their similarity with other users who previously bought that particular book. This method is known as collaborative filtering (CF). If the recommendation was made

solely based on the content of the book only, then it would be considered as CB. Both of the methods use similarity measures. CB uses the similarity between items and CF relies on the similarity between users (Tselenti & Danas 2014; Jannach et al. 2012; Arazy et al. 2010). Both of them have limitations; CB does not consider the target users' similarity information whereas CF does not explicitly consider the content features of the item (Su & Khoshgoftaar 2009). Although CF is one of the most popular methods used in recommendations systems, it has the following limitations: cold start, scalability, shilling attacks, gray sheep and sparsity (Walter et al. 2008; Victor et al. 2009; Su & Khoshgoftaar 2009; Lopez-Nores et al. 2010).

- The *Cold start* problem occurs when a new item or individual is added into the system because no user ratings are available in the beginning; this problem is also called the new user problem or latency
- The *Scalability* problem arises when the number of users and items rises drastically and the computational resources are unable to cope with the pressure.
- *Shilling attacks* are caused by biased behaviour. Since good ratings tend to influence sales, recommendation systems can be manipulated by malicious users (Chirita et al. 2005). These sort of behaviour by biased/malicious users can in some cases be classified as a fraud.
- The *Gray sheep* symptom is when a user's preference is isolated and it is not similar to any other users in the system.
- *Data sparsity* is due to the high number of items to recommend.

Su & Khoshgoftaar (2009) and many others have stated that other filtering techniques are available to overcome these problems. One of them is a combination of CF and CB, which is known as a hybrid method to solve the data sparsity problem. Modern recommendation systems use a number of methods to make hybrid systems to balance out the strengths and weaknesses of individual methods (WeKnowIt 2011). Being more automated, they can create a user profile based on information captured previously e.g. item-based, ratings, demographics, location or any other related information. Burke (2007) suggested using demographic-based and knowledge-based recommendation systems but in existing dental care recommendation systems, CB is used and this takes the number of reviews and star-rates into consideration to filter the list of dentists.

2.2.2. Dental Care Recommendation Systems

Dental care recommendation systems are applications which provide facilities to dental patients by filtering information to find suitable dentists based on their preferences. It attempts to match the most suitable dentist by reducing the overloaded information based on preferences such as location, types of dental treatments, level of insurance, cost, etc. It is similar to traditional search systems. An ever growing amount of information makes it difficult to search and filter. Usually the search ends up with

too many results and creates another paradigm of 'choice overload' (Chiravirakul & Payne 2014) or there is too much to search for to start with.

The number of dental crowdsources has increased in the past few years with the intention of helping dental patients to filter and choose a dentist but it uses very simple matching techniques based on location and the types of dental treatments. This section explores existing dental crowdsources and their matching processes to filter a list of dentists. It also looks at the research work so far that has been done in the area of dental care recommendation systems.

2.2.2.1. Existing Recommendation Techniques in Dental Care

Most of the existing dental care recommendations or search sites allow users to filter a list of dentists by location only. Some of them go beyond asking only location but are limited to types of treatments, demographic (children, adult or retired), and insurance companies. Based on a combination of this information, a list of dentists is filtered. In addition, if the sites have features allowing patients to review and rate scores about their experience with a particular dentist or other staff, the sites also includes the ranks by aggregating the scores and filtering the list of dentists. The actual algorithm is not publicised but it is clear from observation that number of patients' reviews and ratings are important for ranking the dentists.

A summary of existing recommendation methods used by some of the popular dental care recommendation systems is shown in the table below.

Table 2.4: Snap-shot of recommendation methods in dental crowdsources

Dental crowdsources	Recommendation methods	CB or CF or Hybrid
Yelp	Ranking based on the most reviewed or the highest rated or the best match	CB for the best match
DrOogle	Ranked based on highest rated to lowest rated in specific location.	Unknown
RateMDs	Ranked based on aggregated rates and number of reviews	Unknown
Healthgrade	Allowing flexible way to match from different criteria: patient satisfaction, type of treatments or even from distance.	Knowledge based CB and aggregated rates

One of the leading healthcare review sites, Healthgrades which helps patients to filter doctors, dentists and hospitals has increased the number of searchable sub-specialties in dentistry so that patients can easily find experts in the area that they are looking for. In addition, the site allows for comparing 3 dentists side by side to help patients to make decisions in terms of choosing the right dentist

(Healthgrades 2015). In this site, dentists are also able to update their profiles and information about their practice. In addition, another feature called 'your voice' has been added for dentists to describe themselves, which no other sites have provided yet (Pfeffer 2015).

Similarly, the Yelp general business review site has also upgraded its site by adding a feature to rank dentists based on 'best match' from a list of criteria as shown in Figure 2.2 above.

2.2.2.2. Criteria Used in Dental Care Recommendation Systems

Existing dental crowdsources have a list of criteria which dental patients can use to evaluate the performance of their dentists, in addition to free textual feedback or reviews. However, the criteria used differ significantly in each dental crowdsources sites. Table 2.5 below shows a list of criteria used by some of the existing dental crowdsources to show how they differ from each other in evaluating dentists in their sites.

Table 2.5: Criteria used by existing dental crowdsources

Dental care Crowdsource	Criteria used
DrOogle	Comfortable facilities, efficient service, level of pain, result satisfaction
RateMDs	Helpfulness, knowledge
Healthgrades	Patient satisfaction, experience, ease of scheduling appointments, staff friendliness, level of trust to dentist, how well conditions are explained, how well are patients listened to and answered.
DentistDig	Knowledge and experience, quality of work

2.2.3. Open issues in Dental Care Recommendation Systems

Although the popularity of dental crowdsources to find information about dental care and dentists has been rising, there are some challenges faced during the process of finding recommendations for a suitable dentist or related information. Emmert et al. (2013) reviewed doctors' rating websites and pointed out the shortfalls in those websites, which also apply to dentists crowdsources. Some of the issues are briefly outlined below:

- Database is incomplete – not all dentists and dental practices are listed and reviewed by patients, hence this can cause a skew in the data. Only a small number of dentists are rated in those sites (Emmert et al. 2013).

- Lack of transparency – not all sites has disclosed their protocols and policies about their objectives and methods of reviewing.
- Identification challenge – the same person could have written many positive or negative reviews in some of the sites like Yelp. The reviews could be fake to attract new patients (Connelly 2011). This is also known as a shilling attack from a recommendation technology point of view.
- Different criteria to rate the dentist – different reviews and rating sites use different criteria to rate the same dentist. It confuses the patient who is checking all of those sites to make a decision. How can these sites help dental patients to decide when they are focusing on different aspects?
- Terminologies used in criteria – different terminologies are used in criteria to point out the same experience by the patient. Moreover, some symbols and signs are used in the criteria which lead to confusion. For example, $ sign for cost. More $ signs means that the patient is happy with the cost and less means a good price.
- Backlash on reviews sites – since all the possible attributes to rate health professionals such as dentists have not been integrated, professionals are complaining about how unfair and inaccurate the reviews are on sites like consumeraffairs.com, sitejabber.com.
- Certain legislative rules and acts allow some stakeholders to be protected more than others. According to Pfeffer (2015), in the US, the Communication Decency Act protects review site providers because they are not liable for the comments. The first amendment in free speech laws allows patients to upload their reviews anonymously. The Health Insurance Portability and Accountability Act (HIPPA) does not allow doctors to answer negative reviews unless they write in general terms. However, changes in the Affordable Care Act in insurance have allowed patients to find new health professionals online.
- Defamation of dentists and misinformation to patients – abuses and biased reviews create potential damages to both dentists and patients in the long run. The anonymity of reviewers makes the sites vulnerable (Emmert et al. 2013).
- Defamation lawsuits – a few lawsuits against the reviewers have appeared in the US and UK from dentists because they were rated negatively.
- Lack of evidence – to show that the reviews are truthful and useful. The Dental Association argues whether patients are capable of reviewing dentists' work.

2.3. Trust in Dental Care Recommendation Systems

Trust is defined as a psychological state of mind with an intention to accept vulnerability with positive expectations from another entity when there is some risk involved (Kim 2014; Tschannen-Moran 2014). In the context of dental care recommendation systems, a dental patient is vulnerable and intends to find a suitable and trusted dentist through a recommendation system. Trust is a very important factor when choosing a dentist due to the invasive nature of dental treatment. Most of the people often make their healthcare decisions based on the recommendations from people they trust such as good friends and family members (Morris et al. 2010; Victor et al. 2008; Swearingen & Sinha 2001). With the recent explosive growth of the Web 2.0 technologies, friends and internet have been combined into services called social networks (Tselenti &Danas 2014; Lai &Turban 2008) and the users are accustomed to use online sources nowadays to find a dentist as well, especially when they are in the environment where they know no one in the area. However, there is an inherent risk of uncertainty on who is your best friend online and what type of dentist they might recommend. There is a risk in visiting an awful dentist and bearing the consequences such as pain, facial disfigurement, uncomfortableness, etc.

Emergence of HSNs has been useful to facilitate meaningful recommendations promptly (Hackworth & Kunz 2011; Eytan et al. 2011). In the OSN environment, the user has a choice to trust the media especially from health related information websites (Hou & Shim 2010) in the first instance, and then the information posted (content) on the media and who has posted (original source) it and so on. Therefore, trust in recommendation systems is recognised as the reliability of the system to deliver accurate recommendations, perhaps in the form of consumer-generated media (Filieri 2015). If the system has made accurate recommendations in the past, the system is identified as trustworthy and thus a reputation and credibility is established for the system. This section explores different types of trust and their implications in the system.

2.3.1. Complex Nature of Trust

Trust is an important sociological concept which we use in everyday activities. Trust in something or someone depends on many factors such as past experiences, opinions of actions, rumours, influence from others' opinions, and many others (Thirunarayan et al. 2014; Kim & Ahmad 2013). Trust is defined and broadly researched in various contexts and areas such as psychology, sociology, business, science, philosophy and in many other fields (Tselenti & Danas 2014; Brownlie 2008). Many experiments and surveys have been conducted and developed for different trust models yet there is no universal definition of trust that everybody can share and the concept of trust remains elusive (Watanabe 2008). A simple reason for this is that trust has numerous and a diverse meaning in everyday use and it

is a term with many meanings. Regardless, trust always has two parties involved: Trustor and Trustee (Rosaci 2012; Chang et al. 2006). In this study, dental patients are receiving recommendations, hence they are trustors, and the dental care recommendation system is giving them the recommendation hence it is the trustee, however in some cases the dentist or dental practice would be regarded as trustee. Another user could be a trustee if the patient trusted the user solely for the decision. For example, while assessing the trust relationship between dental patients and dentists, dentists are trustees.

In almost all contexts, trust is implied as a judgment in a risky situation that the trustee will act in the best interest of the trustor (Johnson et al. 2015; Josang et al. 2007; Song & Zahedi, 2007; Siegrist et al. 2005; Goudge & Gilson 2005). In the context of dental care, when the patients trust the recommendation system, they trust that the system (trustee) would act in the best interest and gives the best list of suitable dentists based on the preferences they have selected. However, after selecting the dentist from the list, the interaction with the dentist could result differently and based on the result from the dental treatment, the patient may assign a level of trust to the dentist and that information becomes a source for the recommendation system. Eventually, the trusted information makes the recommendation systems more trustworthy. A platform like social media has been an excellent place for patients to discuss the experiences they had in their dental treatments. Understanding who shared what and which information is useful and the trustworthiness within the network is important for recommendations. This adds another level of complexity to the nature of trust in the social media environment and makes it even more dynamic as a trust concept. But such types of information help explore trust which can improve the recommendations in dental care, thus the system can be re-adjusted by integrating that trust information.

Many researchers have studied different aspects of trust in the healthcare domain, examples include design and usability aspects (Carritore et al. 2012; Sillence et al. 2006), privacy and security aspects (Williams 2010), information access aspects (Thiede 2005), the correlation with socioeconomic status (Ye 2011), attributes related to interpersonal trust (Goudge & Gilson 2005) and health information contexts (Johnson et al. 2015; Kim 2014). There have been many studies regarding trust on websites but only a few researchers focus on health related online information. Among them, Johnson et al. (2015); Filieri (2015); Kim & Ahmad (2013); Song & Zahedi (2007) suggest that the quality of information and the level of trust the healthcare consumers have with the health related websites are very important so that they can use the information to make their health or lifestyle decisions. It has been argued that the trust would be more reliant on the content for health related information than other factors such as Human Computer Interaction (HCI) factors or the credibility of the platform (Zahedi et al. 2008).

It is critical that there is a system to assure the quality of health related information and trustworthiness through trust networks (Victor et al. 2009). From that aspect, questions such as, ‘how do patients know

the website is safe or the user is trustworthy and the provided information is well researched or whether health social network sites are safe?' are raised. Some health related platforms have been created either to provide information to facilitate the sales of a product or service (Boyer et al. 2011) or capture private information in exchange for perceived benefit (Williams 2010). Trust plays an important role for patients to reduce uncertainty in the technology-mediated environment (Hernández-Ortega 2011) and to decide whether to use the information or not to make their health related decisions.

Trust has the following distinct properties which assist in clarifying concepts of trust (Guo et al. 2014; Chang et al. 2006).

2.3.1.1. Context Dependence

Trust is context dependent in such a way that a user who is trustworthy in one area such as dental care may not be trustworthy in IT technology (Guo et al. 2014). Even in dental care itself, there are speciality areas and symptoms that need to be taken into considerations. Therefore, trust in the dental care recommendation system would only be relevant based on the context in which other patients have expressed their experiences and rated the information or dentist accordingly. Therefore, not only profiles of dental patients based on location and types of treatments are important but also other context-dependent issues such as oral hygiene behaviour, the type of the patient and other subject matter are important to consider for the system. It is important to understand that trust needs to be measured over time in relevant contexts or issues (Goudge & Gilson 2005; Chang et al. 2006).

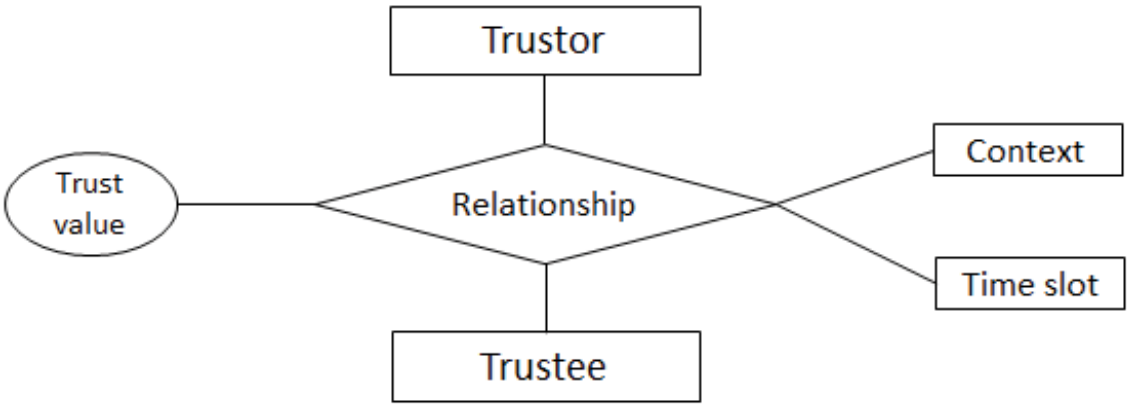

Figure 2.4: Trust is both Context and Time dependent (Source: Chang et al. 2006)

2.3.1.2. Dynamicity

Trust is dynamic and it is dependent on the context, situation, time and goals of a trustor in an interaction and therefore every situation needs to be considered separately (Kwan & Ramachandran 2009). An interaction or information which is useful and trustworthy at one time may not be useful for the next time, which is referred to in the figure 2.4.

This adds complexity in the concept of trust. Trust is gradually established and changed over time as more evidence is collected. If evidence of reliable and positive recommendations is increased, trust is increased and vice versa. However, a small amount of negative evidence can destroy the trust quickly but it takes much positive evidence to build high trust (Guo et al 2014).

2.3.1.3. Transitivity

When trust propagates from one user to another it is referred to as transitivity. Transitivity of trust is generally used in trust-based recommendation systems and social networks. Even in real life, people tend to trust a friend of a friend (FOAF) rather than a stranger. By propagating trust, it is possible to find trusted friends in the social networks. However, trust is not always transitive. Trust propagates while inferring trust from one to another and the level of trust is most probably degraded along a chain of networks (Victor et al. 2011; Kim et al. 2010)

For example, Alice asks Bob to find a good dentist in his town because Alice trusts Bob's knowledge about dentists in general. Alice will then trust the dentist, David because Bob recommends him to her; this is a good example of trust transitivity. Alice may not trust if Bob recommends other matters such as a movie to watch. In this example, the trust can be looked at from two aspects: one for the dentist's competence that's why Bob trusts the dentist (**functional trust)** and the other one to recommend the dentist to Alice (**referral trust**). The referral part of the trust follows the trust transitivity because Alice trusts Bob's word for dentist. Functional trust is direct from Bob to David and the referral trust is direct from Alice to Bob. However, functional trust from Alice to David is indirect because it is through Bob. Alice now trusts David as a good dentist.

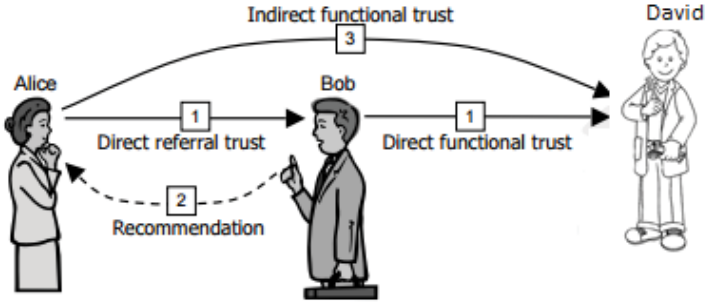

Figure 2.5: Transitive Trust Example (Source: Josang & Pope 2005)

In this example, let's say, Bob does not know a good dentist but knows Claire whom he believes knows a good dentist. It will therefore be a different situation. Clair knows David, a good dentist and she recommends him. As a result of trust transitivity through Bob and Claire, Alice also trusts David, as shown in the figure 2.6 below.

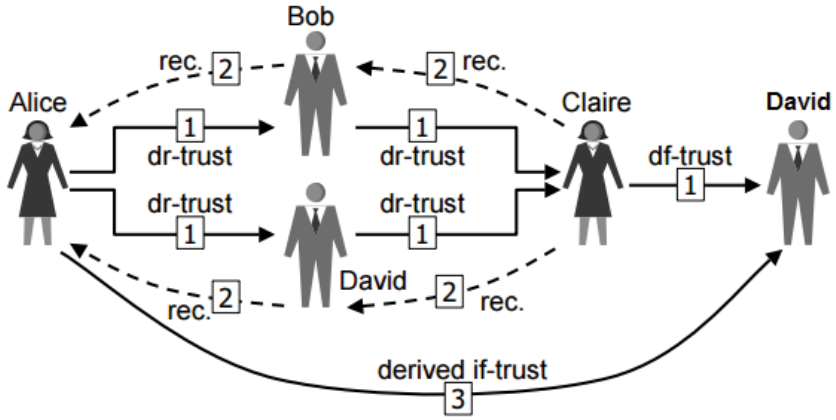

Figure 2.6: Transitive Trust Example (Josang & Pope 2005)

The condition is slightly complicated because Bob trusts Claire to recommend a good dentist but when he recommends the dentist to Alice, due to the indirect functional (if) trust from Claire to Bob before Bob to Alice, it can lead to a problem. It only works if the trust from Bob to Claire is not altered when Bob recommends to Alice. How likely this would be the case, really depends on many other conditions, Claire's confidence on David's competence or experience (functional trust). It is assumed that functional trust existed to the end of the transitive path for a better recommendation system (Josang & Pope 2005). The complexity increases as the chain grows further as discussed in this example.

2.3.1.4. Asymmetry

Trust is asymmetric because two friends in a network would be less likely to have the same amount of trust in each other. In the above example, Alice trusts Bob does not mean that Bob trusts Alice to the same extent. It varies with context, time and other variables which makes trust much more complex.

Trust is very personal and subjective.. Two patients may have very different levels of trust for the same dentist and hence this affects the accuracy of recommendations (Morri 2008).

Golbeck (2005) mentioned in her PhD dissertation that personalisation of trust is important in the social network environment and this has been overlooked. For example, two people may have different opinions about the trustworthiness of a person or a company. To clarify this, let's say in Rugby Union, when the All Blacks are playing against the Wallabies, the opinion depends on where they are from. Chung et al. (2015) and Boutet et al. (2014) further describe the importance of personalisation in recommendation systems by providing users with what they are most likely to be interested in.

Although trust is not totally transitive, trust is propagated in social networks in a situation when two users are not directly connected, by inferring a trust value along the path through which they connect in HSNs and determining how much one might trust the other. This concept has come from the trust transitivity and is also known as referral trust. In addition, the users usually combine experiences and opinions from multiple other users to derive another user's or organisation's reputation (Zhang et al. 2014). The impacts of social influences from social networks are further described to explain the dynamics of the trust. It has been envisaged that there are impacts of these elements when trusting one dental care practice or dentist over others.

In order to make the recommendation systems accurate and effective, personalisation of trust (Boutet et al. 2014) from each patient in the context needs to be captured and taken into consideration. However, information available online is often not enough to gather the details to determine trust related information. Some related work is discussed below.

2.3.2. Trust in Health Information Websites and Dental Crowdsources

A list of dentists which is an outcome from the dental care recommendation system may or may not be used by the dental patient. The intention to use the recommended dentist from a dental care recommendation system also depends on the level of trust in the system first and then the dentist, based on information provided. Kim (2014) conducted systematic literature review and pointed out the following types of trust antecedents that play a role in determining whether the recommended dentist would be selected for dental treatment.

- Individual difference antecedents – every individual is different due to their own upbringing, personal experiences and hence they react differently in different dental treatments. Socio-demographics, personality, health status and health literacy are factors which show individual differences.
- Website-related antecedents – patients use health websites including recommendation systems as long as they perceive that the site provides information quality, ease-of-use, good appearance and overall system quality.
- Consumer-to-website interaction-related antecedents – interaction with websites is important but that would only be effective if patients have had prior experience with using health information websites, perceived reputation, understanding risk and familiarity with the website and information.

Previously, Song & Zahedi (2007) described a model for trust in health informediaries, i.e. an intermediary for information, which is shown in Figure 2.7 below. The intentions to use health

information or take part in interaction or exchange of personal health information in HSNs are derived through a level of trust in the website. If the intentions are positive and the experience turns out to be a favourable experience, this can lead to the development of a relationship with a dental care recommendation system (trustee). Inherently, health consumers including patients would be more likely to re-visit the system and tell their peers about it. This is where power of SNSs comes into play. In terms of gaining trust, the first impression is very important e.g. to be willing to use and share health information within the HSN site, therefore social influence 'who refer to the site' has a critical role. Once the trust is established, there will be more interactions between the trustor and the trustee over time. The level of trust is determined by the information quality (credibility), system quality and satisfaction to the trustor which will be developed over time (Zahedi & Song 2008). Johnson et al. (2015) analysed the distinction between judgements and factors affecting the judgements in trust formation. The external factors in the figure 2.7 are factors influencing the judgements in forming trust.

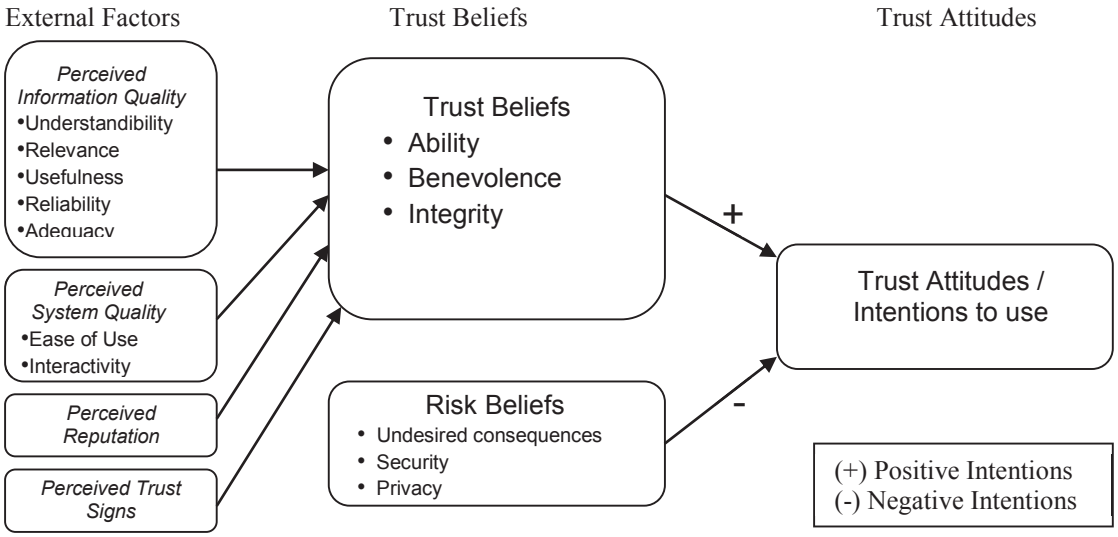

Figure 2.7: Transitive Trust Model for health infomediaries (Source: Song & Zahedi 2007)

The measurement of information quality is evolving with the pervasive ICTs in the healthcare domain. In the model, perceived information quality has been further classified into the following sub-categories:

Perceived Information Quality

- *Understandability*: Understandability means clarity of the information to the user. The medical and scientific vocabulary could create challenges for users to understand. As long as the HSN site is destined for the general public, the trustor needs to be careful of the vocabulary used, so do the users who are posting information online. There is always a danger that users may misunderstand the terminologies, and face consequences.

- *Relevance*: Relevance refers to the appropriateness of the information to the users in regards to how the information satisfies the users' needs. If the information is understood, the users are able to verify whether it is relevant to their needs. Medical or health related knowledge is important to understand the relevance of the information. Relevance is necessary to be looked at from 3 different views: topical relevance (about a subject matter), cognitive relevance (users's knowledge) and situational relevance (for the problem) (Johnson et al. 2015).
- *Usefulness*: Due to the sensitive nature of health information, healthcare consumers are concerned about any form of digital communication. However, perceived usefulness (PU) influences the trust beliefs to a positive territory and eventually influences behavioural intentions (Klein 2007). Johnson et al. (2015) identified that judgments of perceived usefulness is one of the core criteria for trust formation.
- *Reliability*: Reliability refers to the credibility of a dental care recommendation system as a trustee and the accuracy of the information provided by the trustee. It is a broad terminology and may well incorporate technical aspects of the system (Adams 2010). Trust is often measured based on the reliability of the information and reputation (Kim & Ahmad 2013).
- *Adequacy*: Adequacy refers to the completeness and references provided appropriately for the information. Completeness means an extensive coverage of health related information on a specific topic. This could be viewed as a sign of the commitment of the system to the users by providing unbiased information and references.

Perceived System Quality

A study was carried out to determine overall satisfaction with system quality and information quality for health information (Bliemel & Hassanein 2007). It was reported that system quality (usability) played a greater role than information quality in the study. System quality refers to reliability of the system, convenience of access, response time, flexibility, accessibility, etc. (Calisir et al. 2014). Both perceived ease of use (PEOU) and perceived usefulness (PU) are basic ingredients to support the technology acceptance model (TAM), an information system theory which models how users accept and use a technology (Davis 1989). This theory later on formed the trust antecedents of intentions to utilise the health related information as intended at the time of creation.

- Ease of use: The ease of use refers to the usability of a dental care recommendation system which will determine whether users want to spend time on it. Perceived ease of use (PEOU) influences the perceived usefulness (PU)
- Interactivity: Interactivity refers to the web features that ease the user's experience for the search and potentially even personalise the information based on the search criteria.

Perceived reputation

The term reputation can be defined as the social influence of trust, which can be referred as social exchange theory that defines one party's reputation based on a third party's ability to tell stories about its trustworthiness (Zhang et al. 2014). The terms 'reputation' and 'trust' are strongly linked to each other. Reputation is usually influenced by past behaviour. A repeated visit and prior positive experience of a health consumer on the platform denotes the perceived reputation. Any good or bad experiences or results are easily circulated via SNSs instantly in this social media age. It is even more important for health related information to be distributed faster if more people are to benefit or receive protection.

Perceived trust signs

Trust signs are used to reassure the healthcare consumers that there are no risks associated with HSNs to interact to or retrieve information from and reinforce the integrity of the provider. The use of trust signs is necessary to convince the users that they can trust the HSN platform and its information (Song & Zahedi 2007).

Deshpande and Jadad (2009) provide five broad categories to evaluate the quality of online health information and this is depicted as trust signs:

- codes of conduct (e.g. Australian Medical Association),
- quality labels (e.g. Health on the Net Foundation [HONcode]),
- user guides (e.g. DISCERN),
- filters (e.g. intute.ac.uk) and
- third party certification (e.g. Hi-ethics, Utilization Review Accreditation Commission (URAC))

There are other organisations in the world which reinforce criteria for quality health information providers. They are categorised under user guides, quality labels, filter and third party certification (Kitchens et al. 2014; Wilson 2002).

Overall, the external factors from the conceptual model in Figure 2.7 influence the trust beliefs and ultimately influence the HSN site user's intention to act on the information extracted from HSN sites. If the perceived information quality, perceived system quality, perceived reputation, perceived trust signs and satisfaction are all positive, the HSN site users will come back to retrieve and share health information in the site and recommend to others (Rowley & Johnson 2013; Gummerus et al. 2004). Loyalty is critical to sustain the systems however this information tends to have a temporal effect as soon as the user receives the required information, and there is no incentive for them to come back. The user satisfaction is what makes the users loyal and able to recommend the system to others.

The intention of using the information extracted from the dental care recommendation system significantly relies on the individual patient's preference, purpose and urgency of the matter, need and circumstances of the patient at the time and most importantly, trust in the system. In order to include these situations, this study focuses on different trust components which are relevant. Trust is also evaluated from 3 different sources: recommendation systems as a provider, reviewers or previous patients who provided information and dentists or dental practice. The existing trust component which is related to recommendation systems is discussed next.

2.3.3. Existing Trust Components in Recommendation Systems

Trust is one of the major factors on how dental patients decide to choose a recommendation system to find a dentist and choose their dentist. Trust is dynamic hence it can change after the treatment or within a certain time period or for different dental treatments. The trust will be positive if the outcome from the treatment is positive and satisfied. Some aspects of positive comments can influence other users in the recommendation system. The same applies to the flip side i.e. negative comments from patients and in fact it is easier to spread bad (negative) words faster than good words.

But what does that trust mean to the dental patients? How can that trust be retained by the dentist? For the dental care recommendation system, patients choose the system first, then the evaluations and feedback from previous users in the system and lastly the dentist. Trust plays a significant role in each step. Various trust components are reviewed in this section.

As discussed, the reputation trust of the recommendation system is an invaluable part of this study. In order to improve recommendations and the reputation of the system, perceived information quality and system quality is important. Information quality is determined by the quality of information shared and posted in the dental social network to impact the recommendations. Therefore, the patient's trust and honest posts of their experiences are important to fulfil factors of information quality such as understandability, relevance, usefulness, reliability and adequacy (Song & Zahedi 2007). Moreover, the recommendation system's user friendly and interactive qualities play a role in establishing its reputation and popularity.

The information quality of the recommendation system is dependent on how well the dental patients, as users of the network, share their experiences. Strength of the relationships among them, expertise in dental information as well as good involvement in the network are important variables. Zhang et al. (2013) analysed the outcome from a Facebook group concerning diabetes information and emphasised that a coherent group can produce valuable knowledge to benefit the group and eventually wider society. The same principle applies for finding a suitable dentist in the dental care social network. Strength of

relationship and the reputation trust among users within the social network constitute the foundation for the success of the dental care recommendation system. The more the dental patients share their honest opinions, the more likely the recommendation systems will be able to filter a suitable dentist after a search for a dentist. Indeed, it is entirely based on the number of genuine reviews and ratings by the patients in the network.

2.3.4. Types of Trust Components in Online Social Networks

Social networking sites (SNSs) are open platforms for communication and they provide a meeting place to create and share experiences in life. Users are willing to share information with each other, regardless of whether knowing or not knowing remote users (Jiang et al. 2014), and this brings both opportunities and challenges in terms of sensitive health information. For Example, a person who gets new symptoms of a health condition may ask a friend what s/he thinks about it and this friend can ask his/her friend and so on, until someone with trustworthy information about that particular symptom is found. When this is done online, the traditional cues such as facial expression, body language, tone of voice may not always be present but digital cues are available, which are in many cases a better indicator for trust and reputation (Bharadwaj & Al-Shamri 2009; Kwan & Ramachandran 2009).

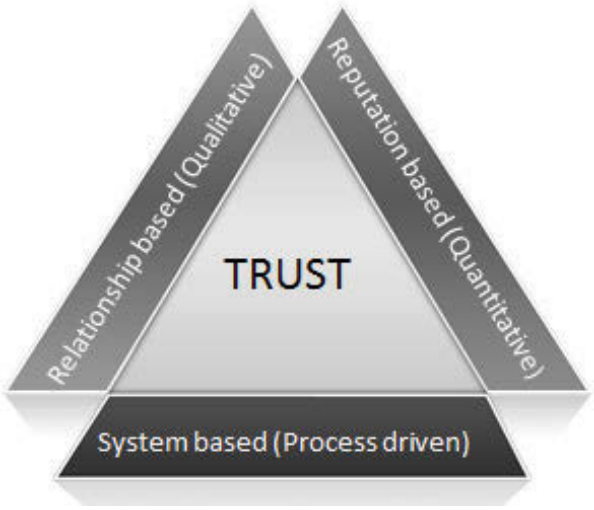

Figure 2.8: nGenera Online Trust Model (Source: Kwan & Ramachandran 2009)

In any activities such as chatting, posting or twittering in the social networks, some sort of trust is inherent whether this is done with or without the availability of complete information (Jiang et al. 2014; Gray et al. 2003). In order to explore on the digital cues in the health social networks environment, a model has been inherited from nGenera Insights 2008 (online trust model) which measures the trust based on reputation (Quantitative), relationship (Qualitative) and system (Process driven) (Kwan & Ramachandran 2009), as shown in Figure 2.8 above.

- **Relationship Based Trust**

Relationship based trust measures rely on connections within the social networks. Social networks provide a natural environment for users to build trust based on relationships, which relies on connections within the network. Social networks help to make new friends but the strength of friendships is very important in determining the trust between them. A level of trust can be derived from the relationship between friends with regard to recommendations (Wei et al. 2011). An extended relationship also has some credibility while finding out the trustworthiness of users and this feature is named either 'degree of separation' or 'common friends' function in the social network (Kwan & Ramachandran 2009). Not only the direct and witnessed experiences but also the social connections through a network are important for building trustworthiness (Kim et al. 2010; Zhang et al. 2014). For example, if 'B' is a friend of your friend 'A', 'B' will have a bit more credibility because s/he is friend of A. This credibility carries some weight when evaluating the trustworthiness of dental care services as well. By contrast, this feature could also potentially contain biased information or one-sided views, hence shilling attacks from the recommendation system are possible, and these could become fraud (Zhang et al. 2014; Kwan & Ramachandran 2009). There is a challenge for users to know the particular situation when health related information is posted online. Users normally depend on information contributed from other users in the network to make decisions about their own health issues, although the information posted might concern a quite different situation to what the user (information seeker) might hope to use the information for.

The trust is enhanced by the direct or indirect relationships in the social network. In social networks, trust propagates within the network through friends and the friends of a friend (FOAF) and it continues. The relationship can also be measured by combining a concept of engagement trust and popularity trust to create social trust from social networks (Nepal et al. 2012). The popularity trust simply means how popular the user is in a community based on relationships and requests from other users. The engagement trust is based on interactions between users in the community. Both of them are associated with relationships with other users.

- **Reputation based trust**

As mentioned earlier, reputation is a social concept which exists in a community but it is generally associated with a person's character or an organisation's standing. This means that reputation is actually collected and processed information about the person or the organisation's former behaviour for health related information experienced by other users. Reputation is an aggregated perception and is usually visible by all members of the network which reflects the global view and helps new users to form a personalised view and predict other member's future behaviour (Bharadwaj & Al-Shamri 2009; Malik & Bouguettaya 2009). In addition, reputation can be assessed by allocating a quantitative score for

trustworthiness in a given particular interaction such as star-ratings for ranking dentists. The concept of reputation increases the trust of the information and ultimately results in providing an incentive for good behaviour and a punishment for bad behaviour (Bharadwaj & Al-Shamri 2009; Kwan & Ramachandran 2009). However, there is a risk involved (due to gaming and anonymity in the health social network environment) to justify the true reputation of the information (Luo & Smith 2011). Therefore, there is a chance that users could misunderstand and use misleading information, which could result in catastrophic consequences (Doyle & Sixsmith 2008; Giustini 2012; Weitzel et al. 2012; Fernandez-Luque et al. 2012). Deng et al (2015) stated that the most influential people and reputation can be filtered by ranking influences to identify the most influential people in a community.

- **System based trust**

Most often trustworthiness is measured solely based on the health information provider's system or site and its interactivity but there is nothing much about the view of another user. This kind of trust is reliant more on designers and administrators of the system which can potentially avoid the risks which might be generated by the relationship and reputation based trust in the health social network environment. There is still a risk of gaming and misleading information online by only focusing on process driven trust in health social networks (Luo & Smith 2011). System based trust is not pursued in this study.

2.3.5. Impacts of Social Influence from OSNs

Social influence is an intuitive dynamic phenomenon that can change the behaviour of people to a certain extent by the decisions of their social contacts or friends or 'word-of-mouth' or imitation within the OSNs. Dynamics of adoption of the information is dependent on the strength of relationships, network distance, and characteristics of users in the network (Sun & Tang 2011). It also determines how influential or trustworthy the user is among others who are sharing and creating health related information in the network. Many studies have been conducted to identify influence and correlation in social networks from different aspects such as social similarity and influence, influence maximization and online social influence (Ma et al. 2014; Aggarwal 2011).

In a social network, people tend to have similar attributes to those of their friends; this characteristic is known as homophily. In the health social networks, users are motivated to find others like them with similar types of illnesses or health condition symptoms (Luo & Smith 2011). This occurs due to some natural mechanisms such as social influence, selection and other confounding variables (Sun & Tang 2011). Social influence affects people in such a way that they follow what their friends do, whereas selection is the process which helps to create a relationship with other people who are similar to them. Other unknown variables may lead people to behave similarly within friends circles as well. Although

both social influence and selection provide a support for the homophily phenomenon in the social network, they have a very different effect in the network. Social influence tends to create uniformity in the overall network with interactions but selection tends to concentrate in a smaller group with likeminded individuals and focuses on similarity. The effect of similarity which is induced by selection is more important and assists to predict in recommendation systems while mining social network data but social influence is useful in viral marketing (Crandall et al. 2008). In order to understand and balance the relationship between social influences and selection, Holme & Newman (2006) proposed a generative model with one opinion and then Crandall et al. (2008) proposed a more expressive model with multi-dimensional opinions for complex social networks. The models predict the user's activities based on their own history, their friends' history and other available variables (Sun & Tang 2011). Forming closed groups of patients with similar habits and attitudes would be ideal to transfer trust within the community to improve quality of recommendations.

The effect of social influences has been studied on health related issues such as obesity, smoking, sleep problems, loneliness, happiness and alcohol consumption by Christakis and Fowler over a long period (Sun & Tang 2011). It has been discovered that users in the health social networks tend to have a similar health status to their friends and in fact the status can be influenced by their friends. The study also shows that users are clustered together and they are extended to 3 degrees of separation within the health social networks (Aggarwal 2011). In a specific study of alcohol consumption, it showed that there was a statistically significant effect on alcohol consumption behaviour from one to others within the network.

2.3.6. Explicit and Implicit Information for Dental care Recommendations

In general, trust in recommendation systems can be classified into two types: explicit and implicit trust depending on types of information as input for the systems. Through social networks, it is possible to capture both explicit and implicit information (Alsaleh et al. 2011). Explicit information is usually collected by asking direct questions such as demographic information, preferences and other characteristics. For example, for dental care recommendations, age groups, frequency of visits to their dentists, type of dental treatments, types of insurance covered, etc. This sort of information is used to filter appropriate dentists to the patients in existing dental care recommendation systems. Meanwhile, social networks are also able to capture users' activities and behaviours (implicit) information such as sending messages, watching profiles, etc.

Many researchers (Guo et al 2014; Zhang & Yu 2012; Tselenti & Danas 2012; Alsaleh et al. 2011; Bhuiyan et al. 2010) pointed out issues concerning existing trust models i.e. that matching algorithms

are only based on explicit information. Hence, recommendations are based on only explicit information without any real values, and are usually biased towards preferences only. Real meaningful relationships cannot be investigated without understanding implicit information in social networks. Therefore, implicit trust based on the activities and behaviour of the users should be considered. There are two kinds of behaviours: active and passive. Active behaviours by the users are, for example, sharing information, sending invitations, commenting on posts and ratings. However, reading other users' posts, viewing contents, etc. is passive behaviour on the OSNs. Taking both active and passive behaviours into consideration, a behaviour graph can be drawn to understand the behaviours of the users (Nepal et al. 2013). Thus, valuable users within the network can be determined and their influence in the network can be measured. In regards to dental care recommendation systems, the recommendations from valuable dental patients would be considered higher than others. Understanding all the users within the dental care social network is valuable for the quality of recommendations that are produced from the system.

2.3.7. Existing Trust-based Recommendation Systems

Trust has been studied and analysed by many researchers in the context of social networks to incorporate in recommendation systems. In the context of the dental care recommendation system, trust is a critical factor because the patient needs to be assured that the dentist is trustworthy because the dentist will operate inside his/her mouth for most of the dental treatments. So far, trust based recommendation systems for social networks have been studied by Massa & Avesani (2004); Golbeck (2006); Josang et al. (2007); Walter et al (2008); Anderson et al (2008); Sarda et al. (2009); Victor et al. (2009); Lopez-Nores et al (2010 and 2011); Mehta & Banati (2012) and others. They have used different parameters such as electronic health records (EHR), positive responses, query responses, frequency-based, property-based, user-based, item-based, reputation, knowledge and others for measuring trust.

The HSNs and dental crowdsources provide great opportunities for information sharing, collaboration and interaction, but there is a chance that users can potentially abuse the system by providing the wrong information in the network for personal benefit (Zhang et al. 2014). Therefore, an appropriate recommendation system is very critical for healthcare information. Trust has been recognised as the most effective factor to determine and filter the right information (O'Doherty et al. 2012; Zhang & Yu 2012). Trust is also identified as a critical factor in dental care when choosing the most suitable dentist due to the nature of invasive treatment. Trust-based recommendation systems are able to refine information by utilising personalised profile-based trust within social networks (Boutet et al. 2014). Growing popularity in social networks and research on trust within social networks have been the main

reasons for the increasing trust-based recommendation systems (Kim & Phalak 2012). There are different methods for calculating trust between users.

TidalTrust by Golbeck (2005) used the explicit trust values given by the users of the network to each other. Trust is calculated as a weighted average of the trust values given to the trustee by the trustor's trusted users. Smyth and O'Donovan (2005) defined item-level and profile-level trust. In general, trust is estimated by measuring past recommendations by the trustee in two levels: general reliability based on profile-level, and fine-tuned item-level which represents the percentage of correctly recommended particular items. MoleTrust by Avesani et al. (2005) is very similar to TidalTrust concerning the explicit trust value of the users. However, it does a depth-first search by looking at the hop distance from the trustor to the trustee because they adopt linear decay in propagating trust through each hop. Matsuo and Yamamoto (2009) predicted trust by extracting information from user profiles, reviews and existing trust relations between users. Skopik et al. (2009) used trust relationships between users by looking at the communication between users. Wang et al. (2011) estimated trust of users based on similarity in taste (classification of items). They used the rating frequency of users to classify the users into different groups of tastes and calculated trust based on common taste. Zhang & Yu (2012) described the category-specific trust relationships between users. In addition, they also used role-based and behaviour-based reasoning functions for users' interest and trust relationships. Kim & Phalak (2012) measured trust metrics based on users' expertise, preferences and feedback rating data. They believed that feedbacks are more frequently expressed than explicit trust in the online social network environment. Fernandez-Luque et al (2012) defined HealthTrust as a trust for content and members of the health community.

Tselenti & Danas (2014) reviewed trust-aware recommendation systems and compared some of the trust models. They were critical of the fact that trust was only established from explicit information from the social networks. Indirect or implicit information from the social networks was not analysed for inclusion in those trust models. Context for each trust model has also not been accounted for well. Understanding the context where users are sharing information and the user behaviour from the social networks are very important factors to determine accurate meaning and trust from the interaction in the social networks.

2.3.8. Existing trust components from patients' perspectives

Hall et al. (2001) measured trust in the physician based on the 5 following dimensions:

- Fidelity – doctor will do whatever it takes to get the patient all the care they need
- Competence – medical skills of the doctor
- Honesty – explaining all the treatments available for the patient

- Confidentiality – knowing what the doctor can share with others
- Global trust – complete trust to put patients' life in doctor's hand.

Patient's trust is broadly defined by Rolfe et al (2014, p.3) 'The belief that a doctor is working in the patient's best interests'. According to Rolfe et al (2014), with that belief, patients expect that their doctors and dentists will:

- Evaluate their patients' problems thoroughly
- Understand their patient's experiences,
- Possess compassion, empathy, advocacy, and reliability,
- Communicate clearly and completely
- Be concerned with continuity of care
- Build a partnership
- Give time in the consultation
- Provide appropriate and effective treatment
- Be honest and respectful to their patients
- Practice patient-centred care
- Display knowledge and learning skills.

In addition to the above interpersonal skills, Rolfe et al (2014) highlighted that trust is correlated with the reputation of the institution or practice that doctors and dentists work in. It is recorded that there is more trust with the doctors and dentists if the insurance companies provide more choice in terms of doctors and dentists.

Furthermore, due to the invasive nature of dental treatments, trust in dentists are also evaluated by considering their chairside manners, taking into account how the patient is greeted and introduced, how the patients' questions are handled and communication through signals even when the patients is not able to speak.

Trust in dentists is the starting point for a recommendation system as the trust is exposed in the dental crowdsources one way or another via star ratings on criteria and feedback. An honest opinion of a dentist which resembles a level of trust is shared in the dental crowdsource so that new patients can make decisions based on honest feedback. Aggregated feedback and rating for a particular dentist is revealed as the reputation trust of the dentist, based on which new patient chose them for a specific dental treatment.

2.3.9. Trust from CRM Perspectives

CRM stands for customer relationship management. Customers in this study are dental patients to the dental practices. So CRM is defined as an approach that a dental practice as a business takes to build long-term relationships with patients in order to optimise their profit (Rosak-Szyrocka et al. 2013). The main objective of implementing CRM is to maintain patients' loyalty which can be regarded as trust from the patients. CRM focuses on customer/patient-oriented culture and processes in the business so that patients gain value by fulfilling their expectations. Trust can be gained from the patients when their expectations are met. For this reason, Rosak-Szyrocka et al (2013) suggested profiling patients based on their demographic, psychological and associated level of risk so that separate promotional strategies could be utilised for each type of patient. The patients' acceptance and satisfaction rate could be utilised as trust variables to promote the practice in the future. Therefore, ongoing analysis of a dental practice from patients is an important step for any dental practice. This approach is important for a dental care recommendation system to gain and retain its reputation as the first choice for dental patients.

2.3.10. Open Issues in Trust Components and Ambiguities

Since trust has many meanings, it is very difficult to pinpoint the exact meaning while discussing the dental care recommendation context. As discussed earlier, in each level, a certain kind of trust is associated in the system whether it be reputation, relationship, system, referral, functional, etc. Trust is subjective in nature and varies with different people.

Understanding properties of trust and context of the particular event or treatment is important to explore for effective dental care recommendation system. Continuous update and opinions from more users should be updated to give accurate information and filter a suitable dentist. Since the meaning of trust changes for different people, perception of trust changes as well and hence the ratings and description for the same scenario changes and makes it more challenging to assess the situation.

General Dental Council, UK (2010) reported that respondents of a focus group expressed mistrust towards dentists in the UK by stating that 'dentists are no longer viewed as healthcare professionals, but rather businessmen'. Similarly Rosak-Szyrocka et al. (2013) stated that dentists should operate their practices on a commercial basis in addition to becoming a good doctor to be successful. They also pointed out that the effectiveness of dental treatment also depends on how patients follow instructions from their dentists. Patients sometimes are not aware of the effect of discontinuing treatments, and blame dentists for the consequences. Therefore, quality of service in dental treatments does not only depend on the work by the dentist but also what was the condition of the patient's teeth before the treatment, how well they follow instructions, and the oral hygiene of the patient.

2.4. Existing Mechanism on Recommending Dentists

A dental care recommendation system helps dental patients to find suitable dentists. Most of the recommendation systems allow the dental patients to search for a dentist based on the specific location such as suburb or post code and name of dentists in that location or nearby. More systems have emerged by adding other objective criteria in addition to location, such as types of dental treatments, age group of patients, type of insurance and insurance providers, etc. In the last few years, the recommendation systems have integrated rankings from ratings and reviews of dental crowdsources. They allow the patients to evaluate dentists or dental practices based on certain criteria in the form of star-ratings to express their experiences with the dentist and other aspects such as staff friendliness, office cleanliness, etc. Some sites allow them to provide free textual feedback on their dental treatment experience. However, users are presented with ranking of dentists based on the aggregated rating scores from the criteria used in each site. A combination of the number of reviews and aggregated ratings are used to filter and rank the dentists in some of the sites. Other sites are able to filter and rank dentists based on specific types or treatments or specialties in specific locations. The sites are evolving continuously due to the upward trend in the usage of dental crowdsources. These rankings are used to filter a list of dentists when a dental patient searches for a dentist as shown in Figure 2.9 below.

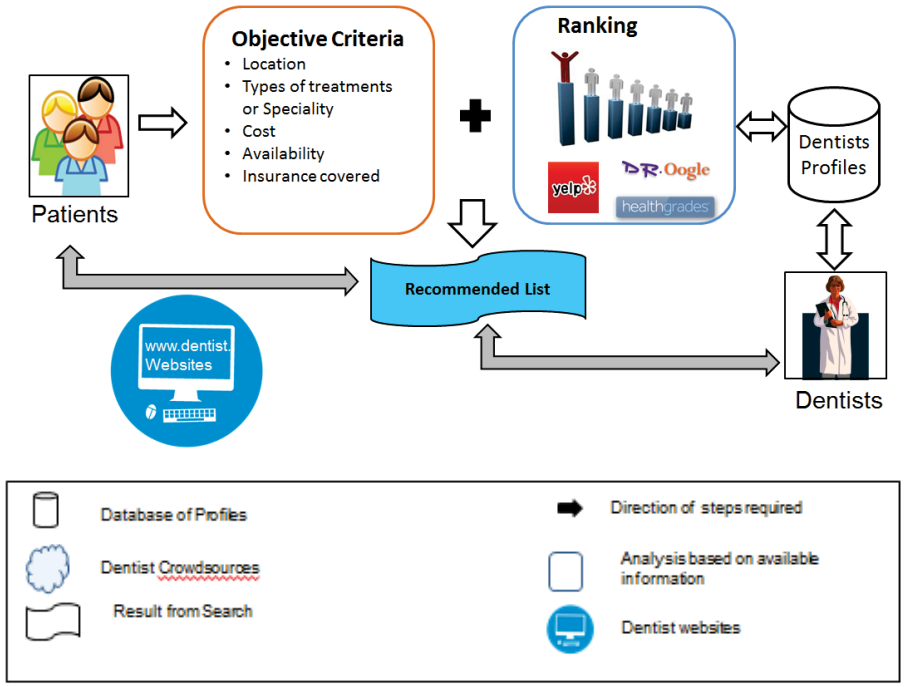

Figure 2.9: Matching process in a dental care recommendation system

As mentioned earlier, there is a discrepancy in the criteria to determine the best dentist in different sites and it has been one of the major challenges in confirming a suitable dentist. Therefore, depending on the recommendation sites chosen, different list of dentists are displayed in the recommended list.

A matching process of typical dental care recommendation systems is shown in the figure above. Some of the most popular dental crowdsources, Yelp, DrOogle and Healthgrades are shown in the figure, as an example to rank the dentists in the system. These sites are very popular in the US to search suitable dentists. There are many other sites available as discussed earlier. The important question is which one to rely on?

It is apparent that different sites have different ways to rank and recommend the best dentists to dental patients. Table 2.6 below shows a brief summary of the criteria used on the sites.

Table 2.6: Comparison of criteria used in dental crowdsources

Sites	Criteria used (1 to 5 Likert Scale)
DrOogle	'like a health spa', 'first class service', 'painless procedures' and 'superb results'
Dental Fear Central	None
National Dental Reviews	'office cleanliness', 'staff cleanliness', 'short wait time', 'chairside manner' and 'explained treatment'
RateMDs	'staff friendliness', punctuality', 'helpfulness' and 'knowledge'
Health Grade	'scheduling appointments', 'office environment', 'office friendliness', 'wait time', 'level of trust', 'helps patients understand their condition', 'listens and answers questions', and 'time spent with patient'
Yelp	Overall

Dental Fear Central does not rate dentists because it is dedicated to providing awareness of dental fear and it provides a forum to discuss dental anxiety as well as giving tips to overcome dental fear.

DrOogle and RateMDs rank the dentists based on the positive reviews and ratings in a specific location or suburb. However, the exact algorithm for the rankings is not known. Some sites including Yelp do not directly recommend to the users. Instead, they provide extensive reviews which eventually mean indirect recommendations. However, the best matched can be determined by applying some filters such as price, distance, availability and dental specialities.

2.4.1. Mismatch of the Criteria

In addition, different dental crowdsources use contrasting vocabulary terms for similar criteria to rate the dental service. The criteria from the above table 2.6 is arranged in terms of categories: quality of service, quality of care, quality of staff, quality of environment, scheduling appointments, waiting time, specific knowledge and explanations to the dental patients. Various criteria used in different sites is given in the table below.

Table 2.7: Comparison of the criteria used in the sites (√ - Yes and × - No)

Criteria	DrOogle	National Dental Reviews	RateMDs	HealthGrades	Yelp
Quality of Service	√	×	×	×	×
Quality of Care	√	×	×	√	×
Quality of Staff	×	√	√	√	×
Quality of Environment	√	√	×	√	×
Schedule appointments	×	×	×	√	×
Wait time	×	√	×	√	×
Specific Knowledge	×	×	√	√	×
Explanation	×	√	√	√	×

The availability of numerous sites with various measurement criteria makes it difficult to decide the right information when choosing a suitable dentist. The same dentist may be ranked differently in different sites due to the various criteria used.

In this study, we investigate various types of trust variables to incorporate in dental care recommendation systems to mitigate and streamline the process of recommending a suitable dentist to patients. Trust can be incorporated in user profiling of recommendation systems and it is discussed in the following section.

2.5. User Profiling for Recommendation Systems

User modelling or profiling is the core process in a recommendation system (Schiaffino & Amandi 2009). User profiling is about gathering the most essential information about the user. In dental care recommendation systems, there are two major stakeholders who need to be profiled: dental patients and dentists. When a dental patient visits a dental care recommendation site, a profile is created by entering location or post (zip) code to search for a dentist. Other explicit information from the patient can be collected e.g. demographic information (age group), types of treatments, type of dental insurance, insurance provider etc. For example, a dental care dedicated website 1800dentist.com in the US requests explicit information from users. But most of the dental crowdsources do not ask much more detail except location to filter the list of dentists.

On the other hand, dentists are often listed with their qualifications, address, contact telephone numbers, website address, photos of the dental practice, etc. Most of the dental crowdsources, collect patients' feedback and star-ratings. The reviews and ratings are listed alongside the dentists' profiles. Matching is done by aggregating ratings from the reviewers in the specific location. However, it is important to personalise the recommendations by exploring the differences (Chung et al. 2015; Boutet 2014; Kim & Ahmad 2013; Schiaffino & Amandi 2009) in dental patients in order to produce efficient recommendation systems. The differences in dental patients stems not only from objective criteria such as location, ages, types of treatments but from their subjective information such as attitudes, behaviour and perceptions. These types of subjective information are usually ingrained within an individual (Zhang et al. 2014) and as a dental patient this behaviour changes the way dental treatments are perceived.

2.5.1. User Profiling from Social Networks for Recommendation Systems

The information from the social network can be divided into static and dynamic information (Kazienko & Musial 2006). Static is similar to explicit information which is gathered by asking the user to explicitly answer certain questions in the social network such as location, treatments types, demographic information (age group), preferences, characteristics, etc. However, dynamic information is inferred from user behaviours based on user activities on the network such as ratings, patterns of the ratings, number of useful postings and other activities in the network. Explicit information such as demographic information, location, interests and other characteristics can easily be found. More information from user activities can be obtained from social networks implicitly as well but they are not easily achieved. Schiaffino & Amandi (2009) stated that the user profile may contain user interests, knowledge background and skills, goals, behaviour, interaction preferences, individual characteristics

and contextual information. For recommendation systems, the more users' personalised information is collected, the better the matching is expected to be (Boutet et al. 2014). Implicit information such as behaviour, perceptions and emotions are possible to be extracted from social networks by monitoring social activities in the specific social networks. Obviously, the content in the network differs as per the type of social network (Schiaffino & Amandi 2009) but behaviour across many different social networking platforms remains the same.

A recommendation system usually helps to make a choice by reducing and ranking a given set of items such as books, games, apps, websites or professionals. It utilises personalised information to identify and filter the list of items which might be of interest to the user either by using CF or CB or a combination of both (i.e. hybrid methods) as mentioned earlier. In the dental care recommendation system, the process of filtering uses a variety of information related to the patient such as demographic information, type of dental treatments, type of insurance covered and information related to the dentist such as popularity, qualifications, and reputation in terms of star ratings.

Both explicit and implicit information can be collected from social network users to profile while they are involved in various activities. According to Zhou et al. (2012), the success of a recommendation system is based on the quality of user profiles captured through explicit and implicit information. However, users are using different types of SNSs (general, microblogging, health specific) and this adds complexity and challenges to be able to extract user profiling across many different platforms. Not only concealing identification (fake id) a challenge in the social network environment but also different types of conversation in different platforms make it harder to profile/recognise a type of user. Moreover, a user can behave differently for different users in a network, referred as the adaptation effect (Brusilovsky & Millan 2007), which adds even more complication to predict a user's behaviour and profile.

Batool et al. (2012) reported that personal posts in SNSs helped to complete patient profiles when the users use healthcare track and share their health symptoms online. These users are relying on social media to make some of their healthcare decisions such as going to hospital, changing their diet, coping with some symptoms, exercises and even finding their doctors and dentists.

Thus, social networks have been a prominent source for user profiling to include both explicit and implicit information. When user profiling for healthcare issues including dental care, extra care should be taken as the impact in health sector is much more sensitive and personal than in other industries.

2.5.1.1. Importance of Information Related to Trust for Profiling

Healthcare and dental care are not immune to the spread of the popularity of social media and recommendation systems. Making decisions for health treatments have been obstructed by overwhelming amount of information online (Wiesner & Pfeifer 2014). However, the trend of searching for health related information and sharing through SNSs has been increasing (Pickard & Swan 2014; Luo & Smith 2011). The HSNs have been used by both health professionals and patients, transforming the way health consumers connect, search and communicate. These sites allow their members to create, retrieve and share information and experiences. Examples include MedHelp, WebMD, PatientsLikeMe, DailyStrength, CureTogether, Tudiabetes, Asthmapolis etc. (Swan 2012). Healthcare consumers have moved from searching information online to sharing information and interacting with other users within the platforms (Lober & Flowers 2011).

The users of HSNs and dental crowdsources are increasing as they can find comments or information related to the specific health condition or symptoms or find others who have experienced similar health issues. The users are not only able to retrieve related information but also create and share their experiences through the sites. Moreover, the users can get emotional support by seeing others with similar health symptoms/conditions and feel "I am not alone", which empowers users and give them a sense of community so that they will go back and share more (Swan 2009). It is one of the most efficient approaches to win users' hearts or allow them to trust the site. Some of the HSNs are successful in allowing their users to share a lot of information about their medication, side effects, and types of therapies along with their symptoms, for example Patientslikeme.com, where patients are sharing details of their treatments and impacts within a timeline.

Batool et al. (2012) and Zhang et al. (2013) studied online social media posts for diabetes. Batool et al. (2012) used smart clinical decision support system to analyse social media posts to provide recommendations and alerts to diabetic patients. Extracting users' interests, health conditions and emotions from social media have helped them to provide personalised information and guidelines to patients and more knowledge about the patients to the doctors. Zhang et al. (2013) only used Facebook groups for their study. The groups experienced social and emotional support and a sense of community. Most of all, they shared a lot of personal information and medical information. The information related to the health conditions is the best source of information for profiling patients with a degree of relatedness to the specific healthcare recommendation system. A combination of direct input or static information from the patients and dynamic and implicit information from the social network, helps to profile patients accurately and effectively.

2.5.1.2. Behavioural Information used for Profiling

Behavioural profiling of customers is very valuable as they can target by customising products and services. It has been used in the advertising and marketing world and is very useful for understanding patients from a behavioural level which helps to filter and match a suitable professional in healthcare and dental care. E-commerce sites use behavioural tracking so that the companies can recommend products or services that are of somewhat interest to the users by using cookies, Javascripts, supercookies, or browser fingerprinting. internet giant Google can build an accurate profile of gmail users and advertise an appropriate product to the users in a timely and accurate fashion (Castellucia 2012). From the users' perspectives, Castellucia (2012) argued that customisation from profiling are seen as benefits because the users are only receiving information about products and services which they are interested in. But, serious privacy concerns arise as some organisations can access a massive amount of information from their customers and internet users. When the information is about the healthcare issues, it is obviously a very sensitive issue, and could lead to detrimental impacts to the users in case anything goes wrong. In some cases, people can lose their lives because of wrong information or treatments.

2.5.1.3. Challenges in User Profiling

Cold start and sparseness problems in recommendation system are prevalent due to not enough information about the users in the network either because the user has just started or the field is very specialised and not many users and information is available (Su & Khoshgoftaar 2009; Lopez-Nores et al. 2010). In addition, malicious or false rating is another big challenge in the industry. These challenges are related to user profiling because the recommendation systems takes consideration of all the user profiles, regardless of the challenges. What is good for profiling is also good for malicious users to launch targeted attacks, spam and phishing attacks (Balduzzi et al. 2010).

With the increasing number of healthcare consumers turning to HSNs and dental crowdsources for retrieving and sharing health and dental care information, the number of the users who rely on the information from these sites to make decisions about their health also rises. It raises the notion of potential danger on a short or long term basis for those healthcare consumers and society. The degree of danger unequivocally depends on the users' skills and the knowledge of the healthcare consumers to interact with the HSN communities and other health related sites, such as medical or scientific vocabularies and biomedical knowledge and understandings (Webster et al. 2011). How can this information be incorporated in to the user profiling? Many other kinds of information can be considered including level of education, friends and influences from others.

Better Health Channel (2015) has listed some of the potential risks associated with health information online, such as wrong diagnosis; misunderstanding of medical jargon; self-medication, which may delay a visit to a health professional and prevent early and appropriate treatment for the illness. A delay may also lead to serious health complications or even death.

As mentioned earlier, the privacy of users in social networks remains a major concern as some organisations can easily access personal information (Gritzalis et al. 2014). In regards to health and dental care, the information is considered even more sensitive and there are certain rules and regulations which need to be followed. However, Pickard & Swan (2014) stated that there is a substantial shift in that health consumers are willing to share personal health information for specific purposes such as research and charities.

There is another big issue in profiling from social networks being fake and anonymous identification. Anyone can create as many ids as they wish in the social network as long as valid emails are provided. This poses a big challenge in terms of trustworthiness for the users of social networks (Baden et al. 209).

2.5.2. User Profiling for Patients

For dental care recommendation systems, dental patients and dentists are profiled with related information for dental treatments, and this is mostly based on the types of treatments required for a patient. However, in this study, the profiles are approached differently to incorporate both explicit and implicit information for better matching in the recommendation system. This section describes how user profiling for patients and dentists are done in the existing dental care recommendation systems and what method is going to be used in this study.

For dental patients, user profiles are generally classified based on

- new or old patient
- age group such as children, adolescent, adult or retired
- types of dental treatments such as general check-ups, scaling, implants, dentures, etc.
- medical history such as diabetic or suffering from any major diseases and
- insurance covered or not. There is variety of insurance covers for dental care which differs with insurance companies and with different countries.

Moreover, dental symptoms, dental work in the past and other dental care related information can be added to understand patients better. Most of the dental crowdsources care about a patient's location to

recommend dentists in a specific location. Other information is rarely asked, except in a few dental crowdsources.

In order to integrate personalised trust from the recommendation system, more information from the dental patient is required. As discussed earlier in this chapter, more implicit information from the social network is possible to collect through social networks. However, due to the privacy and identification challenges, it is still a long way from getting the information from the social network, specific to dental care information.

Behaviour usually is just an expression of personality in a given circumstance. Ontology, a natural way of being, people's attitudes, behaviours and perceptions have been studied from a very long time, in the area of psychology. Therefore the personality of dental patients is included in the user profiling in this study. The level of trust differs according to the types of personality (Chamoro-Premuzic & Funham 2009). Personality is also closely related to the subjective characteristic of the individual. Attitudes and personality traits are underlying hypothetical characteristics that can only be interpreted from external and noticeable cues such as verbal or non-verbal behaviour and the context in which the behaviour occurs (Ajzen 2005). Thus, subjective characteristics have been included as a latent construct with users' rankings and ratings for products (Luo et al. 2008) and rating a professional is about his/her subjective characteristics.

2.5.2.1. Existing Patients' Segmentation

Dental practices and dentists classify their patients according to their visit patterns (regular or irregular), health conditions of the patients, affordability either through insurance company or personal and age groups. Knowing a patient's medical history is a very important step before treating patients for their symptoms. Therefore, the American Society of Anaesthesiologists prepared a classification based on the physical status of patients by analysing medications, medical history, consultations, physical and clinical examinations and other evaluations (Govoni & Leeuw n.d.). Classifications are: healthy patient, patient with mild systemic disease or severe systemic disease or severe systemic disease that is a constant threat to life, etc. The socio-economic status and affordability for regular and proper dental treatments are related to healthy oral health in patients (Musacchio et al. 2007). As per the results from interviews with dentists, it can be summarised that many practices classify their patients based on their affordability whether it is from an insurance company or personal payment.

One of the popular business model developed by Osterwalder & Pigneur (2010) is reviewed to explore patients' segmentation. They designed a business model canvas which incorporates all aspects of a business by drawing 9 building blocks: Customer segments, customer relationship, channels, value proposition, key activities, key resources, key partners, costs and revenue stream. Kevin Riley (2013) replicated the model for healthcare and created an open-source business model canvas, named modelH.

'Customer segmentation' is one of the building blocks used in the original model by Osterwalder and Pigneur. However, in modelH, it has accustomed and classified healthcare consumers (patients) by Archetype, Life Stage, Life Condition and Life Style, as shown in the Figure 2.10 below.

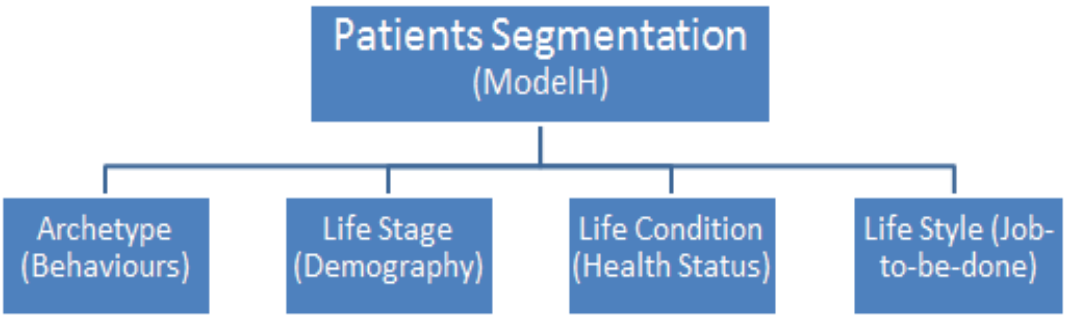

Figure 2.10: Patients Segmentation (HModel) (Source: Riley 2013)

2.5.2.2. Personality-based Segmentation

In this study, we have considered all segments but emphasised behaviour aspects to integrate subjective characteristics while profiling patients. The other segments are confined more or less to objective criteria such age, medical conditions, types of dental treatment required etc. An individual's subjective characteristics including behaviour, attitudes and perception play a vital role in relation to how the treatment is perceived from a professional service provider such as a dentist. For patient's behaviour, attitudes and perception, the personality of the patient is one of the important traits and this is explored in this study. Therefore, we look at the personality of a patient, which affects his or her emotions, motive or behaviours in various situations.

Trust is predominantly dependent on the behaviour, attitude and perception of patients. Therefore, the research is focused on investigating these factors. The next step of the research is profiling patients from an aspect of the archetype.

- **DISC Personality test**

In 1928, Professor W. Marston stated that people, in general, show their emotions and behaviour through in four ways: Dominant (D), Influential (I), Steady (S), and Conscientious (C). DISC characteristics of emotions and behaviours are widely used for personality tests. In the context of dental treatment, we have inherited this DISC model of personality test to classify the patients. Once the personality is determined, it may help to understand certain patterns of the patient's behaviour in certain situations or circumstances. Matching the patient with a dentist who is good and experienced in dealing with that particular type of patient would be a good outcome for a recommendation system.

Extensive lists of behaviour which qualify for the particular categories of DISC are available such as ambitious, outspoken and decisive for D, friendly, expressive and people-oriented for I, good listener, consistent and family-oriented for S and organised, perfectionist and detail-oriented for C (DISCInsights 2015). The table below shows some more characteristics.

Table 2.8: Characteristics under DISC model

Dominant (D) • Direct • Outspoken • Decisive • Assertive • Competitive • Ambitious • Time-conscious • Task-oriented	**Influential (I)** • Influencer • Friendly • Talkative • Expressive • Attention-seeking • Optimistic • Outgoing • People-oriented
Conscientious (C) • Competent • Compliant • Logical • Methodical/Analytical • Perfectionist • Organised • Data driven • Detail-oriented • Observant	**Steady (S)** • Stable • Consistent • Good listener • Patient • Team player • Need time to adjust • Don't like surprises • Family-oriented • Peacemaker

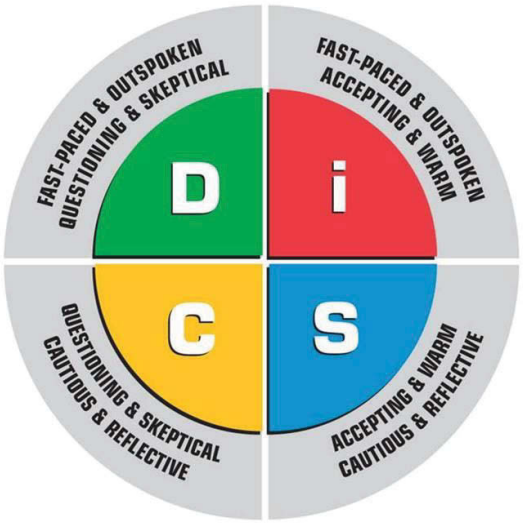

Figure 2.11: 4 Quadrant DISC Personality Model

The personality test was first introduced in 1928. Since then the test has been explored and used in many areas to predict behaviour and analyse the dynamics of team work. Behaviour usually is an expression of personality in any given circumstance. The personality test is freely available through the website: discpersonalitytest.com

A level of trust emerges from an experience of interaction between a patient and a dentist. If the treatment is good and positive, the direct functional trust is positive. However, if it is not a good experience then it is negative. The sentiment and the language on the feedback will reflect the level of functional trust. The experience also depends on the type of patient.

For this study, the DISC personality test has been analysed by employing DISC Classic 2.0 (discprofiles4u 2014) to help people to understand the strengths and challenges of each behaviour style. This has simplified the types of personalities from the DISC test so that there are 15 types of people, as shown in Table 2.8.below. It basically represents 15 combinations of D, I, S and C. For example, pure D is Developer, pure S is Specialist, a combination of S and I, is Agent and so on. Table 3 details the combinations of D, I, S, and C and uses one word to describe the various personality types. It simplifies the DISC personality test so that it is readily understandable.

Table 2.9: Profiles based on DISC personality test (Source: discprofiles4u 2014)

1	**Achiever** - is confident of their personal work accomplishments, and may be reluctant to delegate tasks when under stress.	S/D
2	**Agent** - is easy going, relaxed, and they go with the flow.	S/I
3	**Appraiser** - is practical, and ensures progressive results by developing a detailed plan of action.	IC
4	**Counsellor** - embraces others with their warmth, empathy, and understanding.	IS
5	**Creative** - makes sound decisions yet may lack attention to interpersonal relationships.	DC
6	**Developer** - is self-reliant individuals who prefer to seek their own creative and individualistic solutions.	D
7	**Inspirational** - attempts to control their environment and directs the behaviour of others toward a predetermined goal.	DI
8	**Investigator** - calmly and steadily pursues toward a fixed goal.	S/CD
9	**Thinker** - focuses on achieving complete and total accuracy in everything they do.	C
10	**Perfectionist** - is precise thinker and employs plans and procedures for both their personal and professional lives.	C/S
11	**Persuader** - loves working with and through people to accomplish their own objectives.	ID
12	**Practitioner** - prefers a comfortable and cooperative environment where people are trusting and pleasant.	C/IS
13	**Promoter** - is more interested in interaction, and less interested in accomplishments.	I
14	**Result-oriented** - is competitive and likes difficult tasks and high positions.	DI
15	**Specialist** - is considerate, patient and always stands ready to help others.	S

○ Other types of personality test

Like the DISC personality model, another descriptive model of personality traits, focuses on five dimensions called the Big Five traits (McCrae & John 1991): Openness, Conscientiousness, Extraversion, Agreeableness and Neuroticism.

Openness: includes having wide interests, and being imaginative and insightful.
Conscientiousness: tend to be organised, thorough, and planning oriented.
Extraversion: encompasses more specific traits such as talkative, energetic, and assertive.
Agreeableness: includes traits like sympathetic, kind, and affectionate.
Neuroticism: characterised by traits like tense, moody, and anxious.

There are many other types of personality tests which can be chosen to classify patients in order to match them with a suitable dentist. These include: Personality and Preference Inventory (PAPI), Hermann Brain Dominance Instrument (HBDI) or Big Five Factors. Of these types of personality tests, one of the most popular tests, the DISC personality test is chosen in this study. Obviously, other tests can be used instead for the purpose of profiling patients based on their subjective characteristics. A matching algorithm can be tailored based on the analysis obtained from the particular personality test.

2.5.2.3. Other Factors Important in Patients Profiling

There are many other factors which are important to be considered in the classification of patients such as dental anxiety, dental hygiene behaviour, genetic disease and so on. Carter et al. (2014) pointed out

that although appointments were booked earlier, patients did not show up due to dental fear. The dental patients in general, are conscious about the invasive nature of treatment and cost (i.e. it is not covered by a private fund in many cases) in comparison to other health care treatments. For instance, a study in dental care patients by Rodriguez-Vazquez (2008) revealed that 96.8% of the participants in Spain (out of a total of 804 patients) showed some degree of stress about dental treatment. The same study also quoted that dental fear can upset up to 50% of the general population. Another dental health survey showed that 46% of the participants in Australia were anxious about going to the dentist (Armitage & Reidy 2012).

There is a need to analyse dental fear and incorporate that into classifying dental patients. Although two patients may have undergone the same treatment by the same dentist for the same symptom, the result may be different because of the individual patient's dental hygiene behaviour such as frequency of brushing and flossing teeth, quality of toothbrush, toothpaste etc. (Vani et al. 2010). Such detailed personal information impacts on the outcome of dental treatment, and this represents a challenge in terms of classifying patients.

Moreover, the patients can also be classified based on how they behave such as demanding, annoying, angry, needy, abusive, argumentative, vexatious, inflexible, etc. (Breen & Greenberg 2010). There is no clear guideline on how the patients should be classified because there are many aspects of the patient which need to be considered.

2.5.3. User Profiling for Dentists

Dentists are major stakeholders in the dental care recommendation systems. Accurate and proper profiling of the dentists is very important for success of the dental care recommendation system. This section explains what profiles have been used for dentists and what is used in this study. Usually, dentists are classified based on their qualifications and number of years of experience. They are also categorised according to both the location and the actual place that they work such as hospital or practice run by a health insurance company or a private practice.

Besides the way that the dentists are classified, how patients find the dentist and visit them for a dental treatment is focused on in this dental care recommendation system study.

2.5.3.1. Existing Segmentations of Dentists Profiling

Dentists are usually classified by the type of specialty work that they do. For example, general dentist, periodontist, orthodontist, endodontist, pedodontist, prosthodontist, oral surgeons, or cosmetic dentist. Based on their qualifications and experience, they become specific specialists in particular areas of dentistry. Besides the qualifications and specialty, the actual place that they work such as hospital, private practice, etc., address of dentist's practices, telephone numbers comes into play. When patients search for a dentist they also take into consideration the dentist's years of experience, the university that they graduated from and how long ago, the dentist's working history, the number of awards they have won, the dentist's ethical background or even the dentist's gender.

2.5.3.2. Challenges in Segmentations of Dentists

Even though two dentists may have the same qualifications, training, experience and other criteria, patients perceive the dentists differently because of their other skills such as empathy, communication as well as their attitude and behaviour. Breen and Greenberg (2010) clearly state that the difficult patient is a perception of a medical professional either doctor or dentist, hence if one professional perceive a patient as a difficult patient, it does not necessarily mean that the patient is difficult for another professional. It depends on the professional attitude, communication skills and behaviour of the professional. These attitudes and behaviours are not easy to measure in each dentist to enable matching with a compatible dental patient. Nevertheless, patients have been sharing the information about their experience and the treating dentist in social media with friends and also in dental crowdsources, all of which is publicly available. Is it then possible to analyse the type of dentist from the information available online?

2.5.4. Role of Attitudes and Behaviour

It is important to accurately profile major stakeholders, patients and dentists, for effective and efficient dental care recommendation systems. The attitudes and behaviour of both stakeholders are important factors for suitable matching. However, this information is not easily accessible and it is difficult to attain from both parties. The growth of SNSs has been gradually contributing toward being able to profile the stakeholders from their behaviour over the last few years. As discussed earlier, some researchers (Zhang et al. 2013; Batool et al 2012; Vayena et al 2012) have been successfully profiling patients from posts in social networks but not so much from their behavioural aspects. We envisage that it will be possible to analyse the behaviour of users in the SNSs in the future by analysing sentiments of the text and other variables.

On the other hand, subjective characteristics of dentists have already been described and shared in the dental crowdsources. Not only from the evaluation criteria for the dentist in the dental crowdsources but also from the expression in the review/feedback, it is clear that dentists' behaviour, attitudes are judged and evaluated. The patients discuss their last visit to their dentists and write comments on the experience of the visit mostly by describing the behaviour and attitudes of the dentists such as caring, nice, professional etc. Such subjective information can be included to profile the dentist for an effective dental care recommendation system.

It is very important to understand in what context the information was created and shared. The condition of the patient during or before and after the treatment is also important because traditional cues such as, tone of voice and body language in face to face communication, is missing in the online communication. Understanding the patient's behaviour and attitudes therefore helps to interpret the feedback more accurately to assess for matching, which can be incorporated in the patients' profiles.

2.5.5. Importance of Subjective Information in User Profiling

Many researchers in the area of dental care has been exploring subjective attributes which affect patients during their visit to the dental clinic such as dental fear (Armitage & Reidy 2012; Armfied 2010; McNeil et al. 2011; Rodriguez-Vazquez et al. 2008) and quality of care (Clarkson et al. 2010; Eriksen et al. 2008; Elgin 2012; Merijohn et al. 2008; Sbaraini et al. 2012; St. Louis et al. 2009; Yarascavitch et al. 2009). A few other researchers have discussed other attributes such as regular visits (Beirne et al. 2008; Ito et al. 2012) safety (Perea-Perez et al. 2011) knowledge and education (Hedman et al. 2009). Armfield (2010) defined a term 'dental beliefs scale' as a measurement of dental fear, which calculates the subjective perception of dentist behaviour and beliefs related to lack of power, control, and trust. Subjective measurement is given importance to reduce the level of the stress and anxiety towards dental treatments.

Sbaraini et al. (2012) stated that dental patients' expectations are proportionately related to the dental professionals' friendly caring attitudes, confidence and communication; and also quoted, "The experience of having a dedicated, supportive and caring dental team helped patients to take control of their own oral health." Where do we get this sort of information? Dentist reviews sites are the best places to collect this information.

In dental crowdsources, patients have been discussing their experiences with their dentists. Dentists and their practices are evaluated with certain criteria as mentioned earlier. Most of the criteria are subjective in nature. When patients leave feedback on their dentists, patients subjectively describe their dentists. Luo et al. (2008) stated that subjective characteristics have been included as a latent construct with

users' rankings and ratings for products. The perception of subjective characteristics is critical when reviewing a professional. Reviewing and rating a professional is about his/her subjective characteristics.

The rating criteria used by various dentist reviews sites helps in classifying the dentists. Similarly, post visit feedback about the dentists provides certain subjective information to classify dentists. When patients do the reviews, mostly they mention what type of dentist or doctor the person is. They also mention the service and characteristics of the professionals.

Although subjective criteria have not yet been considered for matching a patient with a doctor or dentist, the ratings are often based on some criteria related to a level of satisfaction which resulted from subjective characteristics such as punctuality, helpfulness, level of trust etc. as shown in table 2.5 above.

Analysing and finding out a type of patient and dentist is accordingly a useful process for matching in a recommendation system. It would be a good match if the type of patient and dentist is suitable to each other and the level of trust is high. For example, dental educator, Cathy Jameson, a dental practice manager stated that the qualification and expertise of a dentist would be important for D (dominant) types of patients as they would not like socialising as much, whereas, the I (influencer) type of patient would prefer discussing in a friendly manner (Meyer 2012). Through this research, we will find out matching rules for all types of patients and dentists.

2.6. Conclusion

Internet users are gradually turning to dental crowdsources to find information about dental care and choose new dentists for specific dental treatments. As the number of providers increases, the recommendation methods used by dental care recommendation systems are mostly based on location and some other objective criteria. Recently, rankings of dentists which are often based on different criteria in different sites are used in addition to traditional methods of filtering dentists from objective criteria. It is critical to standardise the criteria used to evaluate dentists.

Trust is identified as a crucial factor that needs to be integrated to improve the quality of dental care recommendation systems. Trusting dentists is an important element for patients due to the invasive nature of dental treatment. Patients can trust dentists for many different reasons but certain components such as relationship with the referrer and reputation of the referrer are considered as main components.

User profiling of dentists and patients are the core processes for recommendation systems in dental care. Trust elements can be integrated in the profiles to improve the quality of recommendation systems. Both explicit and implicit information are useful when profiling major stakeholders. The latest information on the importance of subjective information which is embedded in implicit or indirect interactions in social networks has been investigated. Subjective criteria to profile dentists and patients are explored. Due to certain restrictions owing to privacy rules and anonymity in users' identification, personality traits are taken into consideration to profile dentists.

Accepted papers from this chapter:

Pradhan, S., Gay, V. and Nepal, S. (2013), Social Networking and Dental Care: State of the Art and Analysis of the Impact on Dentists, Dental Practices and their Patients, *BLED 2013 Proceedings.*

Chapter 3

3. Research Design and Methodology

This chapter discusses the research approach, methods and design of this study on 'enhancing trust in dental care recommendation systems'. This study proposes a trust-enhanced information model for dental care recommendation systems. In order to present the model, dental care recommendation systems are first looked at from a set of viewpoints from the Reference Model for Open Distributed Processing (RM-ODP). This model helps to simplify a complex system specification into a set of coupled but separate pieces (Linington et al. 2011). RM-ODP provides an integrated framework for the system which supports distribution, interworking, interoperability and portability (Raymond 2006). The RM-ODP framework presents five different perspectives or viewpoints: enterprise, information, computational, engineering and technology. Figure 3.1 shows these viewpoints.

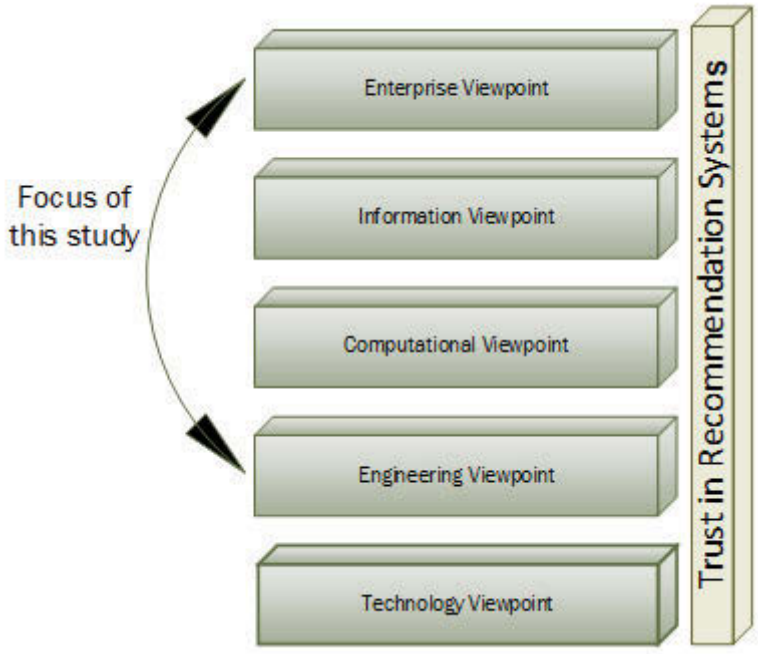

Figure 3.1: RM-ODP Viewpoints on trust in recommendation systems

This thesis focuses on trust aspects in the recommendations of dentists from dental care recommendation systems and investigates the first 4 viewpoints from the enterprise to engineering level.

The first viewpoint is **enterprise** and it focuses on the organisational position by exploring the objectives, scope, policies and business rules that need to be supported by the system. The next level is the **information** viewpoint which investigates the types of information that are important for dental care recommendation systems. This study proposes a trust-enhanced information model to improve the quality of recommendations in dental care. This viewpoint concentrates on the relevance of information

which is processed and interpreted within the system. From the **computational** viewpoint, it specifies the processes of the dental care recommendation system, by showing functional decompositions. The system is decomposed into a set of interrelated and interacting objects. The **engineering** viewpoint deals with the infrastructure required to distribute the system. The final viewpoint of the ODP reference model is **technology** and it looks at the real-world constraints in regard to specific technologies such as the implementation of hardware and software. The technology view point is not investigated in this study. The viewpoints are also summarised in Figure 3.2 below.

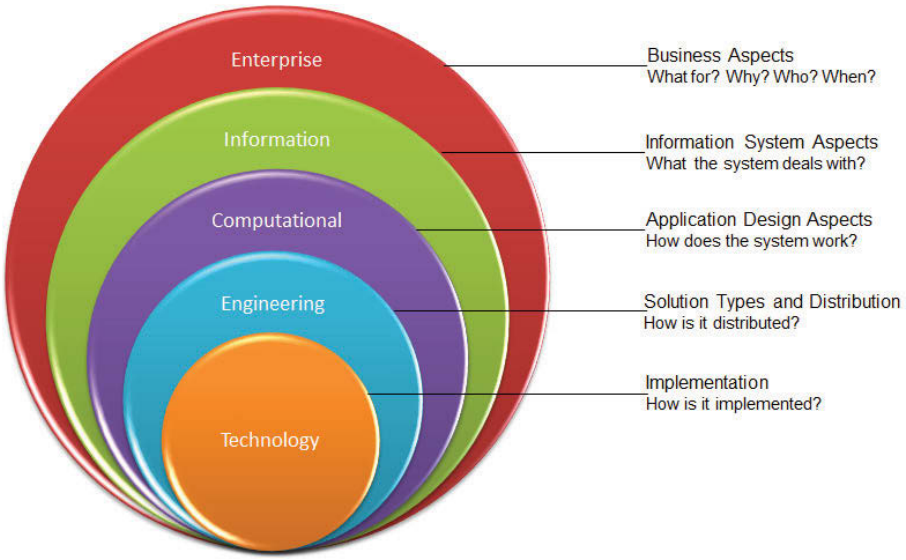

Figure 3.2: RM-ODP Viewpoints (adapated from Source: Vallecillo 2006)

In this chapter, the research methodology of this study is briefly explained. The research methods used at each abstraction level of the RM-ODP framework are described at different stages of the study and are subsequently detailed.

3.1. Research Methodology

The focus of this study is to improve the matching process when recommending dentists to patients through dental care recommendation systems. This is investigated from multiple perspectives of RM-ODP and hence this research is a cross-disciplinary and uses multi research methods from 3 disciplines; Computer Science (CS), Information Systems (IS) and Social & Behavioural Science (SBS).

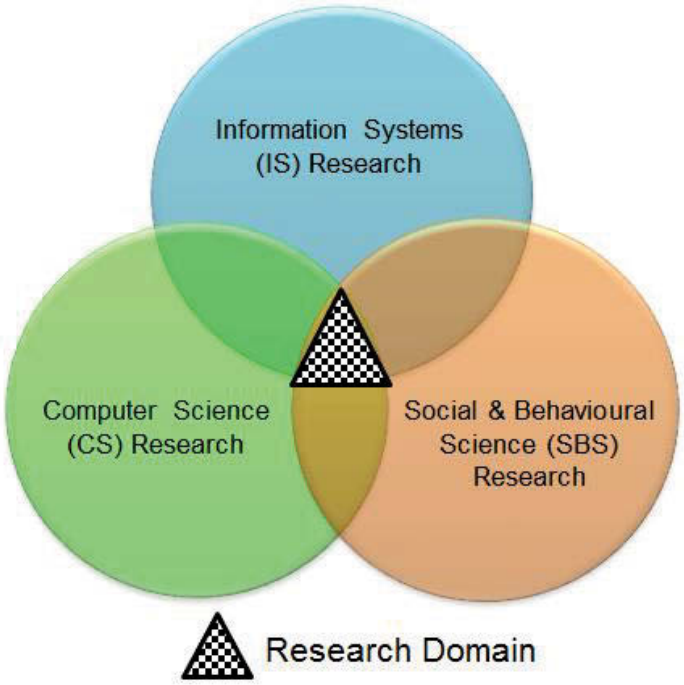

Figure 3.3: Cross-disciplinary research domain

At the enterprise viewpoint of the ODP reference model, a requirement analysis which includes the purposes, policies and the roles of stakeholders within dental care recommendation systems is performed. It is important to satisfy the objectives of the major stakeholders involved. Therefore, the major concerns and interests of the stakeholders are analysed initially by using IS research methods such as interviews and surveys. At the information viewpoint, trust related information to improve the matching process for dental care recommendation systems is investigated by using CS research methods such as web content mining. Similary, at the computational viewpoint, flow of information is analysed so that trust related information can be incorporated to improve the quality of recommendations by using IS and SBS methods such as matching subjective qualities based on results from the survey. Finally at the engineering viewpoint, prototyping, one of the CS research methods, is used and a dental care recommendation website is prepared to demonstrate how the subjective qualities of both patients and dentists can change the recommended list of dentists.

Thus, several different methods are used throughout the study. Literature reviews, surveys, web content mining, interviews and prototyping are used to understand the stakeholders and processes involved in

dental care recommendation systems. A mix of quantitative and qualitative methods are used as they provide the opportunities for evaluating a considerable range of of perspectives (Teddlie & Tashakkori 2003).

A summary of the methods is shown in Figure 3.4 below. The specific procedures and results are detailed in later sections.

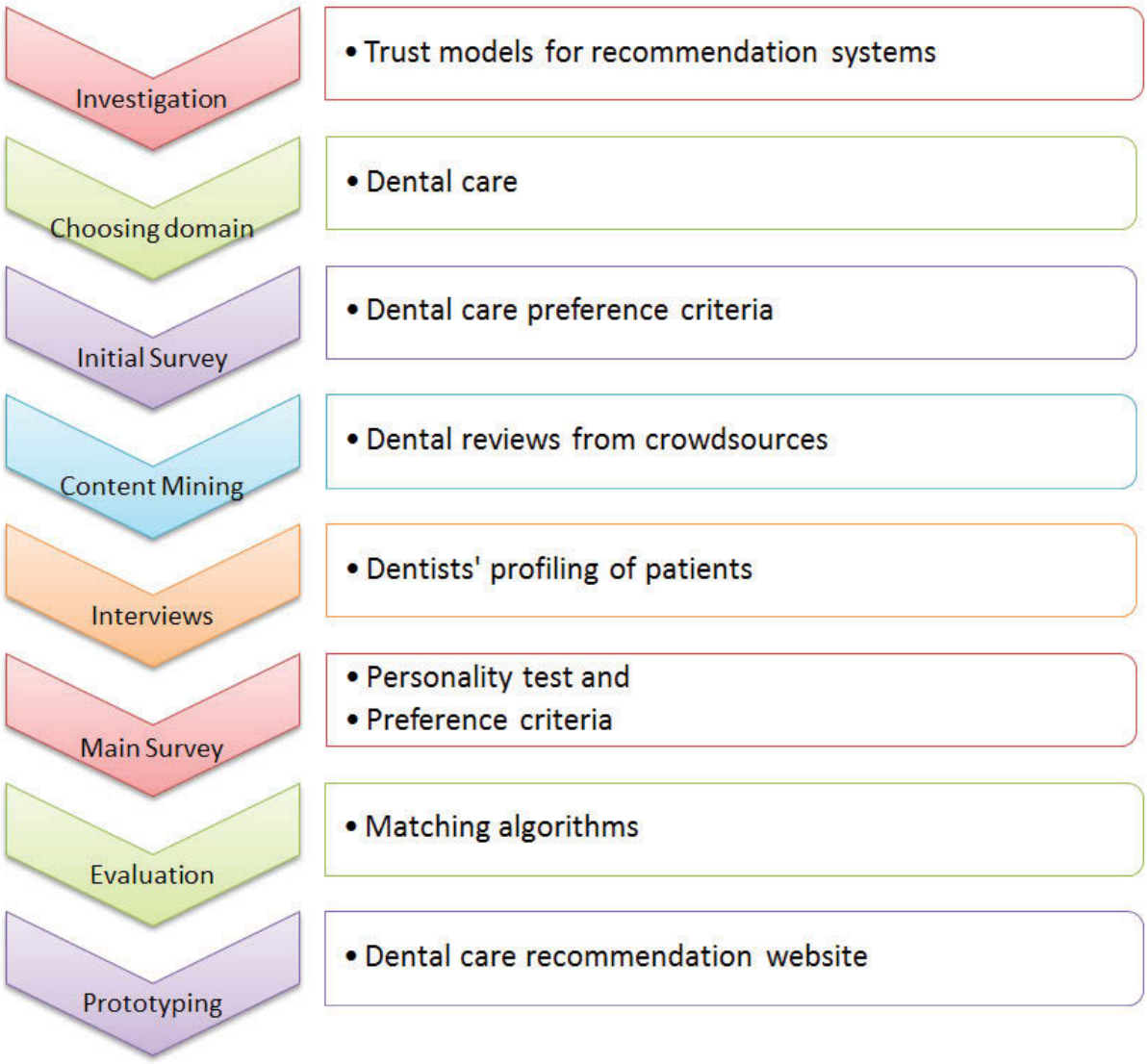

Figure 3.4: Methods at the different phases of this study

- This study started by analysing the risks and trust models for recommendations systems. It predominantly focused on looking at the risk factors to improve recommendations and hence it concentrated on trust models.
- A domain of dental care was chosen for this study since it had a comparatively smaller network and because most of the treatments in dental care are of an invasive nature. It assumed that trust is an important factor when choosing a dentist.

- In the process of analysing the requirements of the enterprise viewpoint, a dental care preference criteria survey was conducted at an early stage of this study to find out how dental patients expressed their trust when searching for a new dentist. This survey is employed in empirical research in many fields including IS (Rossi et al. 2013). A set of questionnaires investigates the participants' use of dental services and the criteria that they employ to choose a dentist with. Results from the survey are analysed and looked at from the information viewpoint of the ODP framework. The survey results have prompted other research questions such as whether dentists' profiles can be classified according to their subjective qualities.
- One of the research methods from the CS discipline, web content mining, is used to explore subjective information about dentists from dental crowdsources. This method intends to extract useful information from web pages (Carmona et al. 2012; Liu & Chang 2004; Kosala & Blockeel 2000) such as dental review and rating websites. Patients usually describe their dentists with subjective qualities when they communicate with others about their dental visits. Similar patterns are found in the online sources. As a result, this method has been applied to crawl online dental reviews and then extract the subjective qualities of dentists from dental crowdsources for this study. Web content from dental reviews is further analysed by using text mining to profile dentists and determine their qualities. This information is taken into considertation to propose a new model from the information viewpoint of the ODP framework, but it only provides information from the patients' viewpoint. This is one of the limitations of the existing dental crowdsources. It raises questions about the dentists' views in relation to their patients and how to improve the matching process of recommendation systems.
- Interviews were planned with dentists to find related information to classify patients. In general, interviews provide opportunities to find more informattion by including open ended questions (Flick 2015). Since there is no information about patients available from online sources, semi-structured interviews were planned to find such information from dentists. From the interviews, it was found that dentists are not classifying their patients by subjective qualities. Therefore, a further literature review was conducted to find the patients' classifications. As discussed in the previous chapter, ModelH designed by Riley (2013) for patient segmentation is reviewed. A patients' archetype is focused on to classify patients subjectively. One of the popular personality tests, the DISC personality test is adopted in this study.
- Rather than directing participants to do the personality test separately, questionnaires from the personality test are included in the main survey. There are individual differences with people in terms of the patterns of thoughts, feelings and actions (Costa & McCrae 1998) and therefore personality traits which can be used to classify patients from their personality traits. The main survey is designed to find the most preferred dentists' subjective qualities as recorded by the participants. The responses from the survey are used to improve the matching process of dental care

recommendation systems by taking subjective information into consideration. Matching algorithms are evaluated from the survey responses.

- Survey data from the main survey is analysed to determine trustworthy information for patients in recommending dentists. The data is also analysed to match patients with dentists according to their subjective qualities and it is evaluated by some matching algorithms.
- Finally, for demonstration purposes, a prototype of the dental care recommendation website is prepared which enables patients to choose to take the personality test or choose their personality traits to find a dentist. The list of dentists recommended is based on objective criteria selected by subjective qualities.

Further details of the research methods from the third phase onwards as listed above are described in the following sub-sections.

3.1.1. Preference Criteria Survey

The dental care preference criteria survey was set up at the initial stage of this study. The objective of the online survey was to find out what dental patients care about most when searching for a new dentist. A set of questionnaires was prepared which aimed to attract participants from different countries around the world.

The online questionnaire was designed using a survey tool called 'Kwik Surveys'. The link was advertised on Facebook and LinkedIn. Additionally, the participants were requested to pass on the survey to their peers. In the online survey, the intention was to get answers to the following questions:

- How often do participants search online for information related to health and in particular, oral health?
- How do people find their dentists (what is the most popular referral source)?
- What do people think of their existing dentist, and do they intend to change?
- How many dentists have they changed in the past? Are they looking to change now?
- What criteria do people look for in selecting a dentist?
- How likely are people to use the dental recommendation sites?

The online survey had 26 questions and they were divided into 3 sections: the first section captured basic demographic information such as age group, gender and country of residence, and the online behaviour of participants with respect to their use of any recommendation systems in the past. The second section captured their dental care profile: how often they visited their dentist, how they chose

their dentist, and the number of dentists that they have had. In the final section, participants were specifically asked to rank the following criteria when choosing a dentist:

- Location – dental practice located proximity
- Quality – quality of care by the dentist
- Service – quality of service in the practice
- Specialist – need of specialist for treatment
- Cost – price for the dental visit/treatment
- Reliability – trustworthiness for bookings and treatments and other activities
- Waiting time – queuing time before appointments
- Reimbursement – refund from insurance company
- Cultural background – community oriented dentist who may speak specific language
- Personality of dentist – general appearance and personality

3.1.1.1. Importance of Subjective Criteria

The survey revealed that the most important criteria for dental patients are subjective qualities of dentists. The subjective criteria (such as quality of service, caring, reliability) of dentists are perceived as the most important criteria when patients are looking for a new dentist.

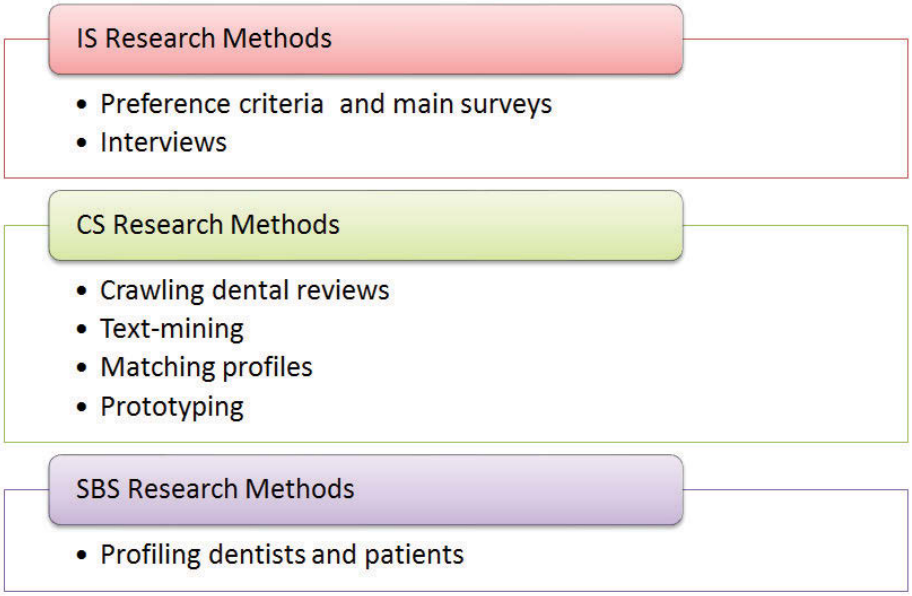

Figure 3.5: Elaboration of cross-disciplinary research methods

By using mixed methodologies, further information is examined such as CS research methods to extract the subjective qualities of dentists from dental crowdsources and to match the profiles. Meanwhile, IS research methods are used to determine other related information to trust and improve the quality of

recommendations? SBS research methods are used to determine the personality traits of patients, and to profile patients and dentists by taking subjective information into consideration. Figure 3.5 above summarises the research methods used in this study.

3.1.2. Web Content Mining

As briefly mentioned above, the subjective qualities of dentists are extracted from online dental reviews posted by patients. Dental patients are able to find certain information on dental care and to filter a list of dentists in the crowdsources, according to the criteria given by the chosen site, as described in Chapter 2. In dental crowdsources and specific dental reviews and rating sites, patients write reviews and rate the service reflecting their experience while undergoing dental treatment. In most cases, their experience is expressed with subjective words such as reliable, professional etc. and this is usually correlated with the ratings given to their dentists. A significant amount of information about dentists or dental practices is publicly available through these sites. We have used the following methods to determine the subjective qualities of dentists and profile them in this study.

- Crawling dental reviews from popular dental crowdsources
- Analysing the words used in the reviews by using emotive lexicon
- Grouping similar words together to define the subjective qualities of dentists
- Classifying dentists based on the subjective qualities described by patients

No specific information about patients was available to classify using the same process. Online postings in SNSs such as Facebook and Twitter can be used to classify users but it is a challenging process for dental patients because there are not enough discussions on dental specific topics at the moment. So, dental patients are classified by using personality traits from personality tests in this study and briefly described the method in a later section of this chapter.

3.1.2.1. Crawling Dental Reviews from Crowdsources

There are many sites where the dental patients can search for dentists and read reviews and ratings from their previous patients. This trend is more popular in many major cities of the US. We have taken two major sites: DrOogle and Yelp from the US, where there are a significant number of reviews which are available for analysis within this study. Both DrOogle and Yelp sites allow dental patients to write reviews to their dentists and rate the dentists. Based on positive reviews, the dentists are ranked on a recommendation list within a specific location in the US.

DrOogle is a dedicated site which is referred to as a dentists' guide in the US. It was easy to access reviews from the DrOogle site by becoming a member. This membership is however available to the user in the US only after receiving payment of US$18. To prepare for the study, dental patients' reviews were also collected from Yelp which is one of the most used review websites for general businesses. However, Yelp only allowed a limited number of crawling per day and therefore, the process of crawling took a longer time. The major cities in the US where the number of reviews per dentist is approximately higher than other cities were selected for crawling purposes. For example, New York, San Francisco, Washington DC, Los Angeles and Chicago had higher number of reviews per dentist than other US cities.

While crawling reviews from Yelp, the program is created to directly access the search result page by the following URL structure:

http://www.yelp.com/search?find_desc=Dentists&find_loc={location}&ns={pageno}

In this URL, {location} and {pageno} are variables. {location} can be changed to the specific location for reviews, for example, San Francisco, CA, USA. {pageno} can be changed to the specific page for specific location. For example, if the URL parameter is set to ?find_desc=Dentists&find_loc San+Francisco,+CA,+USA&ns=3. it displays the third page of dentists who are located in San Francisco. After the program gets the response HTML, it applies regular expression (regex) to get the specific information from the HTML. For example, to apply regex "biz-name" href="([^"]+)"[^>]*>([^<]+)</ matching group 'one' would return the specific dentist page URL and matching group 'two' would return the name of each dentist. Then the program would access each dentist's page and get all reviews from each dentist.

3.1.2.2. Analysing the Words from the Reviews

Massive amount of reviews were crawled from big cities in the US for this study. After careful consideration, New York City was chosen for analysis because it had more reviews per dentist than other cities in the US as well as a better distribution of reviews across a bigger number of dentists, so that the analysis was not just based on a few dentists. Reviews from both DrOogle and Yelp sites were analysed for the same city.

Before analysing reviews collected from the crawling, it is necessary to identify the common words to describe the dentists available. Delbanco (1192) pointed out 7 dimensions of care in the 'doctor-patient relationship' from the patients' perspectives: respect for patient's values, communication, coordination of care, physical comfort, emotional support, involvement of family and friends and finally, continuity and transition. Some researchers in dental care, Sbaraini (2012); Yarascavitch et al. (2009); Hedman et

al. (2009) have indicated that some of the qualities appearing in the table below are important interpersonal skills. With a careful investigation of the words used in the dental reviews, the following 10 dentists' qualities were chosen to describe the dentists for this study. The list is shown in Table 3.1 below

Table 3.1: List of Dentist's Qualities

Friendly	Caring	Professional	Experienced	Knowledgeable
Explains well	Recommendable	Quality of service (QoS)	Reliable	Good personality

3.1.2.3. Grouping Similar Words Together

There are not only many synonyms for a word but the word can also be expressed in many different ways. Since different vocabularies are used by different people, a lexicon prepared by the 'National Research Council Emotion Lexicon' (Mohammad & Turney 2011) is used in this study. The list is further filtered to make it relevant with patients' dental treatments. Some of the examples of the synonyms used for the text mining are listed in Table 3.2 below. WordNet and Dictionary.com are also used to find the lexicons that are synonyms in terms of dentists' qualities, so that if the reviewer used a word that is a synonym for one of the dentist qualities, the system would detect and count the word as one of the qualities. The table below lists the lexicons used for each dentist quality.

Table 3.2: List of keywords and synonyms for dentists' qualities

Dentists' Qualities	Keywords
Friendly	Friendly, affable, amicable, amiable, cordial, loyal, welcome, kind, decent, gentle
Caring	Caring, attentive, attend, considering, consider, familiar, favourable, helpful, sympathetic, tender, nice, polite, comfort, best interest, conscientious, careful, diligent, meticulous, helping
Professional	Competent, qualified, ace, adept, expert, thorough, sensible
Experienced	Experienced, experience, skill, skilled, accomplish, capable, competent , mature, efficient, effective, seasoned, sophisticate, trained, veteran, less pain, painless, pain free, pain free, dutiful, responsible
Knowledgeable	Knowledgeable, astute, brilliant, conscious, shrewd, informed, insightful, intelligent, learned, perceptive, smart, wise, sharp
Explains well	Explains well, explain, certain, direct, precise, simple, understand, transparent, articulate, understandable, understanding
Recommendable	Recommended, recommend, suitable,
Quality of service	Good service, peaceful, positive, good, great, excellent , relax, pleased, pleasant, beautiful, clean, happy, impress, satisfy, appreciate, wonderful
Reliable	Reliable, punctual, rely, trust, depend, honest, authentic, faith, confident, predict, respect, steady, recommend, confide, punctual, rely, honourable
Good personality	Smart, charismatic

3.1.2.4. Classifying Dentists from Subjective Qualities

Dentists are usually classified based on their qualifications and/or specialities of their work. However, in this study, dentists are classified by their subjective qualities, which are extracted from online reviews in the dental crowdsources.

Subjective characteristics of dentists are revealed by their patients when they post reviews after their dental visits. The terminologies used by patients to describe their dentists are mostly of a subjective nature and they also express their dentists' perceived behaviours in the reviews.

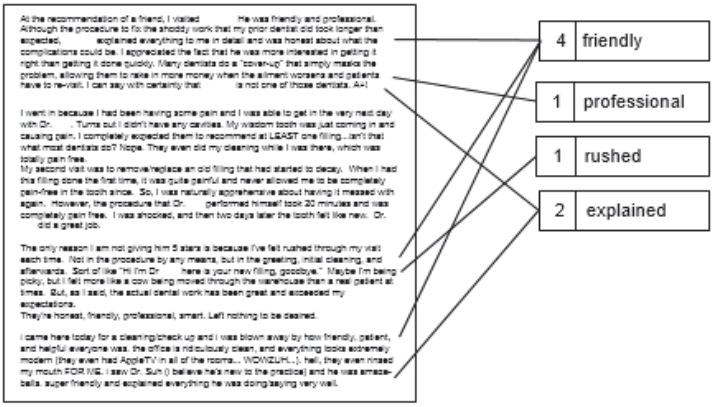

Figure 3.6: Example of how text mining is done from reviews

Frequencies of the terms used by patients to describe a particular dentist in the reviews are analysed. Based on the number of terms used by patients to describe a dentist, the subjective dentist's qualities for the dentist are determined, and these are used to classify the dentist with these qualities.

Regular expression of not|n't is used to detect any negative meaning of the words before the term can be included for the TF_IDF (Term frequency – inverse identity frequency) analysis. The process also checks the number of star-ratings for each review to determine negative or positive reviews. Any review which has a star-rating below 3 is regarded as a negative review in this study. TF-IDF is further described below.

3.1.2.4.1. Term Frequency – Inverse Document Frequency (TF-IDF)

Term frequency Inverse Document frequency (TF-IDF) is a commonly used text mining technique, and it was first introduced by Salton and Buckley (1988). It is used for determining the relevance of a term in a document. It consists of two components: Term frequency and Inverse document frequency.

Term frequency (TF) is the measurement of how frequently a subjective quality as a term (t) appears in a document which is the dental reviews of a dentist. The more times a term appears in a document, the higher the relevance of the terms.

TF (t) = (Number of times term t appears in a review) / (Total number of terms in the review)

Inverse document frequency (IDF) measures how important a term is across all the documents. While calculating TF, all terms are considered to be equally important. However, certain terms such as 'a', 'and', 'of', 'this' and so on, may appear a lot of times but have little importance. It is necessary to weigh down the frequent terms while scaling up the unique words by taking a logarithmic, as shown below.

IDF (t) = $\log_e$ (Total number of reviews / Number of reviews with term t in it)

TF-IDF weight is the product of the term frequency (TF) and inverse document frequency (IDF). Therefore,

TF-IDF = TF * IDF

By comparing the TF-IDF weight, we can determine the relevance of each term (subjective quality) in describing how each dentist from the dental reviews is crawled.

In this study, TF-IDF helps to create profiles for dentists, and gives them a weight for each of their qualities. For example, if a word 'friendly' is used by many patients to describe a dentist in an average, the dentist's behaviour can be depicted as 'friendly'. Similarly, other dentists' qualities are extracted by analysing the online review data from dental crowdsources.

3.1.3. Interviews with Dentists

Dental care recommendation systems allow patients to find the most suitable dentists but patients are not classified by their subjective qualities. Instead patients are usually classified based on 'types of treatments required', 'location', 'insurance covered' and so on Like the way dentists are profiled based pm subjective qualities, patients are profiled subjectively in this study. For this reason, a selection of dentists were contacted for semi-structured interviews.

There were 21 questions in the interview. The first 3 questions (1 to 3) focused on what, where and how long the dentists have been practising. The next 3 questions (4 to 6) focused on their awareness of online reviews in general and those specific to dental care as well as their habits in terms of writing reviews. Results from the survey were briefly shared in the following 4 questions (7 to 10) . Then, in another 4 questions (11 to 14) dentists were asked about the percentage of referred business that they received and their advertising strategy in the future as a result of the online reviews. The last 7 questions (15 to 21) asked dentists about their classification of patients based on subjective characteristics and their opinions on the matching process based on the subjective qualities of both patients and dentists.

The subjective qualities of dentists are important for patients to choose a dentist. By contrast, although the dentists we interviewed pointed out that they are concerned about the subjective qualities of patients, dentists do not classify their patients subjectively. Dental practices usually classify their patients based on the patients' demography, health status and their capacity to afford specific treatments.

3.1.3.1. Literature Review for Patients Classification

Since patients are not classified subjectively by dentists, a further literature review on patients classification was carried out on 4 patients segmentations (Archetype, Life stage, Life condition and Life style) from the ModelH by Riley (2013). In order to take the subjective qualities of patients into consideration in relation to patients' profiles, the archetype is investigated.

In this study, we have chosen personality traits to classify patients subjectively to match them to dentists according to the dentists' qualities as discussed above. As described in Chapter 2, 15 different types of personality traits are used to classify patients from the DISC personality test. 12 questionnaires available from the DISC personality test are used in the survey to profile participants in the main survey.

3.1.4. Main Survey

The main survey was set up to profile various types of patients and find the matching subjective qualities between patients and dentists. The objective of this survey is to capture information from patients' perspectives to improve quality of recommendations in dental care while searching for the most suitable dentist.

A set of questionnaires was prepared to capture related information about dental care. It was aimed to get participants from different countries. The online survey was designed using a survey tool called 'Lime Survey' which was provided by the university e-research team. While participating in two international conferences, the link of the survey was advertised to the participants of PACIS (Pacific Asia Conference on Information Systems), Chengdu in June 2014 and IFIPTM (International Conference on Trust Management), Singapore in July 2014. The link was also distributed through Facebook and LinkedIn and requested participants to pass on to their peers, similar to the previous survey. Through this process, 153 full respondents to the survey were collected, majority were from Australia (98%), 16 from the US, 8 from India, 7 from China. The number of participants was not significant to carry on the analysis of data. Therefore, a third party research group, EKAS was contacted and re-run the survey in October 2014, with a certain cost. Within 2 weeks, more than 1,000 Australian dental patients participated in online survey. 580 out of 1,050 were eligible to complete the survey as the remaining did not meet the selection criteria of 'visiting a dentist at least once in 2 years'.

There were 31 questions in the survey altogether. They were divided into major 5 categories. First 5 questions (1 to 5) were basic demographic information such as, age group, sex, level of education, etc. Next 5 questions (6 to 10) were targeted to learn information about their dental visit such as frequency of dental visits, how many different dentists visited in last 10 years, level of dental fear, and types of dental treatements done in the past. The following 5 questions (11 to 15) were directed to find out about types of their dentists including how they found their dentists, and what is the preferred method to find the next dentist if needed and how they see their dentist based on 10 dentists' qualities described above. The following 2 questions (16 and 17) were the most critical question of this survey, which asked them to choose top 3 most prefered criteria while finding their ideal dentists.

The patients were also instructed to answer a set of questionnaires derived from the DISC personality test. In the final section, we specifically asked the participants to choose the best way they think they can describe themselves from the list of 15 types of personality traits, followed by 12 questionnaires to determine their personality. The questionnaires were imported from freely available DISC personality test (available from discpersonalitytesting.com). The results are discussed in Chapter 5.

3.1.4.1. Classification of Patients

With the growing emergence of social media and technologies, internet users are staying online more than ever. While online, knowingly or unknowingly more data about the user is captured. With advanced data mining technologies, it is possible to profile the users from their behaviour in terms of shopping online, searching, places that they visit regularly and other information that is captured (Vayena et al. 2012). Even as a patient, it is anticipated that there will be enough information online about their habits, treatments used, doctors visited, allergic information, and so on about an individual to be able to profile a patient. Nonetheless, it is not possible to profile dental patients at the moment because there is not enough information available online on dental care. There are other challenges in online communication such as user identity and privacy. Due to these challenges, information from the survey is used by combining the type of personality traits from the DISC personality test in this research, to profile patients subjectively. The types of personality traits and preferences are then stored to construct the patients' profiles from the online survey.

3.1.5. Evaluation of Data Survey

Trust is usually defined from social aspects. The trustworthiness of a dentist is very important so that a patient goes back to visit the same dentist with a certain level of confidence for regular dental treatments. But how do patients gain that trust with a new dentist before visiting? There are many

resources available online about a dentist and possibly about a patient as well. While analysing the subjective qualities of both patients and dentists, the trust between patients and dentists becomes a critical factor, while varying between patients, nonetheless plays a major role in the selection of a dentist for a dental treatment.

Certain types of behaviours for both dentists and patients are important when matching them for the purposes of an accurate recommendation. These behaviours are implicit information, and cannot be retrieved directly from any sources explicitly (Flick 2015). In this study, words described by previous patients are aggregated to classify dentists from subjective qualities. However, from the social and behavioural science research perspective, scientific evidence for personality traits theory is used to categorise patients with subjective qualities.

Various trust components are investigated in this research. For example, interpersonal skills such as who has referred the dentist (social support theory), which system is used to find the dentist, how was the information retrieved (social cognitive theory) (Coreil 2008), and many other level of skill. The quality of recommendations usually depends on the number of factors used throughout the process of matching in the recommendation systems. In addition, behaviour and attitudes are critical types of characteristics in terms of the individual. These are paramount to consider how to improve trust and ultimately match the behaviour and attitudes of both patients and dentists in dental care recommendation systems.

3.1.5.1. Matching Algorithm

Once the profiling of patients and dentists is determined, this study shows a few ways to make the best match between a certain type of patient with a list of dentists available with specific dentist qualities. User profiling for patients is based on a combination of personality traits and other objective criteria such as age-group, type of treatments required, frequency of dental visits, etc. while that of dentists is based on the dentists' qualities derived from dental crowdsources, as discussed above. Matching a patient with a suitable dentist with certain skills is determined for dental care recommendation systems. In order to achieve a suitable match between a patient and a dentist, the result from the extensive online survey is analysed and used to create matching algorithms.

For demonstration purposes, the type of patient is classified by combining personality traits and other objective criteria. The responses to the question on preferred dentists' qualites are aggregated to determine a list of preferred dentists' qualities. The number of dentists' qualities are normalised and presented as weightings. The weighted percentages of those qualities are compared with the dentists' qualities of available dentists in the given specific location. Differences between 10 preferred dentists' qualities by the patient and the same qualities of the available dentists are compared. The values of

differences are transformed into absolute value because it does not matter whether the differences are positive or negative. The absolute values of differences are added to show the preferred list of dentists. The value with the least difference (minimum value) is considered to be the most suitable dentist. This method is shown by the following formula:

$$\min_{n\geq 1} \sum_{i=1}^{m} |X_i - Y_i|$$

Where,

X = preferred dentists' qualities by the type of patients

Y = dentists' qualities of available dentists

i = indices of dentists' qualities

m = number of dentists' qualities (10 in this case)

n = maximum number of dentists available

This method of calculating the distance between the closest points is also known as the distance function and there are many approaches (Linoff & Berry 2011). The normalised distance between two points for each dentists' qualities are added to find the aggregated distance known as Manahattan distance or the nearest neighbour classification. The result is organised in ascending order to recommend the list of dentists to rank them so that the first one will be the most suitable dentist for the patient.

Similarly, the weightings are used to match the most suitable dentists by using a technique called analytical hierarchical process (AHP). AHP was first introduced by Saaty in 1971. This technique is used in making decisions when there are several choices available to choose from. Figure 3.6 below briefly illustrates how this technique works.

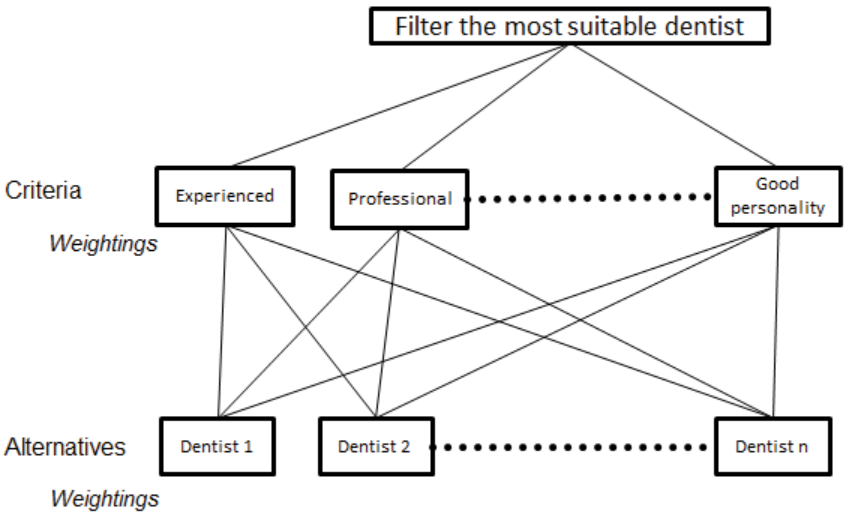

Figure 3.6: AHP as a matching technique

The weightings of dentists' qualities preferred by a typical type of patient is used as criteria. They are compared with dentists' profiles which are also based on the dentists' qualities from the list of dentists

available as alternatives. The weightings of dentists' qualities in dentists' profiles are determined by aggregating the number of terms used in dental crowdsources, as mentioned earlier in the classification of dentists.

In AHP, the weightings of dentists' qualities preferred by a particular group of patients as criteria are multiplied with the dentists' qualities of each dentist's profile in the list of dentists. Matrix multiplication is done as follows:

$$\begin{vmatrix} Y_{11} & Y_{12} \dots\dots\dots & \dots\dots\dots\dots Y_{110} \\ Y_{21} & Y_{22} \dots\dots\dots & \dots\dots\dots\dots Y_{210} \\ \dots & \dots & \dots\dots\dots\dots\dots \\ \dots & \dots & \dots\dots\dots\dots\dots \\ \dots & \dots & \dots\dots\dots\dots\dots \\ Y_{n1} & Y_{n2\dots\dots\dots} & \dots\dots\dots\dots Y_{n10} \end{vmatrix} \times \begin{vmatrix} X_1 \\ X_2 \\ .. \\ .. \\ X_{10} \end{vmatrix} = |D_1, D_2, \dots\dots\dots\dots D_n|$$

Where,

X = preferred dentists' qualities by the type of patients

Y = dentists' qualities of available dentists (each row represents one dentist)

n = maximum number of dentists available

D = Recommended list of dentists in descending order

The list of dentists are recommended from the available dentists in the specific location and the specialities the patients are looking for. The list will be presented with their current status of ranking and the number of reviews from the previous patients.

3.1.5.2. Rank Correlation

The recommended list of dentists from the above two matching algorithms are compared. The lists are first ranked to show the most suitable dentists computed from the algorithms. The Spearman correlation is used to identify and test the relationship between two sets of ranks. The value will show how much the results from two different matching algorithms can be correlated.

The formula used to calculate Spearman's rank is shown below:

Spearman correlation coefficient (rho) $\rho = 1 - \frac{6 \sum d_i^2}{n(n^2-1)}$

Where,

d = difference between ranks from 2 matching techniques

i = indices of different dentists

n = number of dentists available

3.1.6. Prototyping for Demonstration Purpose

A prototype of the dental care recommendation system for demonstration purposes is prepared. Patients' profiles are created as they enter information to search for a dentist (such as location, types of dental treatment, gender, age group etc.). Subjective qualities of patients are captured through the results from a personality test conducted separately or by selecting a personality trait listed in the prototype as well as the level of dental fear. Based on the distance function as one of the matching techniques discussed above, the patient is presented with a list of recommended dentists in the particular location. Alternatively, patients are able to choose the level of dentists' qualities so that the system can recommend a list of dentists available in the location with the specific dentists' qualities that have been chosen.

The list of dentists are revealed with their subjective qualities as well as aggregated ratings and the reviews stored in the database. The ratings and reviews will be updated from the online reviews sites in the real-time environment.

3.2. Conclusion

The aim of this study is to propose a new information model with trust components derived from social networks to improve the quality of recommendations in dental care. Objective criteria such as location, type of treatments, type of insurance cover and insurance provider are important foundations, but this study explores the subjective criteria associated with trust components in order to filter the list of dentists in the dental care recommendation systems. Subjective criteria are qualitative in nature and difficult to measure but they strongly influence patient decision making in terms of choosing a dentist.

This study undertakes cross disciplinary research methodology to improve the matching process for dental care recommendation systems by evaluating the trust components in patient profiles. The proposed model is analysed from the multiple viewpoints of the RM-ODP framework for the purposes of overall understanding and creating interoperable applications for dental care recommendation systems. The subjective qualities for dentists are derived through CS research methodology and these are used to profile dentists. Patient profiles, by contrast, are composed by using IS and SBS research methodologies. The profiles are matched using dentists' qualities derived from dental crowdsources and the results from the survey in the domain of SBS research. Finally a prototype is demonstrated to show how the model is integrated in the dental care recommendation systems.

Accepted paper from this chapter:

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Chapter 4

4. Proposed Trust-enhanced Model for Dental Care Recommendation Systems

This contribution chapter describes the proposed trust-enhanced information model for dental care recommendation systems. Trust has been recognised as one of the most important factors when analysing the quality and suitability of recommended outcomes from recommendation systems. With the growing trend of using social media, trust has been investigated in terms of the social aspects of SNSs to improve recommendations. For dental care recommendations, we have proposed a trust-enhanced information model which incorporates dental crowdsources to improve the matching of patients and dentists. This chapter discusses trust derived from explicit information about patients and dentists as well as implicit information based on their interactions and activities. Subjective information has been a focus in the proposed information model to improve the matching process for dental care recommendation systems. For this reason, the pertinent subjective characteristics of both patients and dentists in the dental treatment environment have been chosen for further exploration. Subjective information has been determined as one of the important factors to improve the quality of recommendations.

This chapter evaluates the proposed trust-enhanced information model for dental care recommendation systems from the first 4 viewpoints of the ***RM-ODP framework***. Initially, trust is looked at from the *enterprise standpoint*. From this perspective, we identify the major stakeholders and their interests from the dental care recommendation systems. We examine what trust means to each stakeholder in terms of their interests and concerns, and determine the distinctive sources of trust in today's internet world.

From the *information viewpoint*, we identify trust related information specifically in the context of dental care recommendation systems and investigate trust related information for patients in dental care treatments. We further investigate subjective information related to trust for dentists and recommendation systems.

In the next section, from the *computational viewpoint*, the proposed trust-enhanced information model for dental care recommendation systems is described to show functional specifications in the process of improving the quality of recommendations. The quality of recommendations refers to the suitability of a dentist to a patient from the perspective of their subjective qualities. The proposed model is described in terms of how trust is related to dental care recommendation systems, especially in relation to profiling dental patients and dentists.

The next viewpoint at the *engineering level* focuses on matching algorithms between patients and dentists. The algorithms are constructed based on the trust factors between dentists and patients. It also presents a basic prototype to demonstrate how the subjective information of both patients and dentists has been integrated in the proposed model. Various trust components derived from subjective information are used for demonstration purposes and briefly discussed towards the end of this chapter.

The last viewpoint of the ODP model is the *technology viewpoint* which focuses on the technologies used in dental care recommendation systems. Trust in the social networks and cloud technologies are also important for consideration in implementing the dental care recommendation systems. However, this viewpoint is out of the scope of this study and hence is not covered here.

This research focuses on the first 4 viewpoints of the RM-ODP framework and the proposed information model provides the necessary steps to integrate trust components while profiling patients and dentists. Further details on the profiling and matching rules required for finding the most suitable dentist for a particular type of patient through the means of matching algorithms are discussed in the next chapter.

4.1. Building trust with major stakeholders

In this information age, dental patients find their dentists through social networks of their friends, families or peers, online or offline. Since social media has been dominating the online world and internet users are interacting daily with their friends, conversations about dentists and dental treatments are also appearing in social media. This argument is supported by two surveys conducted in this study. Nearly 50% of the participants in the first survey (to determine preference criteria) indicated that they would use online dental recommendation systems if was known to them. Similarly, although only 11% of the participants in the second survey used online search methods to find their dentists, more than double the participants (23%) indicated that they would use online search methods to find their next dentist. Details of these results are discussed in the next chapter.

In the social network, the user base increases if the network can gain trust from users in terms of providing quality information. For the dental care social network, patients' trust with the network as a platform can be analysed from many different perspectives. This study mainly focuses on the dental patients' perspectives. For patients, other patients' views and their own experiences can impact the way they trust the information provided in the network and ultimately the particular dentist that they are focusing on. Therefore, dental patients are encouraged to create social network profiles that contain basic personal information, interests, and preferences for dental related information. Through electronic means such as blogs, messages or chatting, dental patients can communicate information about their symptoms, dental visits and particular treatments.

One of the main purposes of the dental social network is that dental patients are able to filter a list of dentists for their specific dental treatment needs at any time and place and then choose the most suitable dentist that is available according to the specific parameters. This section explores the major stakeholders of the dental care social network and their interests for the purposes of recommendation systems. The concerns of these stakeholders including regulatory bodies are briefly discussed to explore the pertinent trust concerns of the stakeholders.

4.1.1. Major stakeholders of dental care social network

There are a number of stakeholders involved in the dental care social network. Although, matching suitable dentists to dental patients is the primary focus of this research, to understand the context of dental care recommendations, deeper understanding of major stakeholders from multiple aspects are important to look at (Montazemi et al. 2009). Briefly major stakeholders involved in the dental care recommendation systems are reviewed and visually illustrated in Figure 4.1 below:

- **Dental patients –** these are the major users of this network. The network is built for dental patients to exchange information and be able to filter and find the most suitable dentist for their purposes. They are also able to share with other patients their particular symptoms, treatments or side effects. By exchanging and sharing dental related information, dental patients become empowered to have more confidence and trust in the system. For example, dental patients who have fears of visiting dentists, are able to lessen their dental fear and other concerns by sharing their experiences with other users, as described in Chapter 2. Dental patients create their own profile and participate in the network by creating and sharing information and searching for the most suitable dentist in their preferred area. Based on the information shared in the network, patients can be categorised which helps the process of finding the most suitable dentist. Subjective information and personality traits are used to classify the dental patients to improve the quality of recommendations.

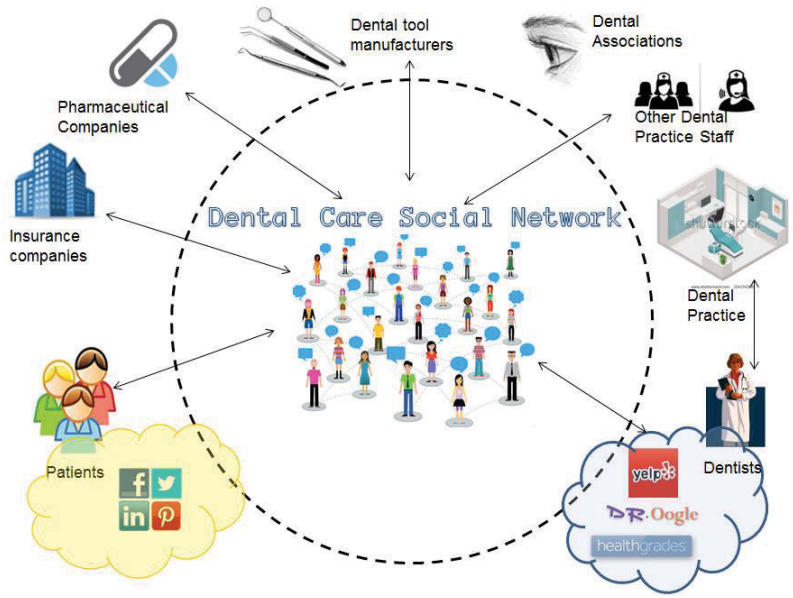


Figure 4.1: Rich picture of the dental care social network

- **Dentists** – these are also major stakeholders in this network. One of the main reasons this network has been created is to exchange information about dentists and match patients to dentists by filtering a list of dentists based on what the dental patients are looking for. A list of dentists is recommended to dental patients according to the matching rules created and discussed in the next chapter. Dentists are usually classified based on their qualifications or the type of treatments that they perform as a specialist but their subjective information is also explored in this study in order to improve the quality and trust of recommendations for dental patients. The profiles of the dentists are created by aggregating the reviews and ratings that they obtain from the major dental crowdsources.

- **Dental practices** – these are the physical places where dentists perform their dental work. There are usually one or more dentists in a particular practice. Sometimes patients refer to a dental practice when they write a review which is an alternative to mentioning specific dentists' names. The practices are reviewed and ranked at a practice level instead of at an individual dentist's level. Dental practice staff are also included when referring to a practice. When dental practice names are listed, these are considered as the combined effort of a group of dentists and their affiliated staff. Often individual dentists within practices are also separately profiled in the dental crowdsources.

- **Other dental practice staff (nurses, hygienists, receptionists)** – are also important stakeholders in terms of running successful dental practices. Staff such as dental nurses, dental assistants, dental hygienists, receptionist, practice managers and so on other than dentists fall under this category. Their commitment and contributions directly or indirectly affect the success of a dentist's work in the practice. Often, patients have specifically mentioned the staff in the practice and their behaviour and manners, or the particular way in which they were greeted. The behaviour of these staff therefore indirectly led to a level of satisfaction in relation to the dental visits and treatments. The activities performed by the staff can be assimilated into the the quality of service provided by the practice or dentist.

- **Patients' dental insurance companies** – these companies provide various levels of dental insurance cover (normally general and major) to dental patients. Insurance companies either run their own dental clinics or run an affiliation with certain dentists. They are interested in the quality of treatments provided by the dentists for their own reputation. Based on the quality of service provided by dentist, patients rate the dentist and this indirectly impacts the reputation of the insurance provider that the dentist is associated with. Hence, insurance companies may use this dental care social network as a monitoring tool. The quality of the work provided by dentists may be directly related to the type of claims made by a number of patients visiting the same dentist.

- **Regulatory bodies (Authorities)** – these bodies are important stakeholders because they monitor the operation of dentistry. They can influence how the dentists are trained and educated. Standards for dentists and dental practices are set out by the regulatory bodies. The quality of dental education and dental practice is usually governed by various regulatory bodies. Dental education institutions and hospitals are also governed by these

bodies. Dental care social networks focusing on recommendation systems need to be approved by the regulatory bodies. The Dental Board of Australia (DBA), Australian Dental Association (ADA) and Australian Dental Council (ADC) are the relevant regulators in Australia.

- **Manufacturers of dentist tools** – these manufacturers are indirectly associated with the dental care social network. Dental tools and chairs are known to be major cost areas in terms of running a dental practice. Does the quality of the tools used including the dental chair vary the level of quality of service provided to the patients? To some, the answer is 'yes'. While of indirect influence, these factors still play an important role in recommending particular dentists because the level of satisfaction that a dentist provides is to a large degree derived from the tools that they use. Manufacturers of these tools are accordingly also stakeholders in the dental care social network.

- **Pharmaceutical companies** – these are stakeholders in the network as they are interested in letting dentists use their products in dental treatments including mouth washes, anaesthetics or other medicines. The impact of anaesthetics and analgesic (pain killers) can also affect the way that dentists are reviewed in the dental crowdsources. The effect of certain medications and brands can impact the way patients review their dentists for particular treatments.

4.1.2. Hopes and concerns of major stakeholders

Every stakeholder has their own interests and concerns in terms of the dental care social network. Based on hopes and concerns, different degrees of trust are accorded to each stakeholder mentioned above. They are briefly listed in the table below:

Table 4.1: List of hopes and concerns of major stakeholders

Hopes	Concerns
Dental Patients	
• Find the most suitable and trusted dentist when required • Find peers with similar symptoms and treatments to share information and become empowered	• Invasion of privacy • Incorrect information • Biased reviews (or False) • Incorrect recommendation outcomes by the system.

• Filter dentists for specific treatments according to particular preferences • Find out more specific information about particular dentists • Find quality, trustworthy information in order to make informed decisions	
Dentists	
• Attract more dental patients • Acquire a good reputation and affirmative reviews from patients • Be found readily by patients • Potentially receive a ranking as the number one dentist in the area.	• Negative reviews affecting reputation • Misleading information • Exposure of any mistakes or wrongdoing • Lose patients due to misleading or incorrect information.
Dental Practices	
• Attract more dental patients • Acquire a good reputation and affirmative reviews from patients • Be found readily by patients • Potentially receive a ranking as the best practice in the area • Gain patient loyalty and return visits	• Negative reviews affecting the practice reputation • Incorrect information • Exposure of any mistakes or wrongdoing • Lose patients owing to misleading or incorrect information. • The mistake(s) of one staff member can impact the whole practice team
Other dental staff	
• Receive affirmative comments from patients • Receive recognition • Contribute to the success of the practice	• Exposure of mistakes or bad behaviour • Loss of employer esteem • Poor patient feedback • Potential loss of job
Insurance companies	
• Attraction of more customers • Receive positive feedback from customers • Increased level of public awareness in terms of the importance of dental insurance	• Loss of company reputation • Negative patient feedback • Loss of customers owing to bad patient reports

• Increased customer base	
Regulatory bodies	
• Dentists and patients are not impacted negatively due to the social network • Patients get help from the network • As a community, everyone benefits • Patients are able to find the right dentist for their treatment.	• False or biased reviews about dentists (shilling attacks) • Negative impacts on dentists due to complaints or reviews • Patients are disadvantaged due to poor or incorrect information conveyed by the network • Difficult situations occurring due to complex issues raised within the dental social network.
Dental tool manufacturers	
• Patients are happy with the tools dentists use. • More dentists use their tools • Promotion of their brand through patients mentioning them in their conversations.	• Poor patient feedback • Loss of sales • Loss of reputation
Pharmaceutical companies	
• Medicine and other chemicals used by dentists work well • Dentists will prescribe more of their products • Patients will like and spread the news about their products	• Side effects or bad reactions experienced by patients • Loss of company reputation owing to negative patient feedback

4.1.3. Role of Regulatory Authorities to Approve the Proposed Model

Regulatory authorities have a significant role to approve the proposed trust-enhanced model for dental care recommendation systems in dentistry. Obviously, the rules in dentistry differ in different countries, but it is important to consider guidelines prepared by the authorities to propose a new model in the industry. Although the dental care social network aims to provide a transparent and quality dental care recommendation system, there are many challenges which exist as mentioned in the table above and the issues section 2.2.3 . By virtue of these challenges, regulatory authorities are concerned with the growing popularity of dental crowdsources and social networks in Australia.

One of the main objectives of the proposed model is to use the popular trend of online reviews to provide benefits to both patients and dentitsts by matching them in the best possible way so that successful dental treatments will be the outcome.

4.1.3.1. Example of Reactions from Governing Authorities in Australia

The responsible regulatories bodies in Australia (the Australian Dental Association (ADA), Australian Dental Council (ADC), Dental Board of Australia (DBA)) released some guidelines for review sites when one of the health insurance providers, NIB Health Insurance Company, launched the 'Whitecoat website (whitecoat.com.au)' which allowed patients to review healthcare providers including dentists. ADA warned all the dentists to be wary and publicly criticised the intention of the site. One of the major points of this criticism was that patients did not have the qualifications or skill to judge professionals like dentists in terms of their work and skills.

Despite all the protests from regulatory bodies, the whitecoat website became publicly accessible and operated as a successful reviews site in Australia. Due to the combination of technological advances and the popularity of social media, writing reviews about anything and everything has become prevalent. Therefore, the regulatory bodies need to update their policies to encourage, rather than attack, review sites. There is mutual benefit to the public (as dental patients) and dentists (as service providers) as long as the system is genuinely used, spread the word about the good service and professionalism of dentists.

All the stakeholders associated with the dental care social network have their own hopes and concerns. These hopes and concerns are directly associated with levels of trust. Some of the concerns and issues can be mitigated by analysing and improving trust factors. This study aims to evaluate the trust factors related to patients in order to improve the suitability of matching between patients and dentits within the dental care recommendation systems. The sources of trust in relation to the dental care recommendation systems are described and analysed in detail in the next section.

4.2.Trust Evaluation for Dental Care Recommendation Systems

Generally trust in a dentist emphasises the positive acceptance of patients to believe that the dentist as a trustee will care about their welfare in a vulnerable situation of oral health (Hall et al. 2001). Due to the invasive nature of dental treatment, potential pain, anxiety and uncomfortableness are considered by patients. Hence, the experience perceived by the patients during the dental treatment and how the dentist handles the situation impacts on how much patients prefer and ultimately trust them. Patients share their experiences about dental treatments in their social networks whether online or offline. This phenomenon helps dental patients to make a decision when choosing a new dentist. In the case of OSN, the number of users is usually higher and hence the impact is higher too.

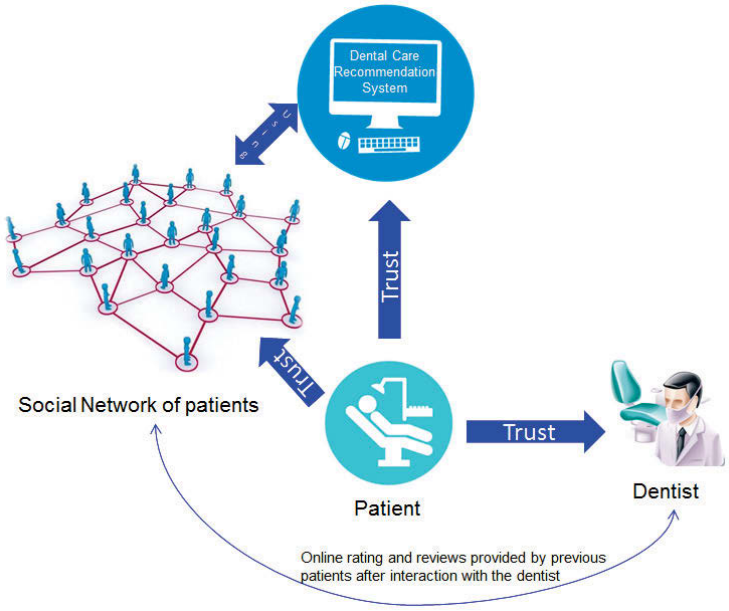


Figure 4.2: Multiple sources of trust

As discussed in Chapter 2, trust in the dental care social network is broadly divided into two dimensions: explicit and implicit trust. *Explicit trust* is usually derived directly from specific information about a dentist, such as qualifications, awards in relation to a specific area, results from treatments, ratings, friendships, etc. However, *implicit trust* is derived indirectly from personal interactions and experiences. For example, information which is not clearly stated but learnt from the behaviour of dentists and described in reviews and ratings. Trust is gradually developed with interactions and experiences which may take different periods of time. Both explicit and implicit trusts in dental care recommendation system are proliferated from multiple sources. Multiple sources of trust and their roles are analysed in the context of dental care recommendations in this section. As shown in Figure 4.2 above, there are mainly 3 types of sources of trust for dental patients: directly from the dentist, from dental recommendation systems or from people in their network.

4.2.1. Three Dimensions of Trust for Dental Care Recommendations

Trust components relevant to dental care recommendation systems are investigated from multiple dimensions in this study. The suitability of a dentist for a patient can be investigated and analysed from many aspects. Recommendations are usually sourced from trusted parties such as family members or friends. In this internet age, the source is gradually transferred to online applications such as recommendation systems. Therefore, trusting users of the network and recommendation system itself are two major sources which need to be analysed to evaluate the suitability of a dentist recommended by the dental care recommendation systems. Thus, 3 dimensions of trust result from explicit and implicit information of dental care recommendation systems. The following 3 dimensions of trust are further elaborated below

- Trust in Dental care recommendation systems
- Trust among dental patients as users
- Trust in dentists or dental practices

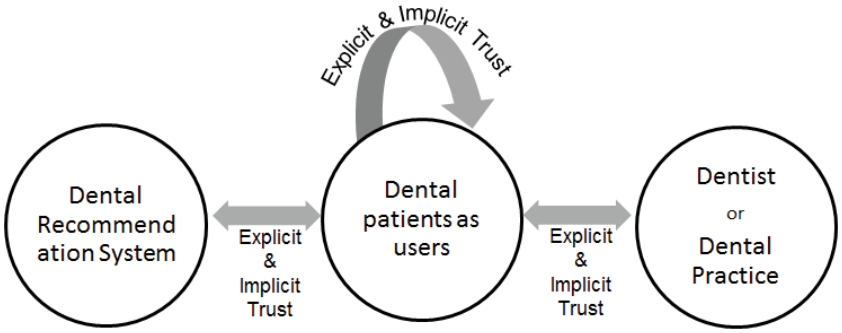


Figure 4.3: Dimensions of trust for dental care recommendations

- **Trust among dental patients as users** – recommendations often depend on the trustworthy sources from which they are generated. If a recommendation is sourced from a reliable and trusted person or friend, it is highly likely that the dental patient (the 'trustor') will trust the friend or other reliable source (the 'trustee') to recommend a dentist. This is an example of explicit trust due to the relationship between the trustor and trustee. Trust by nature is transitive. Trust between users within the network is regarded as '**local trust**' and this impacts the way that dental information is shared so that the dentists are accurately rated and reviewed. It is assumed that the recommendation system provides accurate recommendations on dentists. For example, someone who is an expert or has been sharing useful dental information will have more influence in the dental social network than others who do not know much about dentistry. The trustworthiness of users which is determined by the interactions and sharing of useful information in the network, is referred to as 'implicit trust'.

In the network, patients usually listen to their own friends rather than strangers in the network. Success is largely dependent on the reputation of an individual reviewer or referral source in the dental social network. Users in the network rely on each other's ratings, feedback and recommendations. Hence the success of the recommendation system comes with the success stories and honest opinions of users and the strength of relationships built among them in the network. Both explicit and implicit trust are endorsed in reality within the social network, which helps to improve the quality of dental care recommendations.

- **Trust in the dental care recommendation system** – dental patients will visit a particular recommendation system over other available systems to search for a dentist because of the ability and reputation of the system in the community. The perception of being a reliable source and the belief that the system provides quality recommendations of dentists plays an important role. The reputation of the system is established only after the community recognises the system as a reliable source of information, this is referred to as '**global trust'**. The perception of users of the recommendation system depends on the general appearance and layout of the system as well as other variables such as user friendliness, use of colour and pictures and so on. The popularity of the system is dependent on both the explicit and implicit nature of variables including the number of people using the system, who has recommended the system, the quality of information shared and reviewed, etc.

- **Trust in dentists or dental practices** – trust in dentists or dental practices are influenced by many variables. Mainly, the trust in a dentist is direct functional or competence trust which is experienced by the patient and can be expressed in the social network by giving positive ratings and sharing that information with friends. The star-ratings scored by dental patients to rate the dentists within dental crowdsources are considered as reputation trust for the dentist. In other words, aggregated ratings for the same dentist can be defined as the reputation or global trust of that dentist. It is a type of implicit trust in the dentist. This trust can be developed between patients and dentists over time as they get to know each other better after several interactions. By contrast, the result could be the opposite after a few interactions. The source of the recommendation of the dentist i.e. whether it is a recommendation system or an individual user of the network, also gains a level of trust or distrust from the patient as a trustor. Thus, trust in recommendation systems depends on the accuracy of recommendations of the dentists provided.

Overall, trust among dental patients in the network and the trust relationship between dental patients and dentists has an impact on the trust of the dental care recommendation systems by new patients and vice versa. Therefore, trust is further investigated with more examples from the dental care recommendations environment in the following sub-section.

4.2.2. Analysis of Trust for Dental Care Recommendation Systems

Usually, patients undergo various methods of dental treatments, each corresponding to different levels of severity in terms of pain and discomfort and the situation of the particular patient. It is important to take these situations into consideration when matching a dentist with a patient in dental care recommendation systems. The term 'trust' has been used in this study to describe 'the most suitable dentist' for a patient in particular circumstance when they are looking for a dentist, for example, just moved to new city, travelling overseas, in an emergency when own dentist is not available, etc. Trust has a very broad interpretation and is an important factor when choosing a dentist; to ascertain which dentist makes them feel the most comfortable and understands them best to perform treatments up to a satisfactory level. It is possible that this trust is obtained from other patients' opinions. The explosion of web technologies and social networks assists in examining other patients' opinions and reviews to measure the level of trust between patients and dentists both explicitly and implicitly in order to improve the recommendations of dentists in today's internet age. Trusting recommendation systems or users of the network as sources are based on their reliability to recommend the most suitable dentist to patients.

Besides the importance of trust in dental care recommendation systems, this study focuses on how trust is associated with a dentist. The service provided by the dentist is generally related to their competence and skill. In order to gain the positive trust propagated between dental patients, the quality of service from the dentist who has been recommended by the system is critical. When patients are happy with a dentist's functional capability or competence, they refer the dentist to their friends and other patients that they know. So, the functional trust also determines how patients refer to others, and write reviews online in a given network. In regards to referring a dentist, the source may come from another patient or a friend in the network. So it can be analysed as direct or indirect trust within the network. Trust may have been generated from indirect trust, generated through other patients in the network indirectly. The extent of the impact of the propagation of trust is dependent on other factors such as the strength of relationships, timeliness, similarity in context and so on.

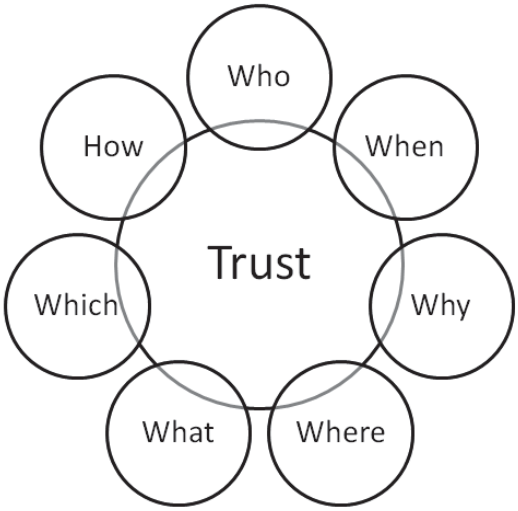


Figure 4.4: Sources of Trust Analysis

Generally, trust can be evaluated from multiple perspectives. All 7 '*Wh*' questions (who, when, why, where, what, which and how) can be asked to understand the trust within the network. For example, the referral trust can be analysed from who has referred, when the referral was made, why are they referring, where was the patient at the time, which part of the service is referred and how the referral was provided?

A few more questions related to 'Wh' questions are listed in the table below in terms of the explicit or implicit nature of questions. Reliability of the recommendation is another crucial factor in recommending a suitable dentist. A patient who is making the recommendation has an identity and profile in the network. The relationship with the other users and the reputation or credibility of the recommending user are important factors for someone who sees this user as a trusted referral party. So trust can be measured from many different aspects and some of them are exhibited in the table below.

The timeliness of the recommendations are important factors for the dental care recommendation system. Hence, recommendations based on when and what information is provided, are critical to determine the suitability of a dentist for a patient. For example, old reviews may not be appropriate to measure the current subjective quality of a dentist. Currency of information is important in recommending a dentist to a patient.

Table 4.2: List of 'Wh' Questions to analyse types of Trust

Wh	Questions	Types of Trust
Who (relationship & reputation)	Who recommended the dentist?	Explicit
	Who has been to the same dentist and provided a positive rating?	Explicit and implicit
	Who is a trustworthy user?	Explicit
When (context)	When was the review written?	Implicit
	When did the person recommend the dentist?	Implicit
	When did the patient share symptoms or opinions?	Implicit

Why (context, relationship & reputation)	Why did the patient review the dentist?	Implicit
	Why did the patient see the dentist?	Explicit
	Why is this dentist so popular among others?	Explicit and implicit
	Why is the dentist recommended by the system or others?	Explicit and implicit
Where (context)	Where did the patient find this dentist?	Explicit
	Where was the treatment provided?	Explicit and implicit
What (context & relationship)	What aspect of the dentist did the patients like?	Explicit and implicit
	What makes this dentist stand out in the list?	Explicit and implicit
	What is the reason the patient chose the dentist?	Explicit and implicit
Which (context, relationship & reputation)	Which treatment was provided?	Explicit
	Which dentist was chosen and why?	Explicit and implicit
	Which system was used to choose this dentist and why?	Explicit and implicit
How (Context & relationship)	How did the patient find the dentist?	Explicit
	How was the treatment performed?	Explicit and implicit

As discussed in Chapter 2, patients are genuinely very happy and satisfied to write positive feedback or are very unhappy to write negative feedback. It is important to have a mechanism to check the integrity of the feedback or other sources of recommendations so that it is not created to benefit a party as a biased or incorrect review (shilling attacks). Understanding the genuineness of the information in terms of why it is provided is paramount in recommending a dentist to a patient.

Similarly, 'where' (in terms of which online platform or system) is used for reviews, plays a significant role in terms of trusting the platform as a global trust. 'Where' in this context may even refer to the geographical location or platform. The semantic meaning of some words depending on the culture may have different meanings. In which context and from where the information is generated are therefore important details to take into account when considering the recommendation of a dentist to a patient.

Similarly, how the information is passed on to generate the recommendation is important. It refers to the methods used to generate the recommendations. In addition, the various types of trust-based information are integrated to find a suitable dentist for a patient. Trust components are further discussed in relation to dental care recommendation systems within the dental care social network in the next section.

4.3. Trust Components from Social Networks for Proposed Model

Trust-based components (often referred to as trust components) in this study are investigated from a variety of sources within a dental care social network. Most of the information related to trust in recommending a suitable dentist are analysed in terms of the social aspects of social networks, and therefore it is referred to as social trust. The focus of this study is on analysing social trust in the context of recommending a dentist to a patient.

The social network is a social structure consisting of individuals with common goals, friends, interests, or belief systems. In the past, networks were limited to a particular geographical location and was predominantly used offline (Young 2011). However, the prospect of social networks has now expanded dramatically due to the latest developments in information and communication technology (Hu et al. 2014). Hence, the growth of online social networks (OSNs) is inevitable and has offered many opportunities including comprehensive user profiling for dental care recommendation systems. Trust from multiple aspects is evaluated to create profiles of both patients and dentists. All the 'wh' questions from the table 4.2 above are considered and assimilated into 4 trust components relating to social aspects: Context analysis, Relationship analysis, Reputation analysis and Personality analysis. Figure 4.5 below modifies Figure 4.3 by integrating the 4 trust components.

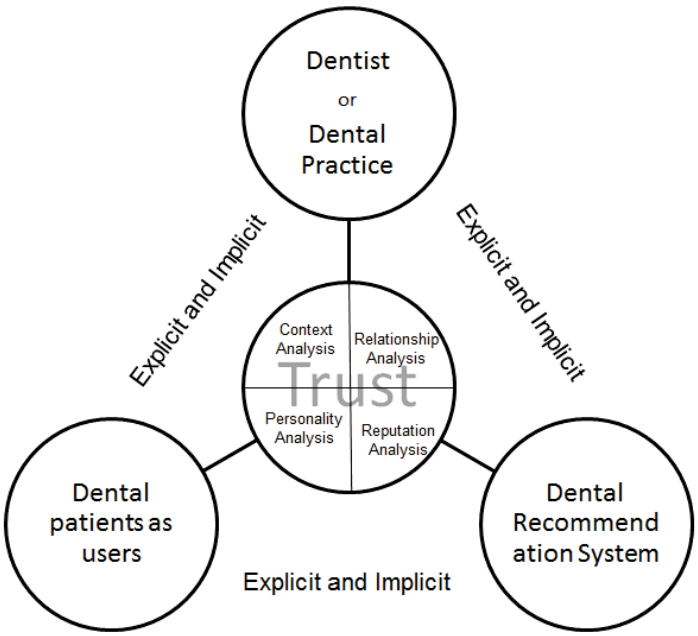


Figure 4.5: Inclusion of Trust components

The trust components from the figure above in this section are elaborated to evaluate and understand each component separately. Information in social networks is evaluated to arrange these components so that trust related information can be incorporated while profiling major stakeholders to improve the quality of recommendations. Besides other objective criteria such as the type of treatments, location,

age-group and so on, other types of information which can be extracted from these 4 different aspects of trust components within social networks are discussed.

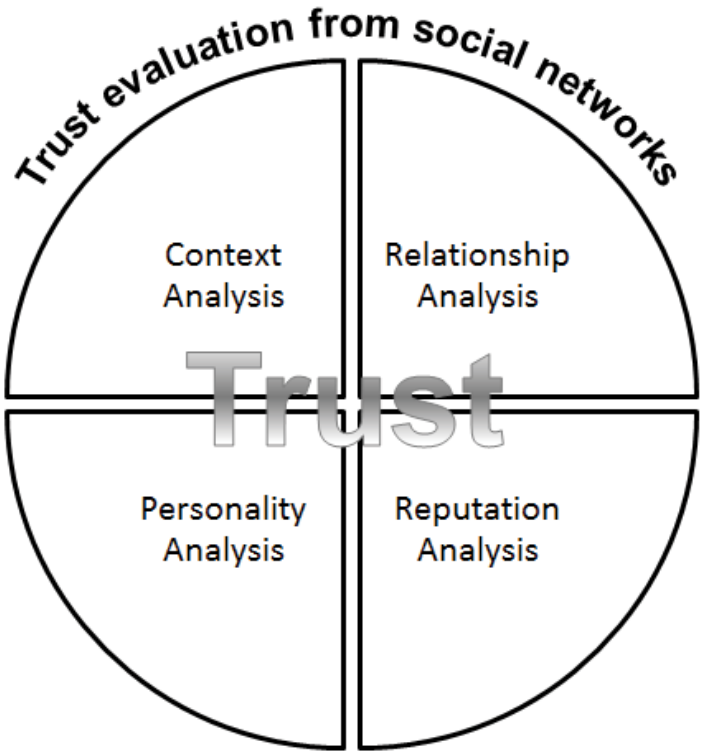


Figure 4.6: 4 major Trust components from Social Networks

User profiling is the backbone of any recommendation system. For the dental care recommendation system, user profiling of both patients and dentists are envisioned by integrating the trust components discussed in this section. Patients are able to ascertain their situation and symptoms better than ever by sharing and comparing information on online social networks (Vayena et al. 2012). For example, patients can compare their own symptoms with others and can relate to each other due to similarities and thus some level of social trust can be generated between them in the network. The patients are also able to question and understand symptoms and treatments online to build explicit and implicit trust with other users in the network. Based on the information shared across the network, social ties (strong relationships) can be generated which eventually influence the choice of a dentist. Such information has precedence in recommending a dentist and needs to be considered for dental recommendation systems.

Social networks help to make new friends but the strength of friendships is very important in determining the trust between the participants. A level of trust can be derived from the relationship between friends in making recommendations. Similarly, the growing number of dental crowdsources is also helping to measure the reputation of dentists and dental practices, owing to the publicly available online ratings by patients. Subjective information of dentists is available in dental crowdsources and plays a vital role in filtering the suitability of dentists for particular patients. The trust components for

this study are considered in relation to social network perspectives i.e. whether they are online or offline. Therefore, this system can be also referred to as a social recommendation system. Trust components from Figure 4.6 above are evaluated separately for patients and dentists in the following sub-sections.

4.3.1. Trust Evaluation for Patients

This research aims to provide the most suitable dentist for patients by providing reliable recommendations from trusted dental care recommendation systems. 4 trust components are evaluated from the patients' point of view in social networks in this section and they are briefly illustrated in Figure 4.7 below.

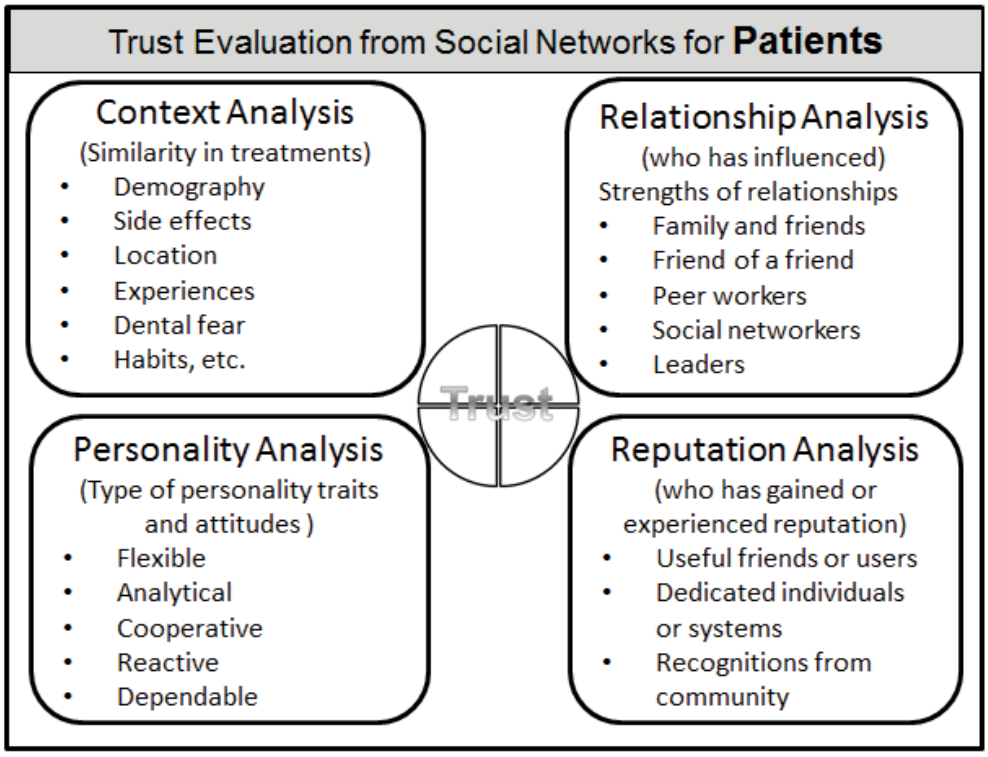


Figure 4.7: Trust evaluation for dental patients

4.3.1.1. Context Analysis

The dynamics of the situation and the context in which the recommendations are made to patients is critical in dental care recommendation systems. The more information that is provided about the dental patient context (situation) the better it is to filter the relevant information to find the most suitable dentist from the pool of dentists in the system. For example, a patient's demographic information, medical history, known causes, or dental symptoms are basic information that need to be provided so that patient users of the system can relate to the information provided by other patients in the network. Therefore,

context is paramount when evaluating the trustworthiness of the information provided by dental patients as users or contributors in the dental social network. For example, a dental patient who has knowledge in dental care either as a staff member of a dental practice or a student in dentistry, may be highly regarded (trusted) in the network. The personal knowledge and experiences that they have had, are important resources, when analysing the trustworthy nature of the recommendations provided by them in the network. A dental patient's expertise or skills in dental care can be analysed by the number of high quality related information or postings on specific dental issues (e.g. reviews, blogs, discussions on forums, feedback or sharing) for. Certainly, this analysis further enhances the trustworthiness of the patient as a contributor, and hence influences the recommendation made by the patient. This information is also related to the reputation of the patient as a user in the network because the user usually gains reputation based on the quality of information provided about the dental care.

Context can usually be established by analysing the similarity of information from the patients' profiles. A unique situation or symptom for a patient at the time of treatment can be a powerful source of information for other patients if they are dealing with similar symptoms. There are many types of information that can be captured through user profiles in social networks (Vayena et al. 2012), and these contribute to form an appropriate context for comparison and impact significantly on trusting users in the network. As Kazienko & Musial (2006) have stated, static information such as demographic, interests or preferences is usually entered by the user themselves, and this helps to build explicit trust. Dynamic information is gathered in the system automatically by monitoring the activities and interactions that have been performed by the user in the network, such as searching, sharing, rating or reviewing, and the time spent on specific information which can be used to construct implicit trust. Collecting and analysing related information from the network while filtering in the recommendation system is an important process to find the most suitable dentist through context analysis.

For understanding the context, the similarity in the static and dynamic information of other dental patients is further analysed in the following sub-section to see how this works in terms of the dental care recommendation systems.

4.3.1.1.1. Similarity Analysis

Similar information shared by dental patients in the dental social network in terms of their needs, type of treatments, motivations and other ancillary information such as demographic, life style, culture, habits, medical history, anxiety, side effects etc is possible to be captured, because the social network is one of commonly used communication methods. Privacy rules operate to attain this kind of information. However, sites like 'PatientsLikeMe' are emerging in the health care area so that patients are able to share their health symptoms, treatments and other information systematically. 'Similarity in symptoms' is one of the most important forms of information that can assist other patients in the network. In addition, 'similarity in treatments' and other similarity information can be compared

between patients, which can help to build trust between them, and eventually develop connections in a social network (Bisgin et al. 2012). When patients see the similarity of their symptoms in the HSNs, they get inspired to share their own information online. Patients with similar symptoms can associate better and start trusting each other by sharing more information.

'Similarity in side-effects' is another profound fom of information which impacts the level of interpersonal trust between patients within the network. If there is a similarity in side-effects to similar treatments and symptoms, there is more likelihood of building trust between others in the network. Additionally, 'similarity in dental fear' can even escalate the level of trust between patients within the dental care social network. These situations increase the possibility of sharing more information and enhancing trust which can impact in terms of improving the quality of recommendations and the decisions that the patients make. Another example, 'DentalFearCentral' describes common fears in dental care and provides tips to deal with them. The intention of aggregating this kind of information is to reduce dental phobia and increase the possibility of connecting with other patients in the social network environment. The site also declares that the level of fear can be reduced with the amount of quality and pertinent information discussed in specific situations. 'Similarity in demographic information' such as age, gender, education, location, social status and so on are additional forms of static information which can assist to enhance the interpersonal trust between patients. Hence, similar geographical proximity of workplace, school or residence may support the trustworthiness of patients in dental care recommendations. In the online world, 'similarity in interests, opinions, thoughts and preferences' binds the users together. This type of information can connect one patient with another to build the trust they need to choose a dentist or dental practice in the dental social network. In offline social networks, 'similarity in religion, faith and cultural background' also plays a major role in propagating interpersonal trust between patients in terms of finding and choosing a suitable dentist.

4.3.1.2. Relationship Analysis

Social networks are gaining popularity as they build and foster relationships among users. Relationships with users in the network could be newly formed, or could have already been continued due to previous experiences/interactions or from profile similarity or they could know each other as a friend or family member, or even a friend of a friend (FOAF) etc. Social network analysis (SNA) based on the strength of relationships (ties), is a powerful tool to determine the trustworthiness of users who can provide accurate and reliable information in the network on specific topics like dental treatments. This feature has great influence when evaluating trust in recommendations. For example, if 'B' is a friend of a friend 'A', 'B' will be more credible, simply based on the link to the relationship. Social media giant, Facebook, uses this method to recommend friends who are not in the friends' list.

Both online and offline social networks provide a natural environment for dental patients to build trust based on relationships, which relies on connections (and the strengths of connections). Both direct and indirect social connections through the network are important for trusting each other. The strength of relationships between the patients (both trustor and trustee) within the dental care social network helps in recommending a suitable dentist. In several studies, when individuals were allowed to choose between recommendations from friends and recommendation systems, they preferred recommendations from friends even though recommendation systems were augmented with novelty factors (Ziegler 2005; Swearingen & Sinha 2001). Friends' relationships have tremendous power because they can share the same pain they go through and they share similar preferences, interests, and opinions. When one of the friends tries something and it works, he/she is able to share it with their friends and hence the recommendation becomes almost direct and very strong. Even when it is propagated through indirect links, the power of friendship impacts in recommendations greatly.

Because of the inherent risk to their health, patients tend to listen to people that they know in order to make good decisions in the health area. Trust generated from strong relationship generally surpasses other sources. With more people interacting through online platforms, the relationships build up strongly and hence recommendation systems gain enormous popularity in the online world.

4.3.1.3. Reputation Analysis

Reputation is a social concept which is known for a publicly recognised achievement or credibility. In this study, reputation for patients within the network is examined to determine the credibility of the users who are posting reviews, articles and rating dentists. The patients' reputation is analysed based on the quality of information shared within the social network. Furthermore, knowledge and skills in dental care are recognised in the network. For example, people who are associated or working with dentists or people who have studied dental related education may have a better understanding in reviewing and rating dentists better than ordinary patients. However, privacy and identification challenges in the social network environment protect against having a clear understanding of each user in the network. Social network users implicitly gather useful information and follow other users in the network and that's what makes the social network such a powerful tool in today's online world.

4.3.1.4. Personality Analysis

The majority of HSNs allow patients to create, share and retrieve health related information and retain personal data and activities online within their profile. The trend of activities is stored in their profile, however, subjective information such as attitude, behaviour or perception is challenging to retrieve. Not

only retrieving subjective characteristics of patient is challenging but privacy provision and anonymity adds even more complexity to the process. Nevertheless, advances in data mining have led to the ability to conduct a sentimental analysis of users based on the words that they use or the way they express their views online (Dasgupta & Ng 2009; Saif et al 2012). Although it is not possible to completely retrieve all subjective information about the user, certain levels of behaviour can be learnt from stored activities in the network. Attitudes and behaviour are related to the personality traits that they have.

Patients can be classified from their subjective characteristics which are potentially identified from the reviews that they write not only on dentists but on other items and services, as well as activities performed within social networks. The online activities and interactions of the users are possible to gather however, this has been restricted due to privacy law. Additionally, the internet users do not necessarily use the same user identification across different social networks; hence it is very challenging to determine the users first and then to be able to find their subjective characteristics. With the ubiquitous nature of social media such as Facebook, Twitter etc., it is anticipated that profiling the subjectivity of any internet user will be possible, based on the types of activities and the nature of activities such as types of post, language used, frequency of posts, and time of the day of postings, and so on There is not only one source for creating a profile but it can be combined with what the user has supplied to various types of social networks, and what other users have said about him/her and the system generated data (Ellison & Boyd 2013). Both static and dynamic information can be used to profile and understand the personality of patients from social networks.

In this study, we have used the DISC personality test to determine the type of personality traits of patients as described in Chapter 2. In the future, it is anticipated that the type of users in the social network will be examined by analysing information available online about the user.

4.3.2. Trust Evaluation for Dentists

Dentists are the service providers and the other major stakeholders for dental care recommendation systems. Four trust components mentioned above are evaluated from the dentist's perspectives in this section which also helps to profile dentists in the system. These are briefly shown in Figure 4.8 below.

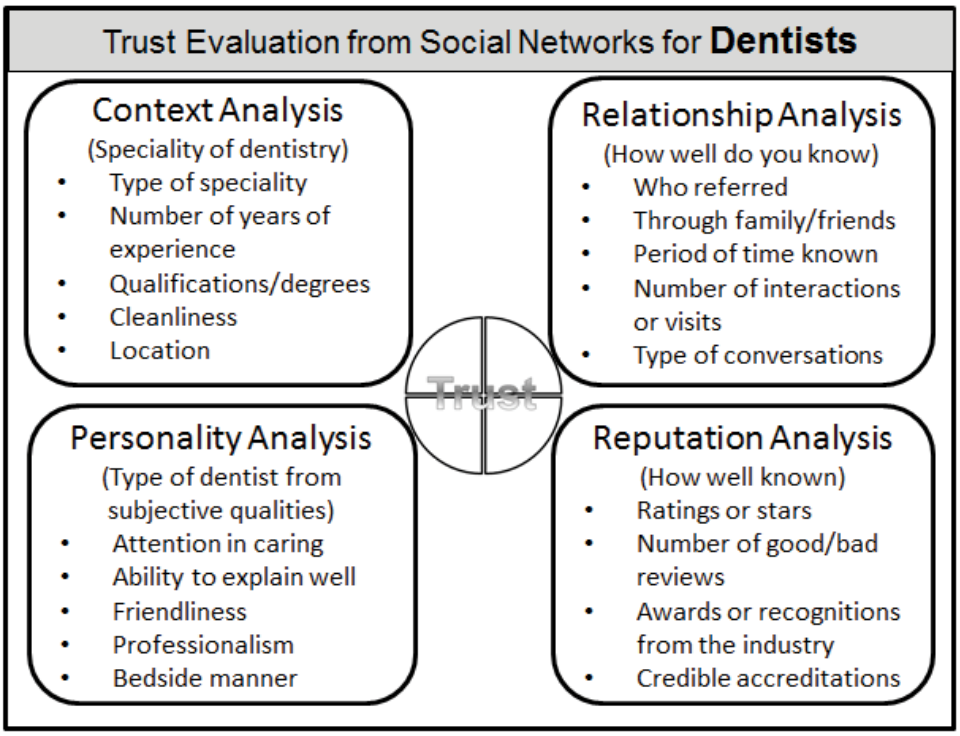


Figure 4.8: Trust evaluation for dentists

4.3.2.1. Context Analysis

For dentists, context is very dynamic and it can be investigated from their qualifications, speciality, number of years of experience, place of work and other information which helps them to be trusted by their patients. It can also be investigated by analysing the way that they treat their patients in different situations and environments. Patients perceive dentists as trustworthy based on many types of information including how long they have worked in which hospital, which university and country they received their degree from, how many patients that they see every week etc. Furthermore, the cleanliness of a dental practice and the manner of the staff at the dental practice are also considered in terms of the context for choosing a dentist. Some of the objective criteria in dental recommendation systems incorporate context driven information such as speciality, location, cost etc.

Specific types of dental treatments and the way the treatment is done to the patients also falls into context analysis. This may include the type of tools used and prescribed medicines for the treatment.

4.3.2.2. Relationship Analysis

Social ties certainly influence the recommendations made to choose a dentist. Relationship analysis is examined from the perspective of how the dentist is known to the patient. It is similar in the way relationship works for patients in dental care recommendation systems, except that it is a direct link with the dentist. Naturally, patients choose a dentist when they are comfortable with the dentist. The comfortableness sometimes comes down to how the dentist is known to the person or the relationship that is built over time. For example, if the dentist is a family member; it is highly likely that the dentist will be selected for treatments. It also depends on how long the patients know the dentist for. If a patient has been going to the same dentist for a number of years, they tend to stay with the same dentist as they are comfortable with him/her.

Due to the invasive nature of dental treatment, the strengths of relationships have a big impact on choosing a dentist and that is why people tend to trust their friends and families to find a dentist in the first place. After this, the relationship built directly with the dentist will determine whether the patient continues with the dentist or changes to another dentist.

4.3.2.3. Reputation Analysis

A significant amount of dental information is publicly available through dental crowdsources as discussed in Chapter 2. The reputation of dentists is based on the aggregated ratings by the patients in dental review rating sites. Ratings are usually based on the patients' perception of the dentist's behaviour at the time of the treatment and represented in the form of star-ratings. The ratings are usually based on a number of criteria used to evaluate the quality of service provided to the patients. As mentioned in Chapter 2, there is no consistency in the criteria across the crowdsources. Therefore, there is a challenge to aggregate ratings across different dental crowdsources. Moreover, some sites only allow for reviewing and rating each dentist once which somewhat limits the possibility of showing dynamic changes in the quality of service by the dentists.

Not only star-ratings but also qualifications, specific industry awards, work in certain hospital and degrees count towards the reputation of dentists. However, it is difficult to quantify these types of reputation as they are often perceived by the community and they differ from one community to the next.

In some cases, ratings have been utilised to filter dentists or dental practices in many dental crowdsources. In this study, the ratings of dentists are analysed to profile dentists, and more details with results are available in the next chapter.

4.3.2.4. Personality Analysis

Subjective information has been included as a latent construct with the users' rankings and ratings (Luo et al. 2008) and the rating of different scores is usually influenced by the dentist's subjective qualities. The subjective characteristics of a dentist have been recognised as an inherent factor when someone is recommending a dentist as a professional. The subjective characteristics of dentists are often derived from their personality. Most of the time, the subjective characteristics of dentists are revealed by the patients when they write reviews after their visit to the dentist. The terminology used by patients to describe their dentists, is often subjective in nature. The patients are able to assess the subjective qualities of dentists aligned to their personality traits to see how they fit with the dentists and to filter the list of dentists. Dentists are recommended based on what their previous patients thought of them in their treatments and it is important to include dentists' qualities when recommending dentists to patients. Therefore, we propose that dentists' qualities are added in classifying dentists in dental care recommendation systems. For example, a dentist may be able to handle certain levels of stress which other dentists are not able to handle. It is not about what treatments dentists are eligible to perform based on their degrees and qualifications but what they are good at performing. Understanding the relevant skills of individual dentist in different situations is important to consider when recommending a suitable dentist to different types of patients.

Thus, the subjective qualities of both patients and dentists are investigated and these are incorporated in the attitudes, behaviours and personalities to classify them. Certain trust components related to the subjective qualities of both patients and dentists are incorporated in profiling. More details on profiling are provided in the next chapter.

4.4. Elements of Trust in Objective and Subjective Criteria

Trust components are evaluated from multiple perspectives for dental care recommendation systems in this study by emphasising the trust of patients to other patients in the network, the recommendation systems and ultimately the dentists. Trust is further examined from the objective and subjective criteria that patients choose in dental care recommendations systems in this section.

4.4.1. Influence of Objective and Subjective Information in Trust

Trust is associated with both objective and subjective information when patients use dental care recommendation systems. This section elaborates on how each trust component described above is associated with objective and subjective criteria. For example, context is created not only by objective criteria such as location, number of years of experience, type of treatments, insurance covered, cleanliness and so on but also by the subjective qualities of the person (either dentist or patient) involved. For example, situation such as the cleanliness of the practice could be perceived differently by different patients when they visit the practice. So, context is dependent on the perception of patients at the time of dealing with the dentist.

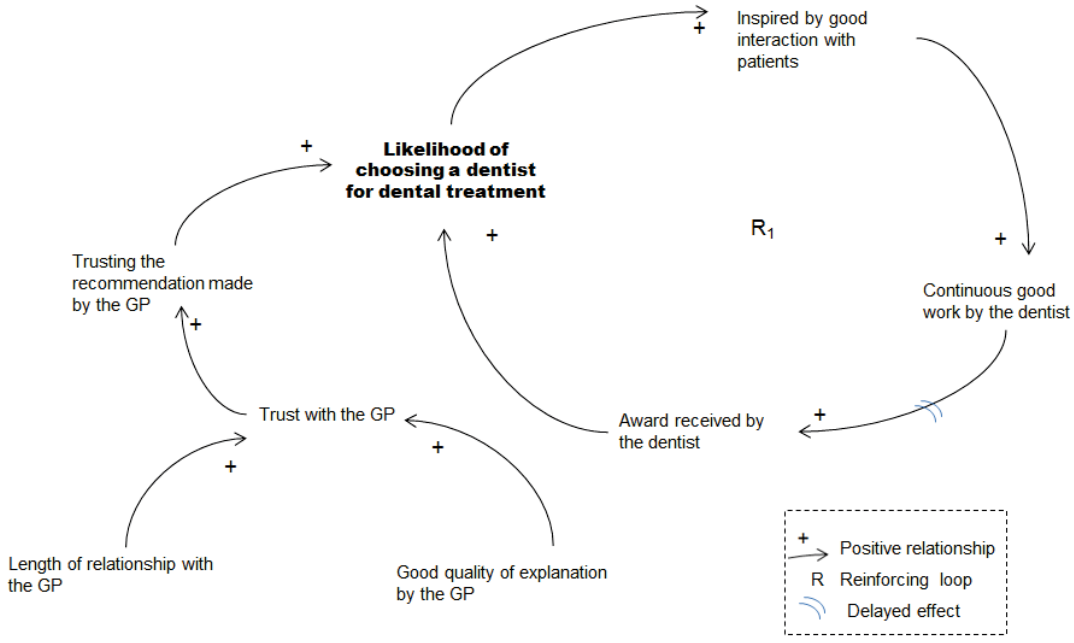


Figure 4.9: Causal loop diagram to analyse objective and subjective criteria

Similarly, some components of relationship and reputation analyses can also be associated with both objective and subjective types of information. For example, a dental patient chooses a specific dentist objectively because s/he was referred by their trusted GP or the award (recognition) the particular dentist

received. In this example, the patient trusts the GP and that can be analysed subjectively. Similarly, the subjective qualities of the dentist can be analysed, which have helped him/her to get the award. Subjective qualities of the GP and the dentist in this example are further examined. Let's say, clear communication skills have resulted in the patient trusting the GP. Good work by the dentist due to inspiration from patients led the dentist to get the award. This scenario is exhibited in Figure 4.9 above with a causal loop diagram.

Certain aspects of each trust component are objective and can be explicitly pointed out but subjective types of nature are difficult to indicate. Hence, personality analysis for patients and dentists are given precedence to incorporate subjective qualities in this study and these are highlighted in Figure 4.10 below.

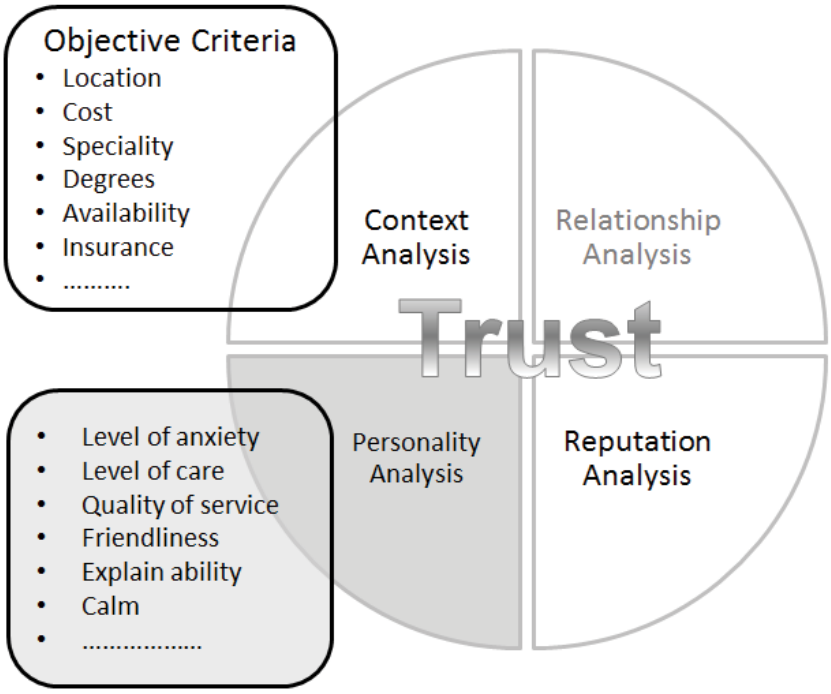


Figure 4.10: Objective and Subjective trust components

4.4.1.1. Objective Criteria

Traditionally, recommendation systems filter information based on search criteria. Mostly search criteria are objective criteria and they combine both the patients' and dentists' perspectives. In the case of dental care recommendation systems, some of the objective criteria are as follows:

- Location – how many kilometres from where they live or work
- cost – willingness to pay
- speciality of dentistry – degrees and qualification the dentist has

- insurance companies – type of insurance policy the patient has
- types of treatments – general check-up or specialist needed
- availability – when the dentist is available for booking and whether this is suitable for the patient.

These criteria depict a certain level of trust as the patients look for a dentist within a certain location.. Some criteria can associate the level of trust to the criteria more than others. However, the level of trust depends on the situation of the patient who is looking for a dentist at a given moment in time when they are looking for a dentist. For example, the patients may place trust in dentists who have graduated from a specific university, or the insurance provider the dentist is associated with, or whether the dentist is practising in a certain location (dental practice or hospital) or has been referred by the specific system. Whether due to limitation or willingness, patients have certain objective preferences in choosing a dentist.

4.4.1.2. Subjective Criteria

The subjective criteria for dental care recommendation systems is investigated in this study. Hence, it focuses more on subjective information associated with patients and dentists in order to find the most suitable match between them. In general, when someone recommends a dentist to a patient, they describe the dentist subjectively more than through objective information. This study also extends to analyse the subjective information of the person who has made a recommendation. This means that a dentist who is very good for some types of patients, may not necessarily be good for other types of patients. This term 'a type of patients' is again prescribed by subjective characteristics and personality.

Recent advances in technology have assisted in collecting subjective information from user profiles in social networks. This study focuses on classifying patients and dentists based on their subjective characteristics which are ultimately derived from their own personality traits. A brief discussion on subjective types of information is discussed below. Subjective criteria for both patients and dentists when profiling them are further elaborated in the following chapter.

- **Subjective information for patients**

People's attitudes, behaviours and perceptions have been studied from a long time in the area of psychology. Subjective characteristics of people vary with their personality traits. Therefore, we have decided to use personality traits to classify patients. There are many ways to determine a person's personality traits and behaviour from online interactions but due to previously mentioned challenges, we have proceeded with the personality test. In this research, one of the most popular personality tests, called the DISC (Dominant, Influential, Steady and Compliant) model is used to measure the subjective characteristics of patients. These 4 types of characteristics of emotions and behaviours are widely used

for personality tests. Extensive lists of behaviours which qualify for the categories of DISC are available such as ambitious, outspoken and decisive for D, friendly, expressive and people-oriented for I, good listener, consistent and family-oriented for S and organised, perfectionist and detail-oriented for C (DISCInsights 2014).

Moreover, another subjective form of information from patients used in this study is the level of dental fear. Patients' profiles are constructed based on the lists of objective and subjective information available.

- **Subjective information for dentists**

From online dental review and rating sites, 10 dentists' qualities are selected to classify dentists by their subjective characteristics. The process is described in chapter 3. While searching for a dentist, patients are able to choose dentists by certain dentists' qualities, for example, a dentists' approach in reducing pain, bedside manner, knowledge, etc. In this study, we propose standardising the subjective qualities of dentists.

10 dentists' qualities are: Friendly, Caring, Professional, Experienced, Knowledgeable, Explains well, Recommendable, Quality of service, Reliable and Good personality

Furthermore, the subjective qualities of both patients and dentists are incorporated while profiling and in later matching them on the system. They are described in the proceeding chapters.

4.5. Proposed Trust-enhanced Information Model

In this section, we propose a trust-enhanced information model by integrating various trust components to improve the quality of recommendations of dentists to dental patients for specific dental treatments. When a patient selects a dentist for his/her dental treatment, a level of trust is always associated in the process of making the decision. The trust could emerge from different factors such as trusted referral source, past experiences, awards won by the dentist, qualification achieved from the reputed institution, information available online or highly rated by many other patients. Most of the factors that influence the decision are of a subjective nature such as the quality of service provided by the dentist in terms of service, care, reliability or communication. Hence, the subjective criteria have been recognised as critical knowledge when searching for a dentist or dental practice in this study. The challenge remains not only how to measure the subjective criteria for a dentist but also how the measurement will actually vary with different types of patients in terms of their behaviour, attitude and perceptions.

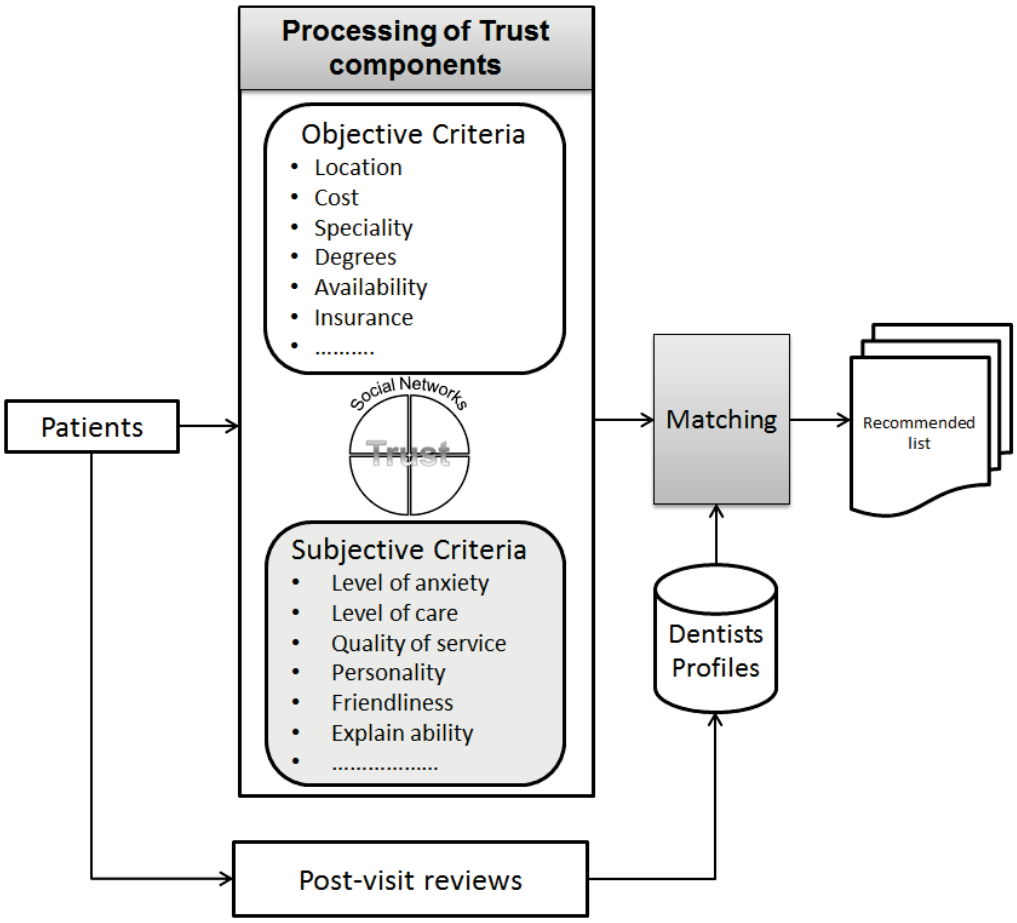


Figure 4.11: Proposed trust-enhanced matching process for a dental care recommendation system

The proposed model suggests that quality recommendations of dentists can be provided to patients by filtering dentists based on the subjective characteristics of both dentists and patients, in addition to the

usual objective criteria sought by patients. Subjective criteria have been further investigated to improve the quality of recommendations from the dental care recommendations systems in this study.

Information related to each trust component is integrated in the profiles of both patients and dentists. Both objective and subjective criteria are combined when filtering dentists, as shown in Figure 4.11 above. Various trust components are considered in the proposed model but the subjective information incorporated in each trust components is further examined in this study to improve the quality of recommendations.

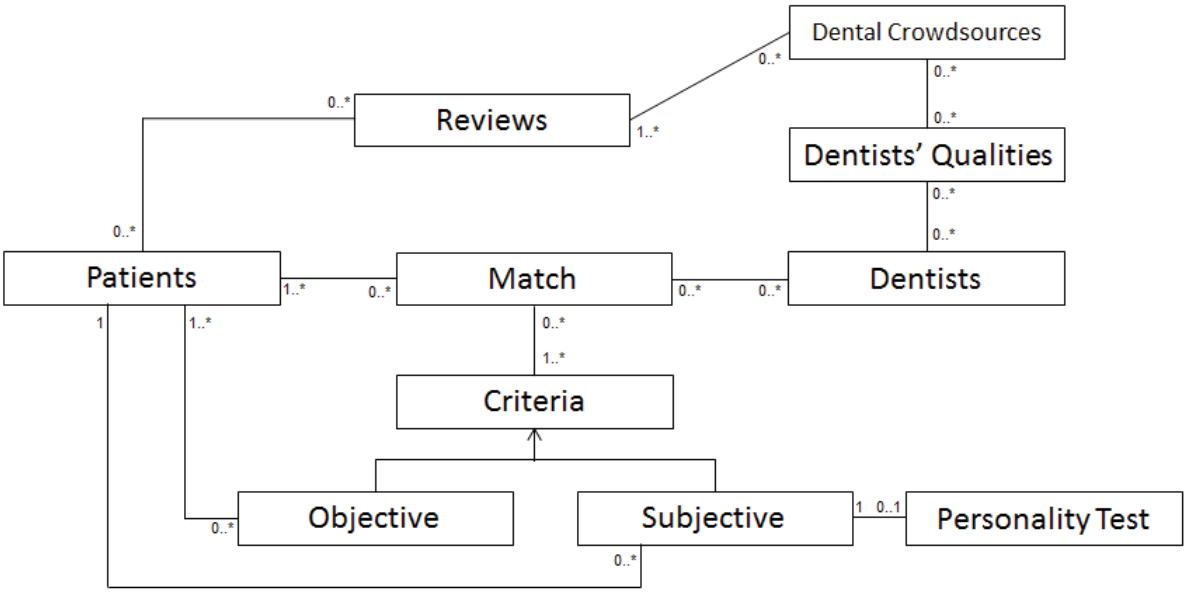


Figure 4.12: Enterprise level diagram for dental care recommendation system

4.5.1. Major Activities of Dental Care Recommendation Systems

In the proposed model, a patient interacts with the dental care social network by creating their own profile and searches for the most suitable dentist for a dental treatment. The system performs the following activities:

Before Automatic process (before patient's intervention)

- Extract up-to-date dental reviews from the network
- Classify dentists based on dentists' qualities derived from online reviews

During when a patient searches for a dentist

- Search for a suitable dentist with some criteria
- Generate patient's profile based on the search criteria
- Provide option to determine personality traits of the patient

After the system returns

- Filter and match a list of suitable dentists by applying matching algorithms
- Remind the patient to provide feedback on recommendation and reviews to dentist
- The patient writes feedback and reviews to the dentist.

Figure 4.13 below briefly shows what major activities are to be carried out by a patient and what the system automatically performs.

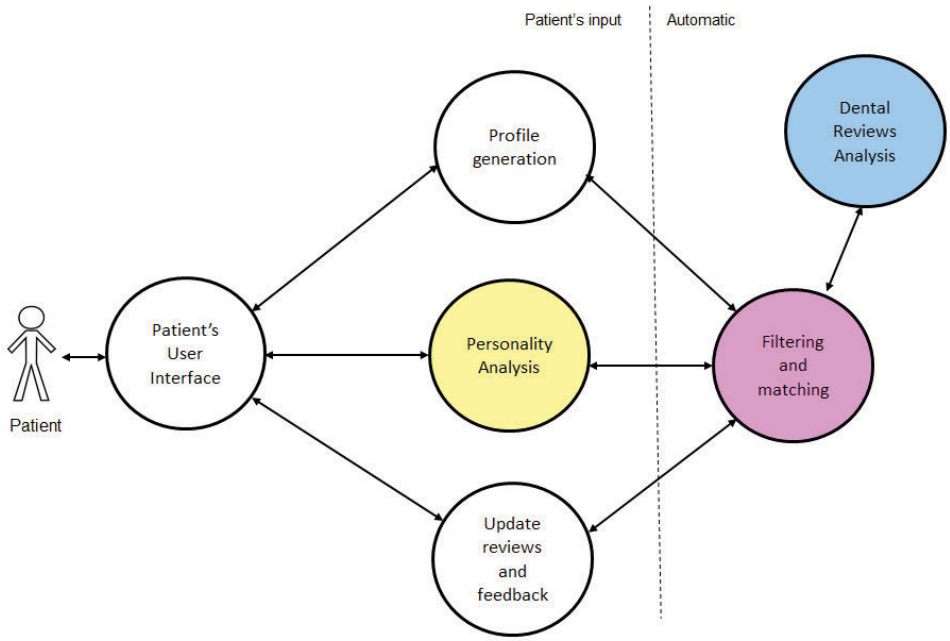


Figure 4.13: Major activities of trust-enhanced dental care recommendation system

Profile generation – all the users are considered as dental patients. They need to join the dental care social network by generating their profile with their basic demographic information and dental related information. When they visit the site and search for dentists, their profile is captured if they have not created their profile before. Objective criteria selected by the patients are combined with other details from the profile information to match the available dentists in the system. This process takes place when the patient searches for a dentist or before searching for a dentist in the system.

Personality analysis – since the major focus of this system is to match dentists based on the subjective characteristics of both patients and dentists, a personality test has been added to find out the type of personality traits of the user as a patient. In the future, it could be replaced by social network analysis to determine the type of patients based on the information available online. At this stage, the users are encouraged to take a personality test to find out their personality traits. In this study, the DISC personality test is used. This process takes place during the time the patient creates their profile.

Update reviews and feedback – patients are encouraged to provide feedback on the recommendations they get from the system. The system will also encourage patients to write reviews about their dentists after their visit to the dentist. The feedback will be automatically added into the system to update the specific dentists' qualities.

The recommendation system is the major functionality of the dental social network and it provides a suitable list of dentists to a patient. The major focus of this study is to find the most suitable dentist for a patient through the dental care social network based on their subjective qualities.

Dental reviews analysis – all the reviews and ratings available from third party dental crowdsources such as Yelp and DrOogle are analysed to classify dentists according to the dentists' respective qualities. The reviews and ratings gathered from 'the patients are also added into the system to update the dentists' qualities and this gives a dynamic nature to the recommendations.

Filtering and matching – once the patient's profile is generated, patients are able to search for a list of suitable dentists from the available list of dentists. The recommended list is provided by filtering the dentists based on the subjective dentists' qualities. Matching rules are discussed in detail in the next chapter.

Scenario:

A dental patient joins the dental care social network supplying a basic profile e.g. age, location, level of dental fear and email address. There is an option to take a 'personality test' for better matching to find a suitable dentist. It is not a mandatory step. Patients are able to view information posted by other patients and post their own experiences in terms of dental visits. They are able to request to become friends based on the information posted by other users in the network.

When they search for a dentist, the system allows for choosing a location, the type of dental treatments, insurance covers and the subjective characteristics of the patients such as level of fear, and personality traits.

A list of dentists is matched based on matching rules for the particular type of patient with age, location, personality, level of fear and other information gathered explicitly and implicitly from the network.

The patients are encouraged to provide short feedback on how useful the recommended list is. A few days later, they are reminded to write reviews about the dentist to provide 'post-visit feedback'. The feedback helps to make this recommendation system dynamic and efficient because the feedback instantly updates and classifies the patient's dentist.

These activities are also described with a sequence diagram in Figure 4.14 below:

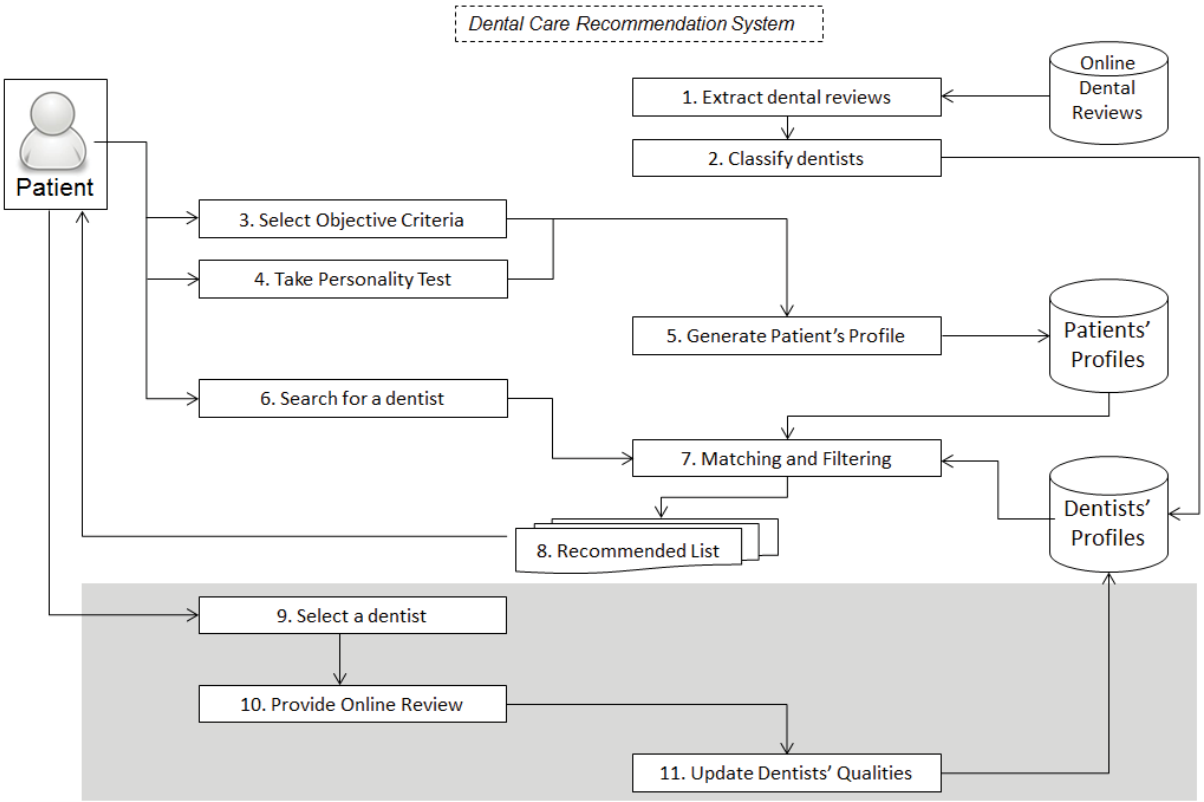


Figure 4.14: Sequence diagram of proposed dental care recommendation system.

When the patient clicks the search for a dentist button in step 6 in the figure above, the following actions are called:

i. Get a list of dentists based on basic search criteria, such as location, postcode and types of treatments.

ii. Then loop each dentist from the list from the above step, get the dentists' qualities from their reviews which has been pre-processed in the database, as described in Chapter 3.

iii. Get a list of dentists' 'qualities from the user's profile or preference. This list of qualities can be directly input from the user's search or can be converted from the DISC personality results.

iv. Compare dentists' qualities based on the the two lists that we have got from the above two steps. A list of the differences in the dentists' qualities between the user's profile and the dentist's profile, are prepared.

v. Sort the list of differences in the dentists' qualities and list the dentists in descending order (the dentist with the least difference first and so on). This is the recommended list of dentists.

It is programmed in C# to match a patient with a suitable dentist based on the dentists' qualities extracted from dental crowdsources. Basic codes used in the matching are shown below in Figure 4.15.

```
foreach ( string DentistName in listDentist.keys
{
        List<double> listDifference = new List<double>();
        foreach (string DentQual in listDentist(DentistName).keys)
        {
        //get difference
        listDifference.Add((double)Math.Abs(listInput[DentQual]– listDentist[DentistName][DentQual]))
        }
        //calculate standard deviation and add
        listCompare.Add(DentistName,Math.Sqrt(listDifference.Average(v => Math.Pow(v –
listDifference.Average(), 2))));
}

// sort descending order
foreach (KeyvlauePair<string,double> kv in listCompare:orderBy(i +> i.value))
{
        listOutput.Add(kv.key, kv.value);
}
Return listOutput;
```

Figure 4.15: Codes in C# for recommended list of dentists

The similarities between dental patients are examined from the type of personality traits and other objective and subjective criteria chosen by the patient. Later on, when patients negatively rate the dentist they visited, the patients' profile is also be stored. By using collaborative filtering methods, a group of users with similar ratings for a particular patient is created. Based on other patients' reactions to new dentists in the network, other patients may recommend the same dentist as well. This automatic process is enforced only after several dental patients as users have used the system.

The output is displayed as a list of dentists with their basic information such as dentists' name, aggregated stars, and number of reviews, with the most suitable dentist appearing first in the list along with the dentist's qualities. The basic prototype in the next section shows the input and output from the proposed model.

4.6. Basic Prototype for Demonstration Purpose

Some parts of trust-enhanced components are implemented in a prototype of the dental care recommendation system for demonstration purposes to illustrate how trust from subjective information can be integrated in existing recommendation systems. It highlights that the matching of dentists with patients based on their subjective characteristics is important for dental care recommendation systems. Dental patients are provided with a choice to determine their personality traits by either taking the personality test or choosing a combination of 4 behavioural traits; dominant (D), influencing (I), steady (S) and compliant (C). Dentists are also classified based on subjective qualities from dental crowdsources.

4.6.1. User Profiling

User profiling of patients and dentists are conducted with their subjective qualities in addition to their major objective criteria. For demonstration purposes, the profiling of patients and dentists are briefly discussed below. The next chapter explains the profiling of patients and dentists in detail.

4.6.1.1. Patients Profiling

Patients are profiled based on subjective characteristics derived from the DISC personality test. In the prototype, they can choose their personality by a sliding scale of 4 major characters (dominant, influencer, steady and compliant) as shown below. Alternatively, they can do the DISC personality test from the link provided. Once they get results from the test, they can scroll the scale accordingly. For example, if the result from the personality test shows 'DSC' the patient can scroll Dominant, Steady and Compliance scales to the right and this will show that the person belongs to the personality traits ascribed to the 'Achiever' as shown in the Figure 4.16 below.

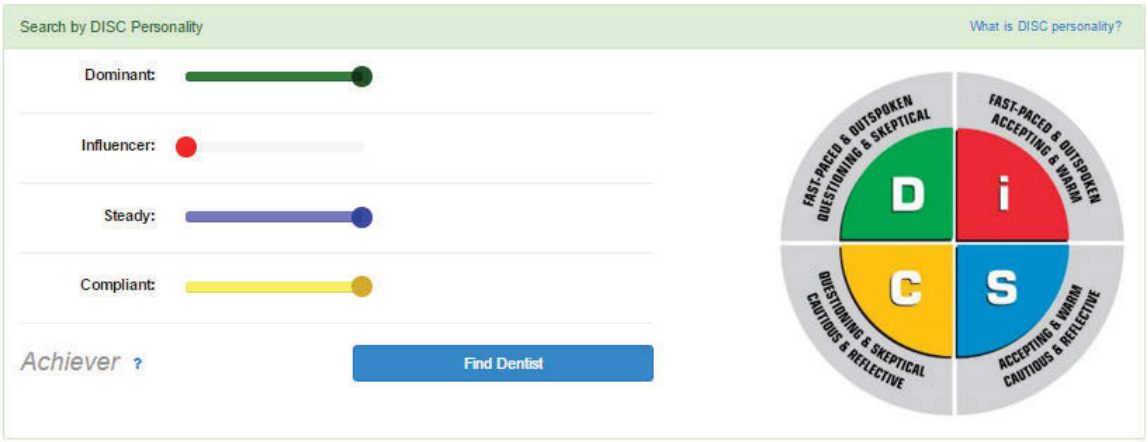


Figure 4.16: An example of personality trait for demonstration

In addition to the type of personality traits, other objective criteria and the level of dental fear for a specific dental treatment can be selected as shown in Figure 4.17 below. In this example, a male patient is looking for a dentist for extraction who has a low level of fear.

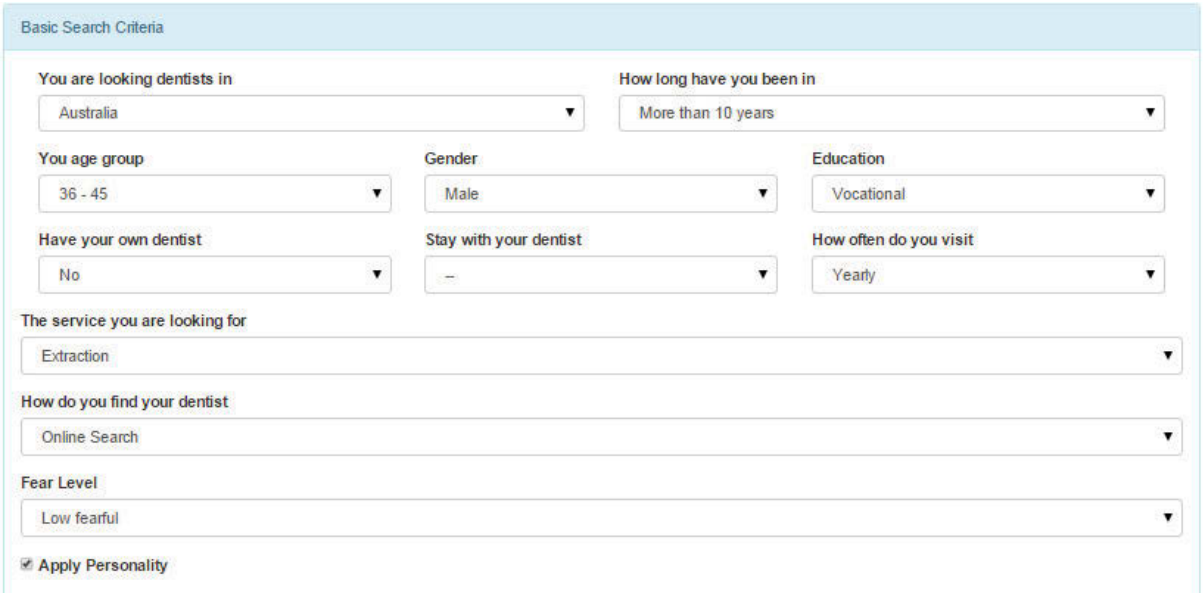


Figure 4.17: List of objective criteria to search for a dentist

4.6.1.2. Dentists Profiling

Dentists are profiled based on how their past dental patients have described them and rated them in online reviews sites. A description of dentists is produced based on the 10 dentists' qualities, defined in this study. This is shown below.

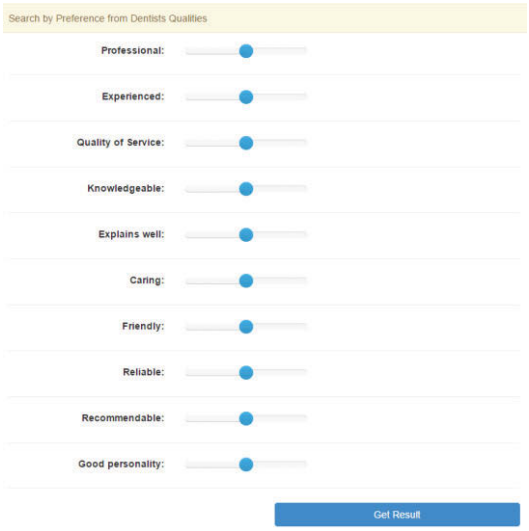


Figure 4.18: Dentists' qualities in the prototype

Dental patients are able to search dentists based on the list of the dentists' qualities as listed above. This is another choice where the patient has to search for their dentist through the means of the profile based on the dentists' qualities.

4.6.2. Matching Dentists and Patients' Profiles

Patients are matched with dentists based on subjective criteria derived from the dental crowdsources in this study. Patients are able to choose dentists' qualities and rank them to get a suitable match to a dentist from the list of dentists. Alternatively, for the best result, they are requested to do the personality test and create their profile, as discussed in the previous section. They will be matched based on the matching algorithm which has been constructed based on the results from the survey. This is discussed in detail in the next chapter.

Figure 4.19: Example of dentists' list as a recommendation.

Simple graphs with the dentists' qualities are displayed as shown in the right hand side of the figure above. Based on the dentists' qualities, and aggregated ratings, the recommended list is exhibited in

Figure 4.19 above. The number of reviews for each dentist is also published with a hyperlink to the actual reviews and the sources of reviews with the reviewer's respective ID's. An example is shown in the figure below.

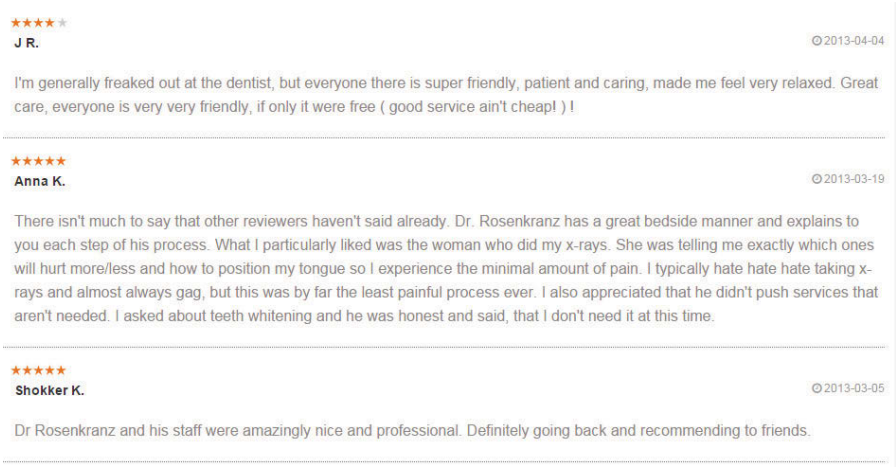


Figure 4.20: Sample of reviews

4.7. Summary

A trust-enhanced model for dental care recommendation systems is proposed by addressing information related to trust from the social networks. Subjective information has a significant impact in regard to recommending a dentist to a patient. This factor has not been investigated for dental care recommendation systems. In this chapter, trust components related to dentists and dental care recommendation systems are evaluated from multiple perspectives. Both the objective and subjective types of information used in dental care recommendation systems carry some level of trust. However, subjective information determined by the personality of patients and dentists is focused on in this study.

Trust is mainly looked at from the first 3 viewpoints of ODP methodology e.g. the Enterprise level, Information level and Computational level when proposing a trust model for dental care recommendation systems. Trust components are identified and then evaluated from multiple perspectives for both patients and dentists. Different types of trust are amalgamated into 4 major trust components; context, relationship, reputation and personality analyses. A Trust model incorporating all four trust components is proposed to improve the quality and effectiveness of the recommendations of dentists to patients. Trust from both objective and subjective criteria serves to improve the outcome from the recommendation systems.

4.7.1. Related work

The concept of trust has been introduced to recommendation systems to improve its effectiveness. Owing to the invasive nature of dental treatment, trust is also identified as a critical factor in dental care when choosing the best dentist. Trust-based recommendation systems are able to refine information by utilising personalised profile-based trust within the social networks. The growing popularity in social networks and research on trust within social networks have been the main reasons for the increase in trust-based recommendation systems (Kim & Phalak 2012).

With the growing use of social media, there is a great potential to extract relevant information to profile users in health. Recently, Waylen et al. (2015) conducted a pilot study for patient-clinician communication in a dental setting at Bristol Hospital, UK, such a set up can be used for profiling dental patients in the future. The intention of measuring implicit information is to recognise the psychological attributes of people such as their attitudes, behaviour, self-esteem and perception (Gawronski & De Houwer 2014). Several researchers have attempted to capture implicit information from social networks to personalise and improve social recommender systems (Ma et al. 2011, Zhou et al. 2012). Fang et al. (2015) added distrust to improve accuracy in recommendation systems.

All these trust-based models for recommendation systems were explored for recommending items and were not about health related items. For health, trust is investigated vigorously due to privacy concerns. In the health sector, the most related work had been done by Kim (2014) and this concerns trust in health websites such as dental care recommendation systems. In this work, individual difference factors, website-related factors and consumer to website interaction related factors have been discussed. The perceived quality of information has been admitted as the most influential factor in trusting websites. Perception is dependent on personal characteristics of the user and therefore the personality of dental patients has been given priority in this study.

4.7.2. Assumptions and Limitations

In the proposed model for dental care recommendation systems, there are several limitations which are outlined below:

- It is assumed that all dental patients will create their own profile to search for a dentist for better recommendation as an output. They will also take a personality test to determine their personality traits.
- A personality test which is generally used to test group dynamics in organisations has been used to profile patients in the context of dental treatments and the trust relationship with dentists.
- Dentists are classified as per the dentists' qualities extracted from multiple dental crowdsources. This may be restricted and it is dependent on the business rules of each organisation.
- Not all dentists in any location have been reviewed by their patients. The proposed model assumes that every dentist has been classified as per the dentists' qualities. In fact, dentists with less than 10 reviews are discarded.
- Some of the dentists' qualities have similar meanings. Such as 'knowledgeable' and 'explains well'. Synonyms used for these qualities are difficult to choose and may not make much difference.
- Matching between patients and dentists is done based on results from the survey conducted in the beginning. Once patients start to review on this system, the dentists' profiles are updated.
- There is not enough data to measure the strength of relationships between users in the Yelp websites. Hence relationship analysis has not been conducted for this study.
- 4 major trust components are evaluated in the proposed model. There are other components which also impact the trust between patients and dentists.
- Trust within dental patients as users of the network is evaluated within the network. Users also need to explicitly show the link and strength of relationships between them in the network.

- There are limitations on the number of attributes which may be considered for context analysis. It is virtually impossible to include detailed information about the practice and the situation.
- Subjective criteria are difficult to measure and quantify. For example, the level of satisfaction perceived by two different users will be different for the same service provided by the same dentist.

4.7.3. Open Issues

Measuring subjective information implicitly from interactions and activities in OSNs is a challenging task. This kind of skill is colloquially spoken of as 'reading between lines'. In this study, subjective information aligns with trust components and the dentists' qualities are determined from online dental reviews. This is what is used to profile dentists. However, patients' conversations about dentists are not that common in online social networks. There is not much data available to profile patients based on information available online. Hence, the personality test is used to classify patients.

Profiling of both patients and dentists is discussed with results in the next chapter.

Accepted papers from this chapter:

Pradhan, S. and Gay, V. (2013) "Towards a New Trust Model for Health Social Networks" The 8th international conference on Internet and Web applications and services (ICIW) IARIA Conference, Rome, Italy, June 23-28, **ISBN:** 978-1-61208-280-6

Pradhan, S. and Gay, V. (2014) "Introducing patient and dentist profiling and crowdsourcing to improve trust in dental care recommendation systems", The 8th IFIP WG 11.11 International Conference on Trust Management VIII (IFIPTM 2014), Singapore, 7-10 July 2014, pp. 221-228.

Pradhan, S., Gay, V and Nepal, S. (2014) "Improving dental care recommendation systems using trust and social networks", The IEEE International conference on communications (ICC 2014), Sydney, Australia, 10-14 June 2014 pp.4264-4269. DOI: 10.1109/ICC.2014.6883990.

Pradhan, S., Gay, V and Nepal, S. (2016) "An innovative approach to the use of trust derived from social media to improve matching in dental care recommendation systems" The 20th Pacific Asia Conference on Information Systems (PACIS 2016), Chiayi, Taiwan.

Chapter 5

5. Profiling and Matching of Patients and Dentists by using Subjective Criteria

This is the other contribution chapter where the proposed model for dental care recommendation systems from the previous chapter is analysed by exploring possible research methods. The trust components from the model are investigated to improve the matching process of dental care recommendation systems.

Profiling of major stakeholders such as patients and dentists is crucial for dental care recommendation systems. Trust related information from multiple perspectives is examined for inclusion in the profiles so that that the suitability between patients and dentists can be improved in the recommendations. The quality of recommendations provided by the system is directly dependent upon the quality of information entered in the profiling. This concept is also reinforced by the popular phrase 'garbage in and garbage out'. This chapter introduces a novel approach for the most suitable matching of dentists by identifying important criteria for both patients and dentists through dental care recommendation systems. The importance of subjective criteria to improve the suitability of the best match between patients and dentists is first discussed. The proposed trust-enhanced information model is then revisited to show how the subjective qualities of both patients and dentists are incorporated in their profiles for dental care recommendation systems. It focuses not only on the subjective characteristics of dentists but also clearly identifies the necessity to evaluate the subjective characteristics of patients. Subjective criteria are included in the profiling of patients and dentists to improve the trust in the recommendations provided. Dentists are profiled from the dental crowdsources while patients are profiled by combining their selection criteria for dental treatments and personality traits.

Based on the web content mining and the main survey conducted in this study, the subjective criteria for both patients and dentists are analysed and incorporated in their profiles. Trust is evaluated from the patients' preferred criteria, preferred methods to find dentists, preferred dentists' qualities, etc. In the final section, two different matching algorithms for dental care recommendation systems are evaluated for the different types of dental patients participating in the survey. Matching rules are deduced by examining the results from the survey. The results are discussed throughout this chapter.

5.1. Preferred criteria in dental care

Dental patients are matched with dentists based on certain criteria chosen by patients. As discussed in Chapter 2, the criteria provided by the existing dental care recommendation systems are insufficient and inconsistent for the purposes of finding the most suitable dentists. Therefore, a dental care preference criteria survey was conducted at the beginning of this study to examine which criteria was preferred by the patients. The preferred criteria by the patients was considered in terms of the trust factors for choosing a dentist from the dental care recommendation systems. A list of criteria which encompasses the criteria required and preferred by patients when choosing a dentist, was prepared. The main results on the preferred criteria when the participants were choosing or recommending a dentist are exhibited in the next sub-section.

183 participants completed the survey from different countries in the world, predominately (133) from Australia and 15 other countries. All participants were by default assumed to be dental patients. From the survey, along with other information about dental treatments, the most preferred criteria for patients when choosing a dentist or dental practice were analysed.

5.1.1. Results from the preference criteria survey

From the list of criteria provided in the survey, the participants ranked quality, service and reliability as the most important criteria when choosing a dentist.

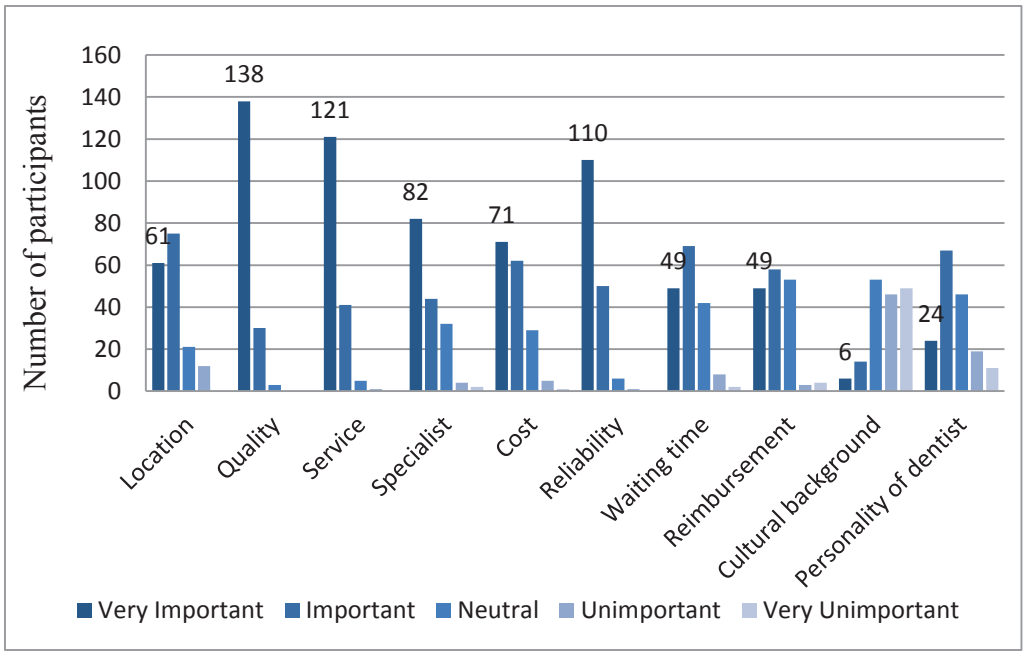


Figure 5.1: Preferred criteria to choose a dentist

Other criteria such as specialised skill, cost, location, reimbursement and waiting time were also ranked as very important or important as shown in Figure 5.1 above. The least preferred criteria were 'Cultural background' and 'Personality of dentist'. As shown in the bar chart from the figure above, the three most important criteria (quality, service and reliability) selected by the participants were all of a subjective nature.

The subjective qualities of dentists are further explored in this study to improve the matching process and the quality of recommendations provided to dental patients. The preferred criteria vary with different types of participants as they have their own subjective characteristics and this phenomenon has led to another research question about the subjective qualities of participants in order to profile them accordingly.

The subjective characteristic of both patients and dentists alters the choice of preferred criteria in determining the most suitable dentist. Hence the proposed trust-enhanced information model for dental care recommendation systems is re-visited in the next section to examine how the subjective criteria is included in their profiles.

5.2. Proposed model and profiling for dental care recommendation systems

The proposed trust-enhanced information model for dental care recommendation systems in Chapter 4 implies that patients choose their dentists based on multiple trust components. The model also reinforces the importance of subjective information to improve the suitability of dentists. The trust components are investigated through the objective and subjective criteria chosen by dental patients in the process of filtering the most suitable dentist, as shown in Figure 5.2 below.

Dentists and patients are two major stakeholders that need to be profiled for dental care recommendation systems. Information related to specific dental treatments is fundamental to profiling patients and dentists. For example, the type of dental treatments and the speciality of the dentist is the most related information for patients in dental care recommendation systems. However, other related information such as location, cost, insurance, availability, and the number of years of experience are important to help the matching process in the system. In this chapter, we discuss important information related to dental treatments that can be retrieved from dental crowdsources and other social networks as well as the information which is important but challenging to retrieve.

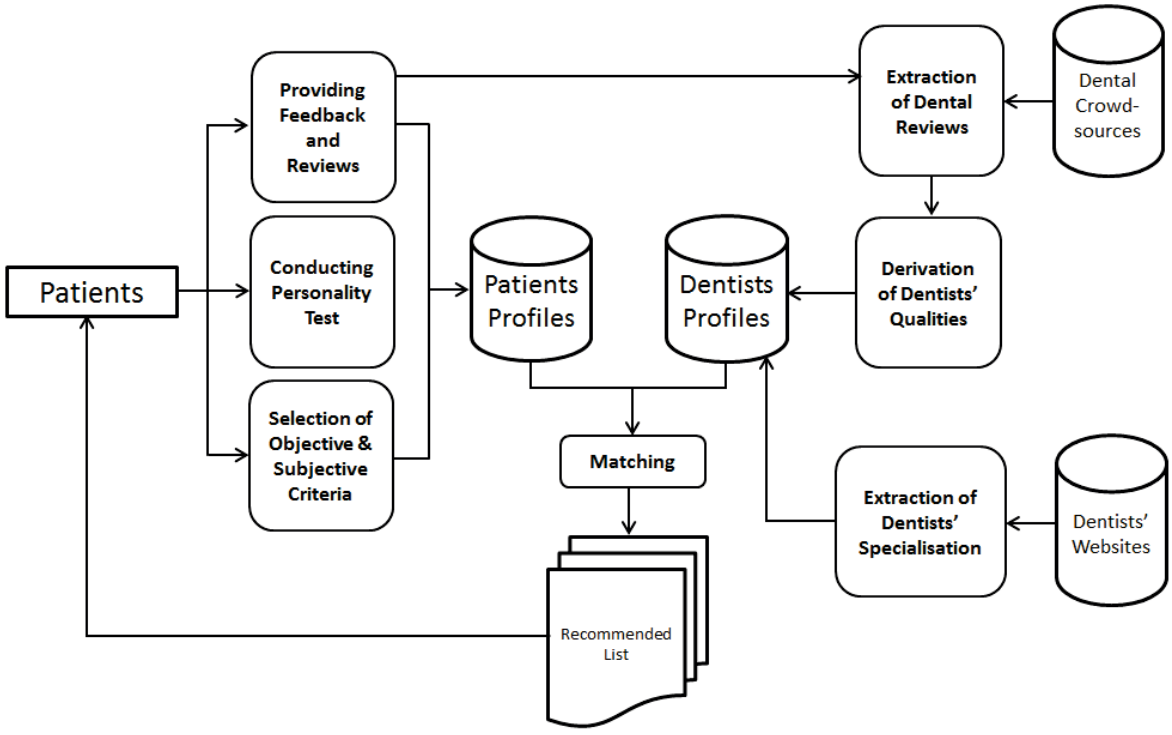


Figure 5.2: Overview of Dental Care Recommendation System

Based on the profiles of both patients and dentists, the matching process is carried out to recommend the most suitable dentist to a particular patient. The aim of this study is to improve the quality of recommendations by including the subjective qualities of both patients and dentists in addition to general objective criteria used in traditional dental recommendation sites. The patients select their

objective and subjective criteria while searching for the most suitable dentist. Figure 5.2 above shows an overview of how the recommendation system matches patients with suitable dentists.

The left hand side of the figure above illustrates the process undertaken by patients in searching for a dentist through the dental care recommendation systems. Patients' profiles get created based on the selected criteria when searching for a suitable dentist. In order to capture the subjective qualities of dental patients, however, this study uses the subjective information of their personality traits by allowing them to take a personality test separately. It is anticipated that the information gathered from the way the patients review dentists after their visits will also be included in profiling patients in the future. The patients are profiled based on the information provided (such as age-group, location, type of dental treatments, type of insurance cover, and so on) and subjective information such as personality traits from personality tests and level of dental fear since implicit information from the social networks is not available.

The top right hand side of Figure 5.2 illustrates that dentists' information from dental crowdsources (such as online dental reviews and rating sites) is extracted and analysed to profile dentists. In these sites, patients are expressing their views about dentists and evaluating them by giving star-ratings to certain criteria based on their satisfaction level after dental visits. Most of the reviews written by patients describe dentists subjectively. Therefore, dentists are profiled based on the words used by their patients to describe them. In this study, dental crowdsources like DrOogle and Yelp are taken as sources of reviews for dentists, as shown in Chapter 2 and 3. The dental reviews are extracted and analysed to determine the dentists' qualities and they are used to create the dentists' profiles. Dental reviews provided by patients as users of this system are also updated in the system to dynamically change the dentists' profiles.

The profiling of patients and dentists is the core process of dental care recommendation systems. Existing dental care recommendation systems do not record patients' profiles, but allow them to search dentists based on different objective criteria. In this study, we propose to store patients' profiles in databases (as shown in the above figure) to improve the quality of recommendations so that patients can be profiled in terms of their subjective qualities by analysing implicit information. Based on the study's matching rules, patients are provided with a list of recommended of dentists. The patients are then encouraged to provide feedback on the recommendation system and write reviews of dentists after their dental visits/treatments to make the system dynamic.

With the growing trend of using online methods, online recommendations for dentists have gradually become acceptable. The integration of trust components into recommendation systems is therefore proposed to find the most suitable dentist. The following section details the profiling of patients and dentists by including trust variables in order to improve the matching process and thereby the quality of recommendations provided by the dental care recommendation systems.

5.3. User profiling in dental care recommendation systems

User profiles should contain both explicit and implicit information about the user such as the users' background, interests, knowledge, goals, characteristics, behaviour, context and interactions (Schiaffino & Amandi 2009). In this study, patients and dentists are profiled based on objective and subjective information which are associated with trust components as highlighted in the previous chapter.

In the proposed trust-enhanced information model for dental care recommendation systems, besides the objective criteria chosen by patients (such as dental conditions or symptoms, type of dental treatments, age, speciality of dentist, cost, availability, etc.), a variety of subjective information is emphasised while profiling. Subjective information includes the characteristics, attitudes, perception and behaviour of patients and dentists. For patients, such subjective information is obtained from social networks by collecting and analysing information from their interactions with other users. Specific dental knowledge and skills also add distinct characteristics to the patient's profile. Combining their subjective qualities with objective preferences creates customised patient profiles for the dental care recommendation systems.

There are two major challenges raised in terms of collecting information from social networks to profile patients. The first one is the privacy policies implemented across the web, which restrict the ability to accurately gather enough information about users to profile patients. The second challenge is due to the anonymous nature of user IDs in the online world. These rules have resulted in restrictions particularly in relation to gathering data from patients as the public users in the social networks. Features of social networks such as the ability to create more anonymous identifications on social networks can reduce the possibility of the impact of trust components in dental care recommendation systems. Keeping the importance of subjective qualities in mind and understanding the constraints outlined above, personality traits of patients are used to profile patients in this study.

The processes and results are discussed in the following sub-sections.

5.3.1. Profiling of patients

Patients' profiles have rarely been recorded by existing dental care recommendation systems except through cookies, which are temporary. In this study, a trust-enhanced information model is proposed based on the extensive nature of analysis in profiling both patients and dentists to enhance the efficiency of matching between patients and dentists. Patients are examined carefully from both explicit and implicit information. They are profiled not only on explicit objective criteria but also implicit information such as subjective qualities. The reason for this is that although a dentist may use exactly

the same treatment procedure and manner on two different types of patients, the service is generally perceived differently by the two patients. Therefore, it is important to profile types of patients from subjective aspects. For example, when a dentist is described as a caring dentist by one type of patient, he/she may not be perceived the same way by another type of patient.

As per the proposed trust-enhanced information model, patients can be profiled based on individual personality and their subjective characteristics, the situations they are in (context), the type of relationship with previous patients of the same dentist, word of mouth (WoM) referrals from other patients and the perceived reputation from previous posts shared in the network. Subjective information is associated with all 4 types of trust components proposed in the model. Most of these trust components are interdependent of each other. For example, situational variables (context analysis) of reviews can be analysed if there is enough information provided in the reviews so that profiling for patients can be even more accurate. Existing review sites do not have provisions to provide any situational information from patients and therefore cannot be used to profile patients. Specific questions about condition, symptoms and other information such as how long it has been uncomfortable for patients or details about other previous treatments or medications, avoided medications, etc. can help to make clear the situation of patients so that profiling can be enhanced. Another important component is relationship analysis, which is based on the strength of relationships between patients (one being the trustor as a new patient and the other being the trustee as an existing patient to the same dentist) or between patients and dentists. Trust derived from the strength of relationships can influence recommendations significantly.

Profiling users from online social networks has been gaining popularity. However, there is not enough information about dental specific posts or information online to be able to profile dental patients. It is anticipated that more subjective information on dental patients from other social networks such as Facebook, Twitter, Google+, Pinterest, Tumblr, etc. will be possible in the future, which will provide abundant implicit information to profile patients more accurately. Implicit information derived from social networks is useful to profile social networkers but the privacy and identification challenges deter the capability.

Due to the constraints mentioned above in social networks, this study focuses on the integration of subjective information such as level of dental fear and personality traits while profiling patients. Personality traits are combined with a number of other objective and subjective criteria to classify types of patients to create matching rules in this study.

5.3.1.1. Types of personality traits

Based on the results from the personality tests, the dental patients are classified into specific type of patients. As mentioned in Chapter 2, the DISC personality test is used to profile patients in this study. There are 15 possible combinations from 4 different distinct types of personalities (D, I, S and C) as per the DISC Classic of the DISC personality test.

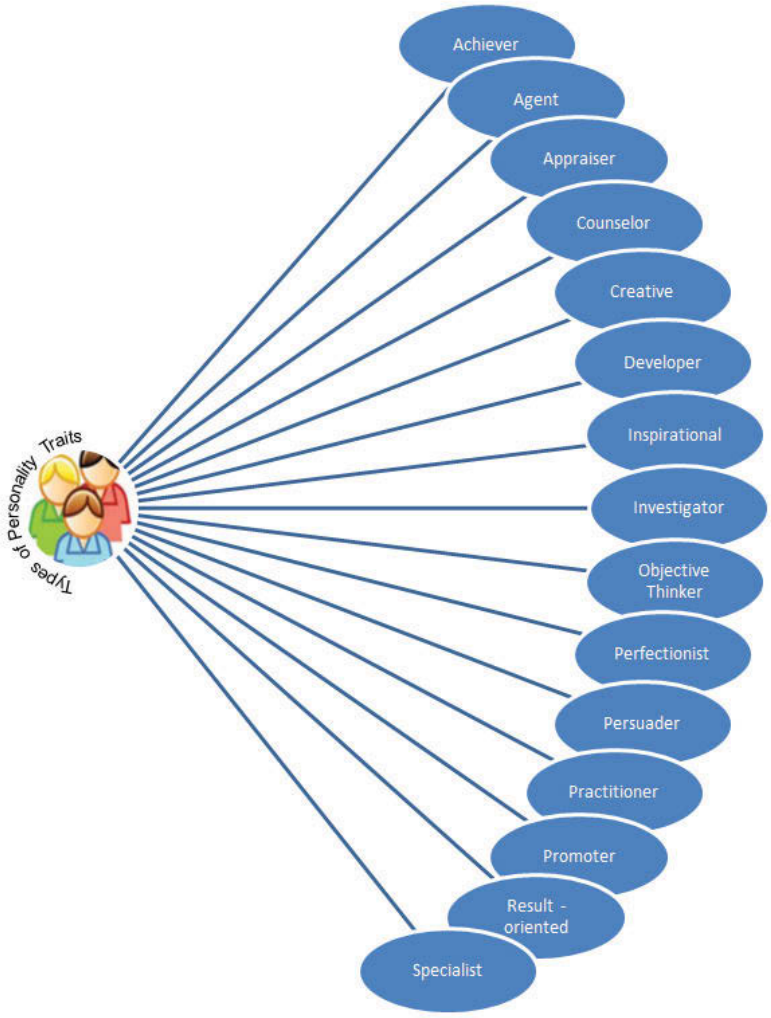


Figure 5.3: Types of personality traits from DISC Personality test

15 types of personalities, as mentioned above, are also listed in Table 5.1 below with their indicative combination of D, I, S and C from Classic 2.0 (Discprofile.com 2014).

In order to determine the type of personality traits, there are a number of questions to be answered. The DISC Classic follows a structured way to create one of the 15 profiles by asking people to answer 28 multiple choices questions on paper designed by the company called Inscape Publishing. While answering these questions participants need to choose 'most likely' and 'least likely', which then counts the number of D, I, S or C for both the most and least likelihood. A graph is plotted for the number of DISC in both the most and least likelihood as well as the difference between the most and least. From

the graph of the difference between most and least, a '4 digit' number is calculated and referred to the number in the list to determine one of the personality traits as shown in the table below.

Table 5.1: Combination of DISC to classify patients

No. of letter	Types of Personality traits						No. of personality traits
1	D Developer	I Promoter	S Specialist	C Objective Thinker			4
2	DC Creative	IC Appraiser	SI Counselor	CS Perfectionist	SD Achiever	DI Inspirational	6
3	SCD Investigator	CIS Practitioner	ISD Agent	DIC Result oriented			4
4	DISC Persuader						1
	Total number of types of personality traits						15

In this study, the participants in the online survey were given 12 questions from the DISC personality test site. After answering those 12 questions, the site generated one of the combinations shown in the table above. DISC Classic 2.0 has listed descriptions of personality traits with various possible combinations discussed and shown in Table 5.1.

A patient's profile for dental care usually describes the type of dental treatments he/she is looking for, their age-group, dental or medical history, symptoms, dental fear, cultural background, occupation, dental habits, etc. Moreover, patients are profiled based on the type of personality traits they have exhibited in addition to the usual objective and subjective criteria (such as location, gender, age group, level of fear, and so on) to improve the compatibility of dentists to patients.

5.3.1.2. Profiling dental patients with personality traits

In this study, personality traits are taken as major contributing factors which are closely associated with subjective characteristics of dental patients in terms of their attitude, behaviour and perception. Figure 5.4 below shows how patients' profiles are created by combining objective and subjective criteria plus

personality traits from the personality test. When a patient searches for a dentist, they first enter objective criteria such as location, types of dental treatments etc. They may also be prompted to add more subjective information such as level of dental fear. Objective criteria and subjective qualities of the patient are stored in the patients' profiles. Subjective quality is also further investigated by allowing patients to take the personality test separately. The results from the personality test are then combined with the objective and subjective information of the patient to construct a patient profile. The profile is then used to match the patient with a suitable dentist in the proposed model for recommendation systems.

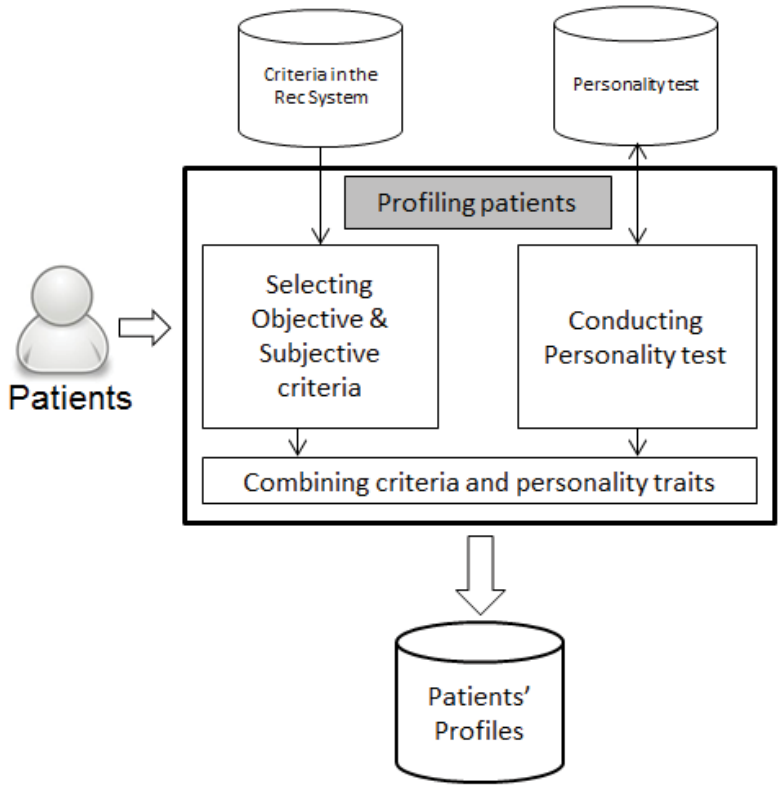


Figure 5.4: Process to create patients' profiles

The process outlined in Figure 5.4 was used to create dental patients' profiles in this study. In the second online survey, the participants were requested to answer 12 questions from the standard DISC personality test (available from Discpersonalitytesting.com). Answers to those questions were manually entered into the DISC personality test site to generate one of the personality traits shown in Table 5.1. The specific type of personality trait is used to profile patients with other information provided by the patient (such as age, type of dental treatments and level of dental fear).

5.3.1.3. Results of patients' profiles

In the survey, the participants were also asked to choose one of the personality traits from the list of 15 different personality traits from Figure 5.3. This was in addition to the DISC personality test questions. Instruction was given to choose one of the personality traits by providing a bit more information for each personality trait. Out of the total 580 participants, 3 did not continue with the additional 12 questionnaires and hence were removed from the list. Table 5.2 below shows the number of participants for each personality trait resulting from the personality test as well as those chosen by the participants themselves.

Table 5.2: Number of participants with specific personality traits

S. No.	Personality Traits	From Personality Test	Chosen by participants	Correctly identified personality traits
1	*Achiever*	**126**	85	17
2	*Agent*	34	66	4
3	*Appraiser*	9	60	1
4	*Counselor*	11	59	2
5	*Creative*	**79**	25	3
6	*Developer*	1	23	0
7	*Inspirational*	12	17	0
8	*Investigator*	**78**	29	5
9	*Objective Thinker*	**50**	44	5
10	*Perfectionist*	**137**	39	12
11	*Persuader*	16	8	0
12	*Practitioner*	13	57	3
13	*Promoter*	0	10	0
14	*Result-oriented*	8	6	0
15	*Specialist*	3	49	0
	TOTAL	577	577	52

There is a significant discrepancy between the number of participants for each personality trait resulting from the DISC personality test and chosen by participants, as shown in the table above. Only less than 10% (52 out of 577) were able to identify their personality traits correctly. Generally how people perceive themselves is different to what they actually are, as per the results shown above. For example, the first row in the table above shows that 85 out of 577 chose to describe themselves as 'Achievers' but the personality test resulted in 126 of them being classified as 'Achievers'. 17 of them were successful in identifying themselves as 'Achievers'. However, 66 of all participants described themselves as 'Agent' but only 34 out of 577were truly 'Agent' as per the DISC personality test in the second row. Only 4 correctly identified that they have 'Agent' personality traits. Similarly, 10 of the

participants chose to describe themselves as ‘Promoters’, but according to the personality test, none of the participants were ‘Promoters’.

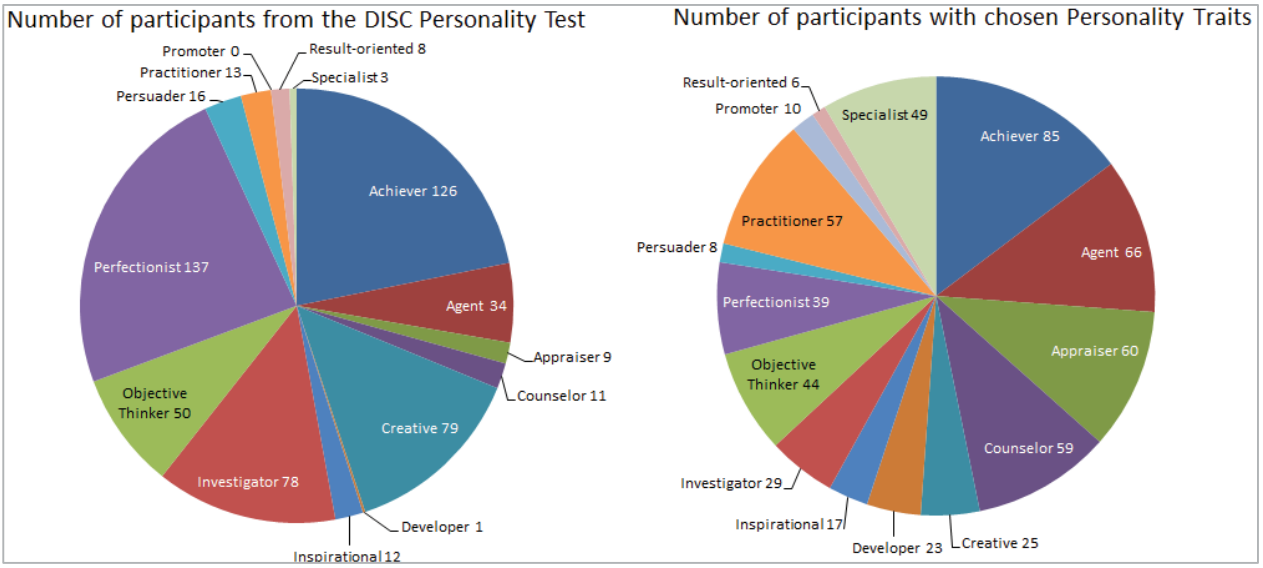


Figure 5.5: Number of participants from Personality Test and self-selected personality traits

For the purpose of this study to derive matching rules, the top 5 types of personality traits with a greater number of participants are chosen for further analysis and are highlighted in the table above. Figure 5.5 above shows the number of participants for each personality trait from the personality test and those self-nominated traits from the survey respectively.

Table 5.3: Variance between self-nominated and test resulted personality traits

Personality Traits (Self vs Test)	Achiever	Agent	Appraiser	Counsellor	Creative	Developer	Inspirational	Investigator	Objective Thinker	Perfectionist	Persuader	Practitioner	Promoter	Result-oriented	Specialist	Total
Achiever	17	12	13	12	7	1	5	12	5	8	2	15	4	2	11	**126**
Agent	5	4	3	8	2	0	1	2	1	1	0	5	0	0	2	**34**
Appraiser	4	2	1	2	0	0	0	0	0	0	0	0	0	0	0	**9**
Counsellor	2	0	2	2	0	0	0	0	1	1	0	0	2	0	1	**11**
Creative	18	4	8	4	3	7	2	6	9	9	1	5	1	0	2	**79**
Developer	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	**1**
Inspirational	2	2	2	1	2	0	0	0	0	0	0	1	0	0	2	**12**
Investigator	8	11	12	7	1	2	2	5	5	2	2	10	0	0	11	**78**
Objective Thinker	7	6	4	4	1	4	1	0	5	5	1	4	0	3	5	**50**
Perfectionist	13	20	11	18	6	6	5	3	15	12	1	12	1	0	14	**137**
Persuader	6	1	1	0	0	1	1	0	2	1	0	1	1	0	1	**16**
Practitioner	1	2	1	0	1	1	0	1	1	0	1	3	0	1	0	**13**
Result-oriented	2	2	2	0	2	0	0	0	0	0	0	0	0	0	0	**8**
Specialist	0	0	0	1	0	1	0	0	0	0	0	0	1	0	0	**3**
Total	**85**	**66**	**60**	**59**	**25**	**23**	**17**	**29**	**44**	**39**	**8**	**57**	**10**	**6**	**49**	**577**

Table 5.3 above shows the variances between the distribution of personality traits between the self-chosen by the participants and those from the personality test. Self-chosen personality traits are represented by vertical rows and the traits from the personality tests are shown horizontally in the table.

The following graph also shows how the profile varies between the self-chosen trait and the results of the personality test.
(Test = the results from the personality test and Self = the self-chosen personality traits)

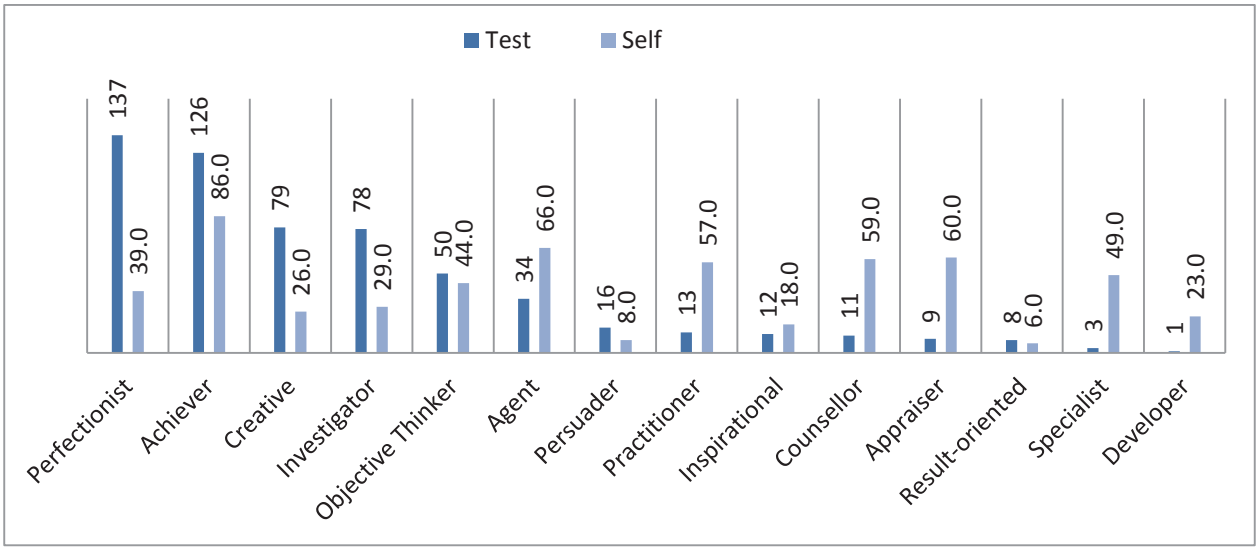


Figure 5.6: Variance in number of participants from Personality test vs self-selected personality traits

- **Major participants in the online survey**

Personality traits identified from the personality test are regarded as better methods to classify participants rather than self-chosen traits. Hence, we have chosen the traits based on the personality test. The distribution of participants in each category of personality traits is wide and some numbers are significantly low. Therefore, we have carried out further analysis in this study only for those participants who belong to personality traits which have 50 or more in terms of the number of participants from the total participants above; they are *Achiever* (126), *Creative* (79), *Investigator* (78), *Objective thinker* (50) and *Perfectionist* (137). The graph below shows the number of participants in these 5 types of personality traits.

In the survey, participants from these 5 personality traits represent 81.5% (470) of the total (577) participants derived from the personality test. When the number of participants is lower, it is difficult to interpret the result and they can produce biased results. Hence, dental patients in each of the personality traits with less than 50 participants are not taken into consideration for analysing matching rules in this study.

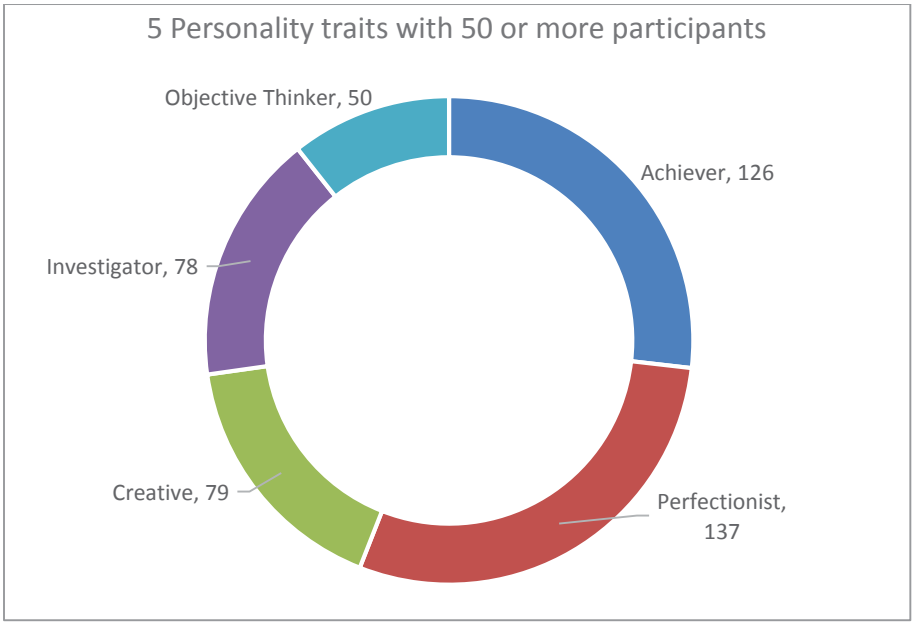


Figure 5.7: Major participants of the survey from the personality test

Participants (as dental patients) from the major 5 personality traits are profiled by combining other variables that they have chosen to search for dentists (such as age-group, types of treatments, level of dental fear, frequencies of dental visits etc.). Thus, the dental patients from the survey are classified by combining personality traits with other information such as their respective age-group. The graph in Figure 5.8 shows that participants predominantly came from age groups of 36-45, 46-55 and 56-65.

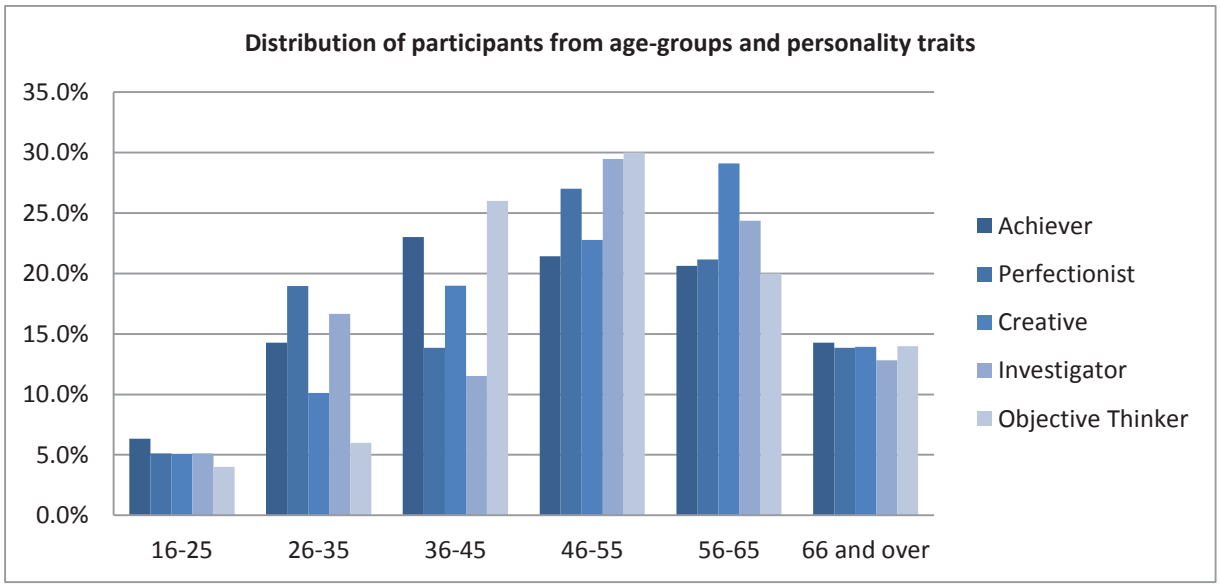


Figure 5.8: Age groups of the 5 major participants

Participants from the major 5 personality traits are further analysed from the survey data. Some of the information used to classify patients is shown below:

- demographic information (gender, level of education, and so on)

- level of dental fear
- types of dental treatments (scaling, dental fillings, root canal etc.)
- dental behaviour (frequency of dental visits, whether they have their own regular dentist, the number of times they have changed their dentist in the last 10 years)

Similarly, participants from the major personality traits are also categorised according to their level of dental fear as shown below in Table 5.4 and Figure 5.9. The majority of participants (41%) stated that they have a low level of fear in relation to seeing a dentist. 36% (172 out of 470) of the participants pointed out that they are either fearful or highly fearful of visiting their dentist. When the level of dental fear is investigated for each personality trait, participants who belong to the 'Perfectionist' personality trait seem to be more fearful than those with other personality traits from Figure 5.9 below.

Table 5.4: Distribution of participants with different level of dental fear

Personality Traits	Low fearful	Moderately fearful	Fearful	Highly fearful	Total
Achiever	53	26	38	9	126
Perfectionist	48	26	51	12	137
Creative	37	23	15	4	79
Investigator	33	17	21	7	78
Objective Thinker	23	12	13	2	50
Total	194	104	138	34	470
	41%	22%	29%	7%	100%

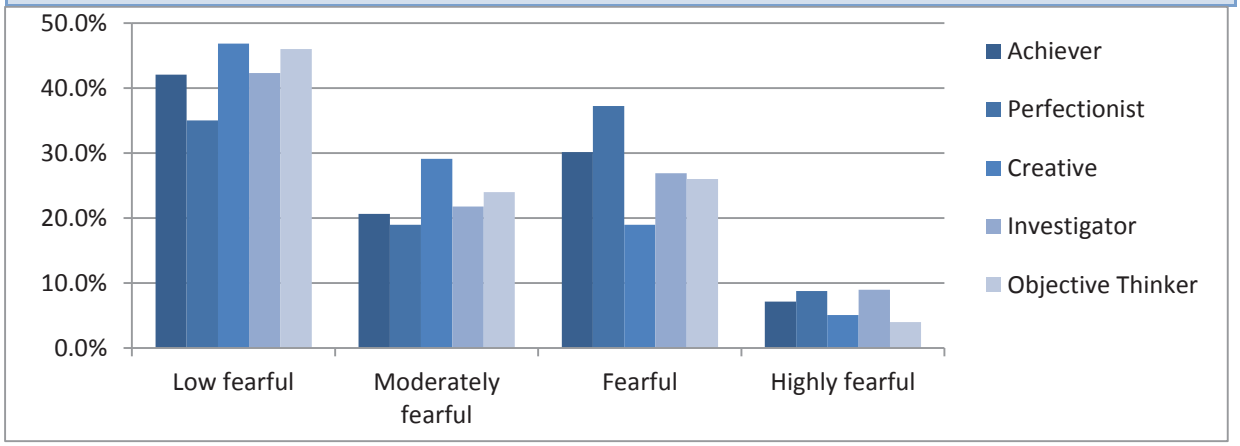


Figure 5.9: Level of dental fear from the 5 major participants

Thus, dental patients are classified and profiled in this study to derive matching rules. Both objective and subjective criteria are incorporated to profile dental patients.

5.3.2. Profiling of dentists

Dentists are usually classified based on their degrees and qualifications for their speciality in dentistry, the price they charge and the number of years of experience in their profession, or in working for a particular hospital. But in this study, dentists are profiled based on subjective qualities extracted from dental social networks as discussed in the previous chapter. Because patients care about which hospital dentists practice from, where they graduated, how their previous patients feel about them, their ability to explain dental procedures and many other factors, these types of information are discussed in reviews that patients write after visiting their dentists. Therefore, online dental review sites are explored to see how patients see and describe a particular dentist. This section discusses the analysis of dental reviews to profile dentists.

From a subjective prospective, terminologies used by patients to describe their dentists subjectively are referred as dentist's qualities in this study. Figure 5.10 below shows two major processes to derive the subjective qualities of dentists: extraction of dental reviews by crawling from popular dental crowdsources in the US and analysis of the reviews to assign dentists' qualities to profile dentists..

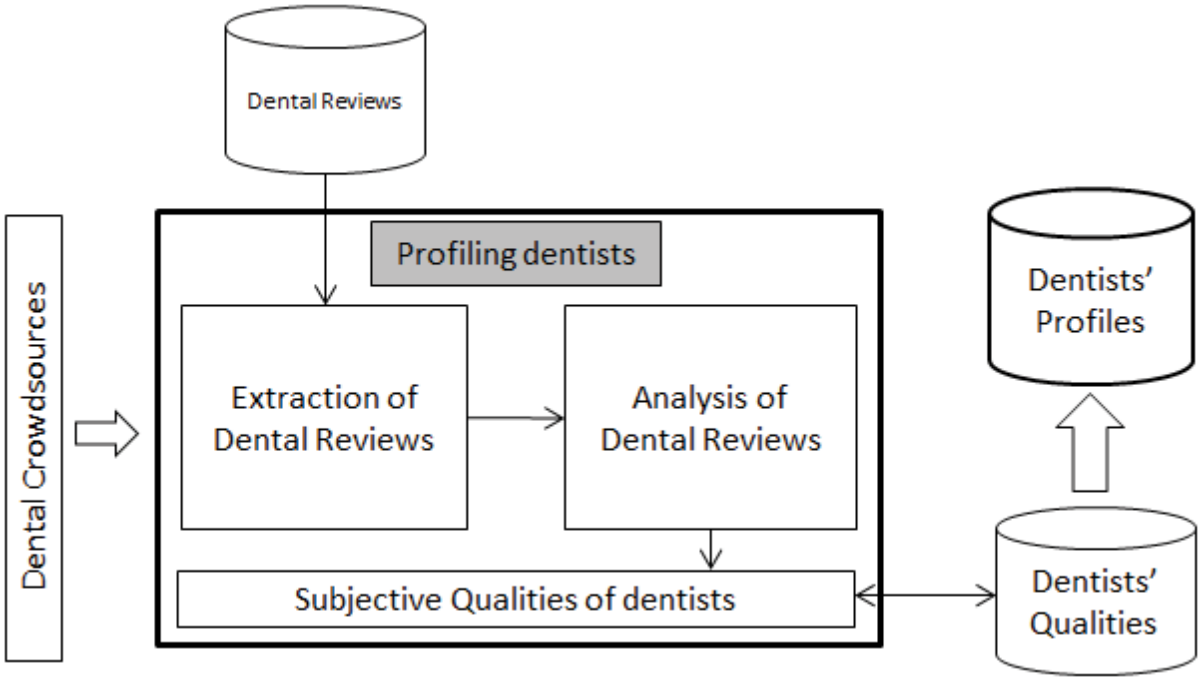


Figure 5.10: Process to create dentists' profiles

5.3.2.1. Extraction of dental reviews

As the users are increasingly engaged with social media, the trend of writing dental reviews by dental patients after visiting their dentist is also gradually increasing. There were only a few dedicated sites and very few dental reviews available in Australia at the beginning of this study. However, some dental

review sites have emerged since then and these have a few dental reviews of dentists (for example, whitecoat.com.au from NIB insurance provider and womo.com.au site). The number of reviews on these sites does not qualify as mentioned in Chapter 3 for inclusion in the analysis for profiling dentists in Australia. We have only selected dentists with a minimum of 10 dental reviews to profile in this study.

In contrast, some of the sites in the USA have many dental reviews for a few dentists in the big cities. For example, DrOogle site has some dentists with a large number of dental reviews. Figure 5.11 below is a snapshot that shows the number of dental reviews for some dentists in Manhattan, New York. Significant numbers of reviews per dentist are shown such as 1388, 926, 307 and so on.

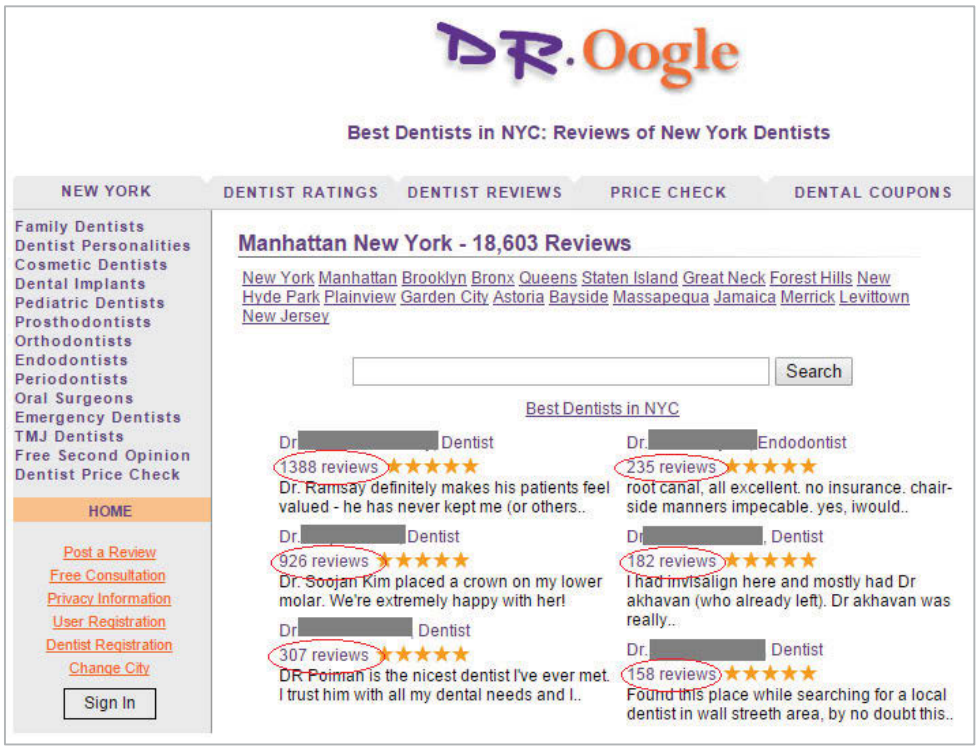


Figure 5.11: Snapshot of DrOogle showing the number of reviews per dentist in New York

Yelp is another popular review site in the USA where patients have written many dental reviews after their visits to their dentists. We have also extracted dental reviews from this site as there are a significant number of reviews per dentist.

5.3.2.2. Analysis of dental reviews

Dental reviews from two of the most popular dental crowdsources in the USA; DrOogle and Yelp are used to analyse subjective information about dentists. In the reviews, patients provide subjective descriptions of dentists and similar words which describe certain characteristic of dentists are grouped together. The text-mining method of extracting and analysing the subjective characteristics of dentists are explained in Chapter 3. After analysing these words, terminologies used to describe dentists are

classified into 10 dentist qualities: Friendly, Caring, Professional, Experienced, Knowledgeable, Explains well, Recommendable, Quality of service, Reliable and Good personality.

Thus, user profiling for dentists are affirmed by extracting subjective characteristics used by their patients from dental crowdsources. Star ratings in the dental crowdsources have helped to determine the reputation of a dentist or dental practice. Dentists' qualities derived from patients' reviews and star ratings are combined to profile dentists.

5.3.2.3. Status of dentists listed in Dental crowdsources

As mentioned earlier, DrOogle and Yelp are selected to analyse dental reviews to profile dentists. Initially, a number of dentists available on these 2 sites for 50 top cities are listed below.

Table 5.4 Number of dentists listed in Yelp and DrOogle in the USA

RANKING	CITIES	Yelp	DrOogle	RANKING	CITIES	Yelp	DrOogle
1	New York	8203	2625	26	Baltimore	478	268
2	Los Angeles	4693	2678	27	Louisville-Jefferson County	985	26
3	Chicago	2799	1524	28	Portland	1386	610
4	Houston	1498	814	29	Oklahoma City	753	220
5	Philadelphia	739	764	30	Milwaukee	862	140
6	Phoenix	3113	803	31	Las Vegas	1370	330
7	San Antonio	1089	297	32	Albuquerque	505	180
8	San Diego	1919	1014	33	Tucson	649	225
9	Dallas	1643	743	34	Fresno	460	166
10	San Jose	2125	1237	35	Sacramento	1113	445
11	Austin	916	356	36	Long Beach	693	81
12	Jacksonville	619	179	37	Kansas City	720	257
13	Indianapolis	924	249	38	Mesa	1249	102
14	San Francisco	1321	862	39	Virginia Beach	765	237
15	Columbus	1126	347	40	Atlanta	1775	717
16	Fort Worth	757	334	41	Colorado Springs	513	163
17	Charlotte	812	259	42	Raleigh	727	113
18	Detroit	1214	1065	43	Omaha	592	151
19	El Paso	238	67	44	Miami	1573	854
20	Memphis	424	155	45	Oakland	656	101
21	Boston	1248	1216	46	Tulsa	500	202
22	Seattle	1478	1212	47	Minneapolis	1290	430
23	Denver	1758	625	48	Cleveland	124	145
24	Washington DC	1354	1335	49	Wichita	300	118
25	Nashville-Davidson	620	176	50	Arlington	334	60

Adapted from Source: Yelp.com and Droogle.com

Based on a large number of reviews available for dentists in both sites, the following 5 cities are chosen for further analysis. The following table shows the number of dentists with more than 10 dental reviews.

Table 5.5 Number of dentists with a minimum 10 dental reviews in the top 5 cities of the USA

	Cities	Yelp	DrOogle
1	New York	40+	30
2	Los Angeles	40+	12
3	Chicago	40+	16
4	Washington DC	40+	28
5	Miami	13	8

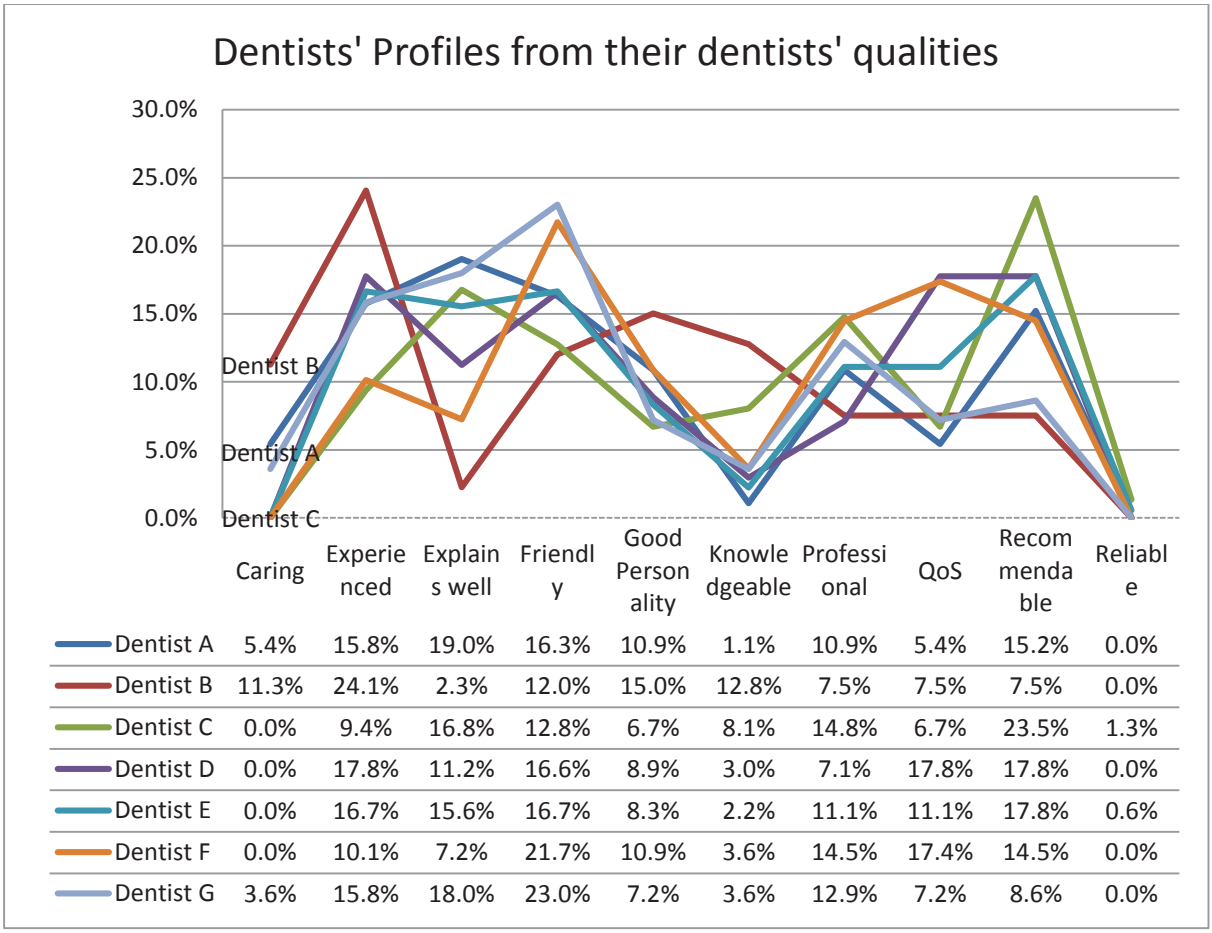
Only dentists with a minimum of 10 dental reviews are used for our analysis. It has limited our scope for the analysis but it is important to consider that number due to possible 'shilling attacks' where a dentist's own friends and people could be writing biased reviews. Some of the results from the analysis are discussed in the following sub-sections.

5.3.2.4. Results from profiling dentists

Dentists' profiles are formulated by using text-mining analysis (TF-IDF) of the reviews written by more than 10 previous patients in the study. Weightings of dentists' qualities recorded against each dentist's profile are shown in Figure 5.12 below.

Figure 5.12. Example of dentists profiles

The dentists from the figure above can be compared to each other from a line graph as shown below.



	Caring	Experienced	Explains well	Friendly	Good Personality	Knowledgeable	Professional	QoS	Recommendable	Reliable
Dentist A	5.4%	15.8%	19.0%	16.3%	10.9%	1.1%	10.9%	5.4%	15.2%	0.0%
Dentist B	11.3%	24.1%	2.3%	12.0%	15.0%	12.8%	7.5%	7.5%	7.5%	0.0%
Dentist C	0.0%	9.4%	16.8%	12.8%	6.7%	8.1%	14.8%	6.7%	23.5%	1.3%
Dentist D	0.0%	17.8%	11.2%	16.6%	8.9%	3.0%	7.1%	17.8%	17.8%	0.0%
Dentist E	0.0%	16.7%	15.6%	16.7%	8.3%	2.2%	11.1%	11.1%	17.8%	0.6%
Dentist F	0.0%	10.1%	7.2%	21.7%	10.9%	3.6%	14.5%	17.4%	14.5%	0.0%
Dentist G	3.6%	15.8%	18.0%	23.0%	7.2%	3.6%	12.9%	7.2%	8.6%	0.0%

Figure 5.13 Classification of dentists from dentists' qualities

Some of the challenges in determining dentists' qualities from the text mining analysis to profile dentists were managed, as described below.

Filtering negative statements

One of the most prevalent challenges in text mining is the positive or negative connotation of the terms used to describe the qualities of dentists. For example, a simple word 'good' may be mentioned with 'not good' in the reviews. When recording the frequency of use of a particular word to describe dentists' qualities (as listed in Table 3.1), any negative expression of the words used are filtered out by using the regular expression (not|n't) to detect negativity before the word. The number of stars used to rate a dentist are also taken into consideration to determine if the review has a positive or negative meaning from each review.

A feature has been added to the program to select reviews for a specified dentist ranked by the range of star ratings (reputation trust) out of 5 as shown in Figure 5.14. When the star ratings are from 3 to 5, the selected qualities are considered to have been attributed to a positive connotation. Similarly, when

the rating stars are selected from 1 to 2, the qualities are deemed to have a negative connotation and are hence rated low for the dentist.

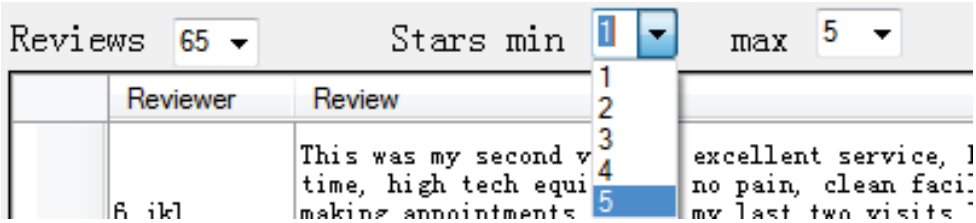


Figure 5.14: Selection of rating stars.

Reputation trust is integrated in the dentists' profile by selecting higher star ratings to give the dentists in positive reviews and vice versa. We note that there were significantly less reviews employing negative words or descriptions. One of the reasons for this could be that the reviews are filtered in some of the sites (like DrOogle) before they are published online. In general, there are more positive reviews than negative reviews for dental care.

Comparison of two sources (DrOogle vs Yelp)

Another challenge is whether the same dentist has been reviewed and rated consistently across different online review platforms or dental crowdsources. While the dental review sites are using various criteria to rate the dentists, the terms used by reviewers to describe the same dentist in two popular dental reviews sites are consistent. This is verified by analysing the terms used in two of the most popular dental reviews sites: DrOogle and Yelp for the same dentist. In Figure 5.15, a dentist from New York, who has a significant number of reviews in both sites, was chosen for verification purposes.

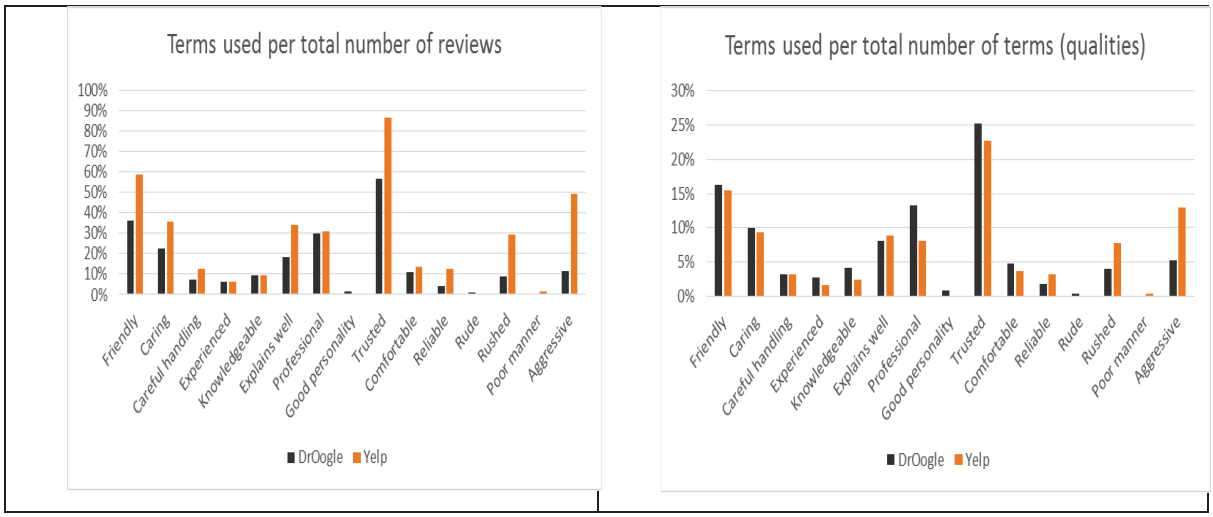


Figure 5.15: Comparison of terms used (DrOogle vs Yelp) (Y-axis: Percentage of terms used)

There were 556 reviews for this dentist in the DrOogle site and 65 reviews in the Yelp site. We have used the method, TF-IDF to assess the dentists' qualities that are detailed in all those reviews. The result is shown in Figure 5.15. The number of terms used is shown as a percentage based on the total number

of reviews for the dentist in the first graph. In the second graph, the number of terms is shown as a percentage based on the total number of terms to describe the dentist's qualities (1,247 and 246 in DrOogle and Yelp respectively). The graphs show that the way patients describe their dentists are similar, although sourced from two different sites (DrOogle and Yelp). In addition, even when the actual number of reviews is significantly different (556 versus 65) the proportions of actual terms used in the reviews are almost evenly distributed across both sites. This shows that the dentist's qualities are consistently recognised and conceded by the patients and asserts that the dentist has the qualities described by their patients.

Profiles of both dentists and patients are further analysed later in this chapter when constructing matching algorithms for dental care recommendation systems.

5.4. Integrating trust components for the matching in dental care recommendation systems

Dental care recommendation systems provide patients with a recommended list of dentists from which to filter and choose the most suitable dentist for their dental treatments. Both objective and subjective criteria are used in the process of choosing a suitable dentist. A level of trust is associated with the preferred objective and subjective criteria chosen by the patients. The preferred criteria, the methods used to search for dentists and preferred dentists' qualities are analysed from the data collected in the survey.

5.4.1. Preferred Criteria

After analysing the preference criteria survey, the preferred objective and subjective criteria selected by dental patients to choose their dentist were identified and the importance of the subjective qualities of the dentists was acknowledged. Again, in the second survey for dental patients, the participants were asked to select their top 3 important criteria for choosing a dentist. 580 participants chose their 3 most preferred criteria out of 9 criteria provided: location, experienced dentists, degrees and qualifications, online ratings, online reviews, cost, available for booking and dentists' qualities. The results from the participants showed that they prefer 'experienced dentists', followed by location, cost and recommendations consecutively as shown below.

Table 5.6: Ranking of preferred criteria to choose a dentist by all participants

Ranking Order	Criteria	Percentage	Objective or Subjective
1	Experienced	21.8%	Subjective
2	Location	19.6%	Objective
3	Cost	16.7%	Objective
4	Recommendations	13.9%	Subjective

The overall percentage for the preferred criteria is shown in the graph below.

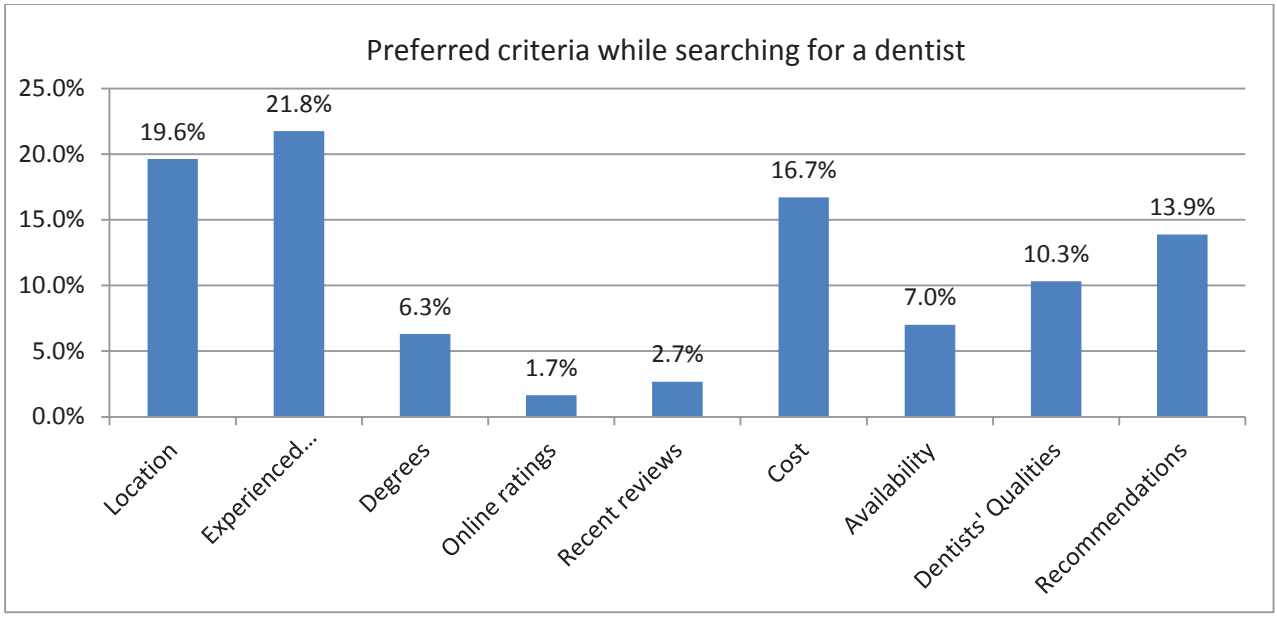
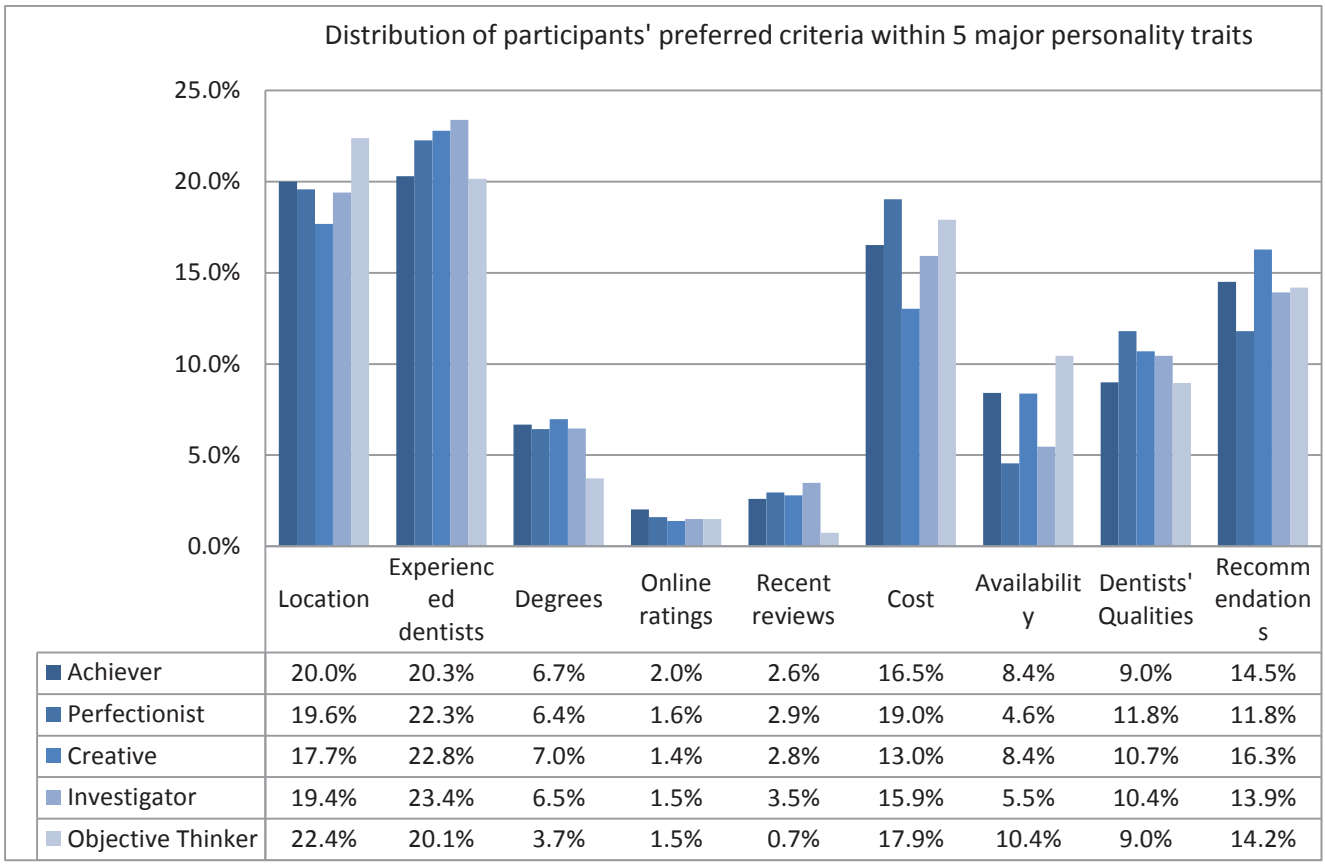


Figure 5.16: Preferred criteria to choose a dentist

When patients perceive some aspects of the dental treatment from their dentists are good, they recommend them to other people. Since the recommendations are based on perception, they are subjective in nature but nonetheless important for patients when looking for dentists, as shown in the graph above.



	Location	Experienced dentists	Degrees	Online ratings	Recent reviews	Cost	Availability	Dentists' Qualities	Recommendations
Achiever	20.0%	20.3%	6.7%	2.0%	2.6%	16.5%	8.4%	9.0%	14.5%
Perfectionist	19.6%	22.3%	6.4%	1.6%	2.9%	19.0%	4.6%	11.8%	11.8%
Creative	17.7%	22.8%	7.0%	1.4%	2.8%	13.0%	8.4%	10.7%	16.3%
Investigator	19.4%	23.4%	6.5%	1.5%	3.5%	15.9%	5.5%	10.4%	13.9%
Objective Thinker	22.4%	20.1%	3.7%	1.5%	0.7%	17.9%	10.4%	9.0%	14.2%

Figure 5.17: Preferred criteria by 5 major personality traits to choose a dentist

This study focuses on improving the quality of recommendations of dentists to patients. There are many other factors involved to make recommendations trustworthy. The proposed trust model discusses four major trust components. Some of the trust components were integrated in profiling patients and dentists earlier in this chapter.

When the preferred criteria were further investigated by filtering the survey data from the participants who belong to the five major personality traits: Achiever, Perfectionist, Creative, Investigator and Objective Thinker, rankings of the preferred criteria varied slightly for the participants belonging to 'Creative' and 'Objective Thinker' personality traits, as shown in Figure 5.17. The participants with 'Creative' personality traits ranked recommendations as the third most important instead of cost. However, participants from the personality traits 'Objective Thinker' chose location over experienced dentists as their first priority.

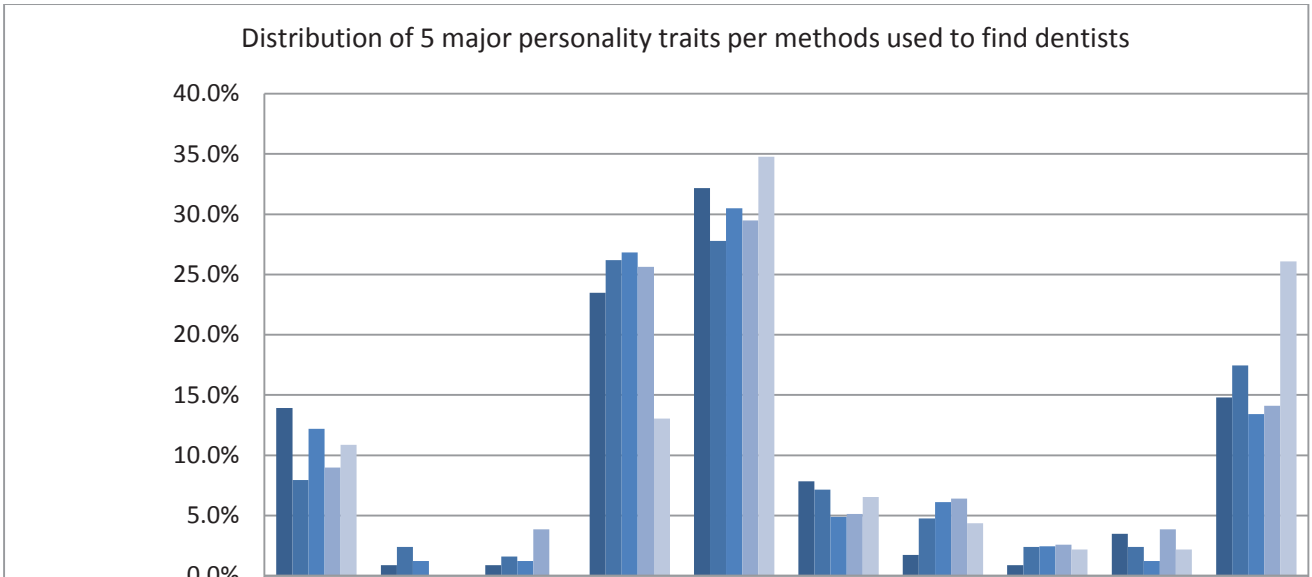
Thus, when the participants are grouped based on their personality traits, it started to become visible how preferences may vary from the point of view of different groups. Similar analysis is done for other preferences such as preferred search methods for dentists and preferred dentists' qualities.

5.4.2. Preferred Search methods to find a dentist

Similar to the preferred criteria to choose a suitable dentist, the participants were asked to select search methods that they have used to find their existing dentists. They were presented with a list of 10 different searching methods: online search, dentists' sites, social media, recommended by a good friend, recommended by a family member, recommended by the GP, recommended by professional peers, from advertisement, yellow pages or local area. They were also asked to choose a search method if they were to search for a different dentist in the future and presented with two separate questions listed below:

- How did you find your dentist?
- If you were to search for a different dentist, which method would you use?

Most of the participants indicated that their family members and good friends are the most reliable source to find a dentist. More than 50% of the participants selected either of these sources not only for their existing dentist but also indicated that they would use them to find a different dentist in future. When the results were analysed from different groups of participants who belong to the 5 major personality traits, family members and good friends were the most preferred search methods across 4 major personality traits except for participants who belong to the 'Objective Thinker' personality traits, as shown in the table and graph below. They prioritised location rather than recommendations from friends.

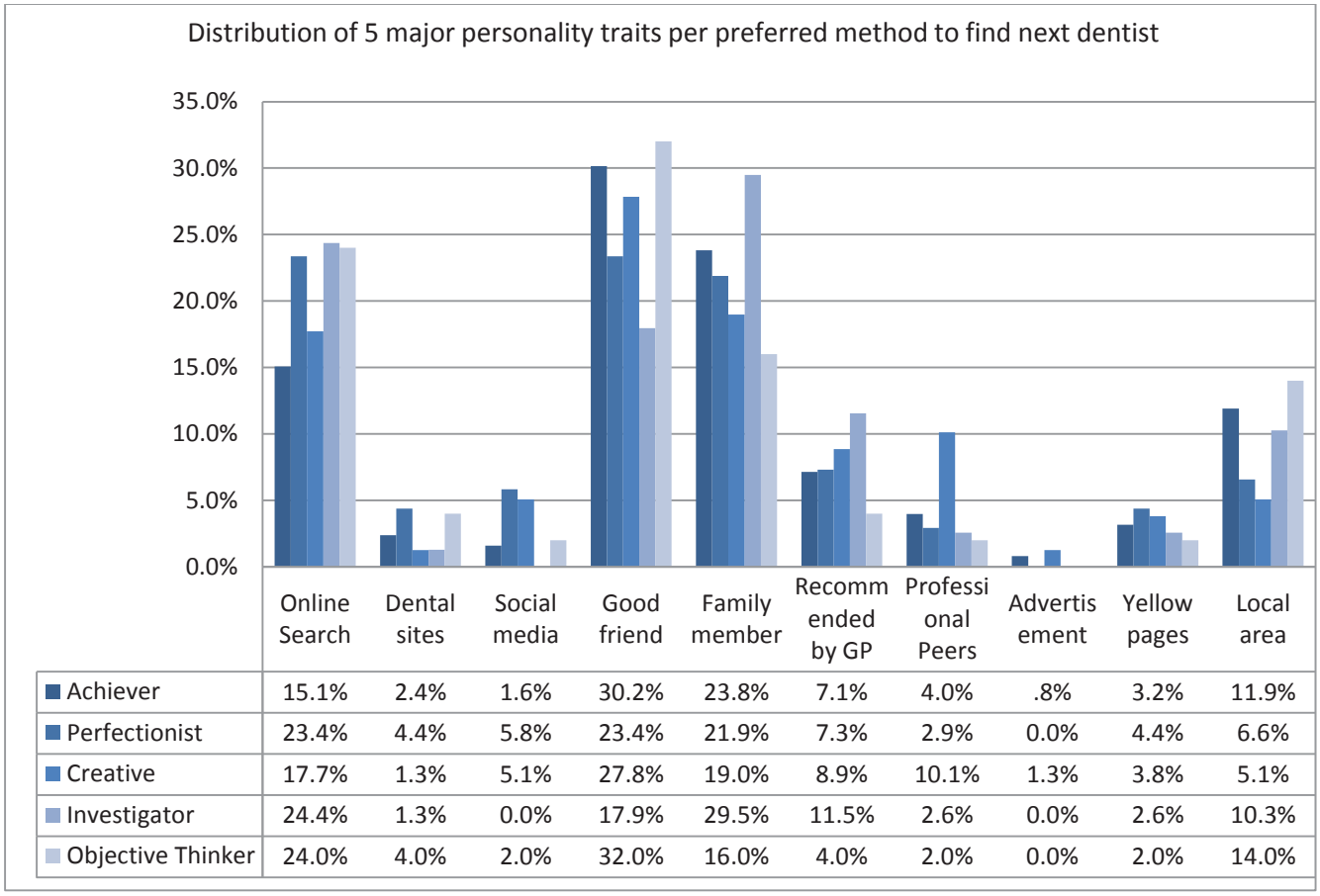


	Online Search	Dentists' sites	Social media	Good friend	Family member	GP	Peers	Adversti sement	Yellow pages	Local area
Achiever	13.9%	0.9%	0.9%	23.5%	32.2%	7.8%	1.7%	0.9%	3.5%	14.8%
Perfectionist	7.9%	2.4%	1.6%	26.2%	27.8%	7.1%	4.8%	2.4%	2.4%	17.5%
Creative	12.2%	1.2%	1.2%	26.8%	30.5%	4.9%	6.1%	2.4%	1.2%	13.4%
Investigator	9.0%	0.0%	3.8%	25.6%	29.5%	5.1%	6.4%	2.6%	3.8%	14.1%
Objective Thinker	10.9%	0.0%	0.0%	13.0%	34.8%	6.5%	4.3%	2.2%	2.2%	26.1%

Figure 5.18: Search Methods used to find existing dentist by 5 major personality traits

From the second question in regards to the preferred search methods to find a different dentist in the future, all the participants ranked the online search as the third most preferred method after two popular sources: friends and family members. From the table in Figure 5.18 above, the percentage of participants who used online search to find their existing dentist was 10.7% but the number of participants who ranked online search as the 1st preferred method to find their next dentist almost doubled to 20.4%, as shown in Figure 5.19. This increment proves the fact that, in general, there is an upward trend in trusting online methods or recommendation systems to search for a dentist. Looking at it from the technology viewpoint of the RM-ODP framework, the underlying technology needs to be trusted first to let the system be used.

Figure 5.19 below shows the distribution of the percentage of participants from the 5 major personality traits who used various search methods to find their next dentist. Family members and good friends remained the main trustable sources for finding a different dentist followed by online search.



	Online Search	Dental sites	Social media	Good friend	Family member	Recommended by GP	Professional Peers	Advertisement	Yellow pages	Local area
Achiever	15.1%	2.4%	1.6%	30.2%	23.8%	7.1%	4.0%	.8%	3.2%	11.9%
Perfectionist	23.4%	4.4%	5.8%	23.4%	21.9%	7.3%	2.9%	0.0%	4.4%	6.6%
Creative	17.7%	1.3%	5.1%	27.8%	19.0%	8.9%	10.1%	1.3%	3.8%	5.1%
Investigator	24.4%	1.3%	0.0%	17.9%	29.5%	11.5%	2.6%	0.0%	2.6%	10.3%
Objective Thinker	24.0%	4.0%	2.0%	32.0%	16.0%	4.0%	2.0%	0.0%	2.0%	14.0%

Figure 5.19: Methods ranked 1st to find a different dentist by 5 major personality traits

However, there is one peculiar result from the participants who belong to 'Objective Thinker' personality traits which showed that 34.8% of them used family members and 13% followed friends' recommendations to find their existing dentists, as shown in Figure 5.18. The figures seem to be swapped from family members (16%) to good friends (32%) to find their next dentist for the same cohort, as shown in Figure 5.19 above.

In regards to online search as the preferred method to find a new dentist, all the participants who belong to the 5 major personality traits indicated that they would use online search methods more than they would have used them in the past. Particularly, participants who belong to the personality traits categories of 'Perfectionist', 'Investigator' and 'Objective Thinker' pointed out that they would be more likely to use online methods to find their next dentist. For example, 7.9% of the participants who belong to personality traits 'Perfectionist' used an online search to find their current dentist but 23.4% of them preferred online search as the first choice. Similarly 9% of the participants from the 'Investigator' personality trait stated that they used online search but 24.4% would prefer to use that platform as the first choice to find their next dentist. The line graph in Figure 5.20 compares the percentage of participants from different personality traits who used 'online Search' as a method to find their existing dentists and the percentage of the participants who would use the online method to find their next dentist in the future.

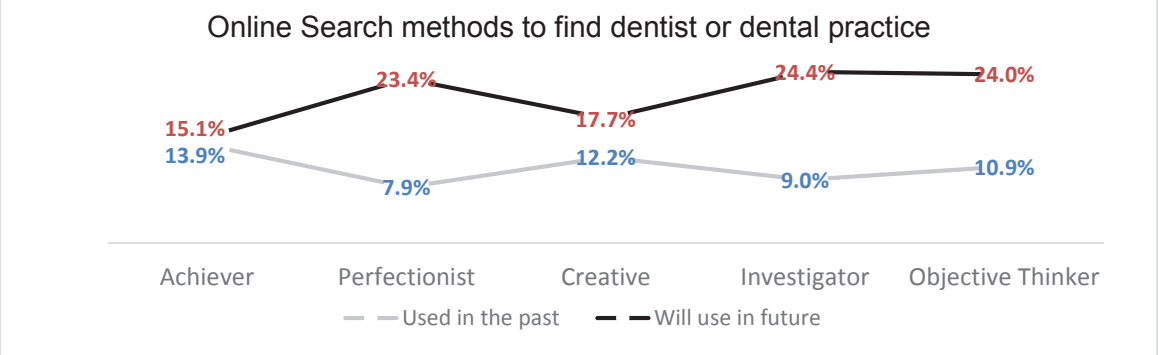


Figure 5.20: Online search as a method to find dentist by 5 major personality traits in the past vs. future

The graph above only showed the results from the participants who ranked 'online search' as the first preferred method. Subsequently, 6.4% and 11.45% of the participants chose online search as the second and third most preferred searching method to find their respective dentist. Altogether, approximately 40% of the participants indicated that they are likely to use an online search to find their next dentist.

This result is correlated with the result from the previous preference criteria survey on how likely the participants would be to use a dental care recommendation system to find their dentist. Almost 50% of the participants mentioned that they would be likely to use the recommendation system for dental care if the system was available to them. Figure 5.21 below shows the responses from the survey.

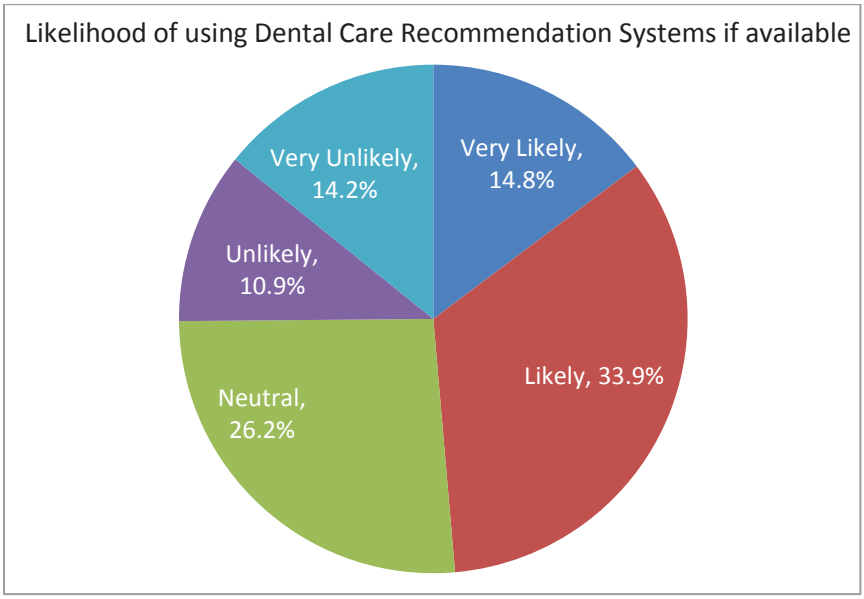


Figure 5.21: Likelihood of using Dental Care Recommendation System

Due to the upward trend in trusting online recommendation sites to search for a dentist, this study of trust model for dental care recommendation systems is important so that quality recommendations of dentists can be provided. This study proposed the trust-enhanced information model to improve the quality of online recommendations so that dental patients would be satisfied with the list of dentists provided by the systems.

5.4.3. Preferred Dentists' Qualities

The proposed trust-enhanced information model for dental care recommendation systems specifies the importance of subjective criteria when filtering and matching dentists with patients. Earlier in this chapter, we discussed subjective characteristics and how they can be included in the profiling of both patients and dentists. Patients are classified based on subjective characteristics such as types of personality traits and level of dental fear plus other objective criteria. For dentists, 10 dentists' qualities derived from online dental reviews are used to profile dentists. It is anticipated that a mixture of dentists' qualities is preferred by different patients as per their personality traits and these are used to filter the list of dentists available in the system.

In order to determine preferred dentists' qualities the participants of the survey were asked to choose the top 3 most important qualities out of 10 dentists' qualities to describe their ideal dentist. Table 5.7 ranks the first 5 most preferred dentists' qualities chosen by the participants of the survey.

Table 5.7: Top 5 Preferred Dentists' Qualities by all participants

S. No	Dentists' Qualities	Percentage
1.	Experienced	20%
2.	Professional	18%
3.	Quality of Service	17%
4.	Knowledgeable	13%
5.	Explains well	9%

The bar chart in Figure 5.22 below shows the distribution of dentists' qualities by all the participants to describe the ideal dentist they would like to visit for their dental treatments.

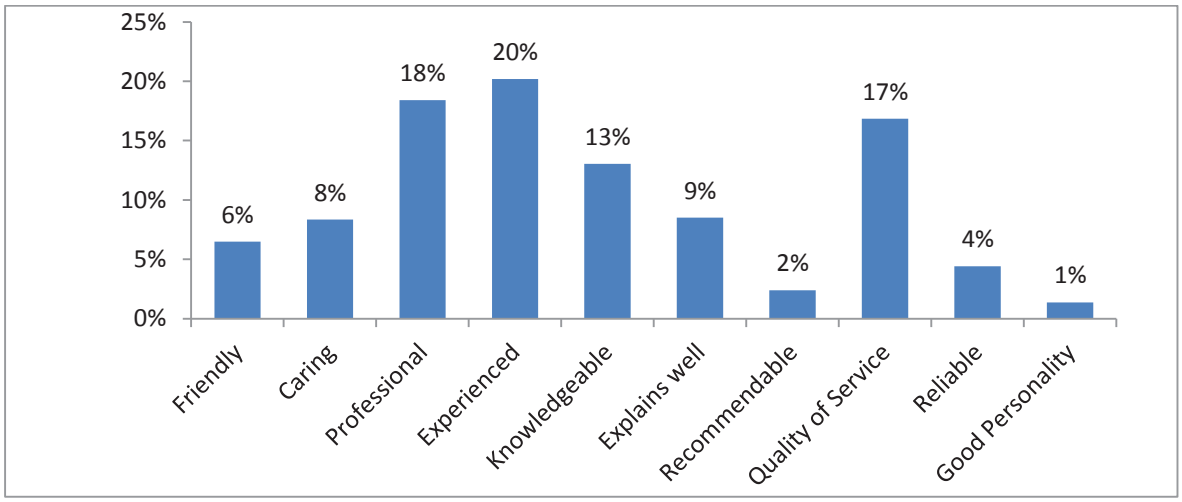


Figure 5.22: Distribution of Preferred Dentists' Qualities by all participants

The participants were also asked to describe their existing dentists by choosing the 3 most suitable dentists' qualities from the same list of 10 dentists' qualities to analyse the difference between what their dentists have and what dentists' qualities they wish to have in their ideal dentists.

The preferred dentists' qualities are analysed from two different subjective variables of the participants as dental patients: types of personality traits and levels of dental fear.

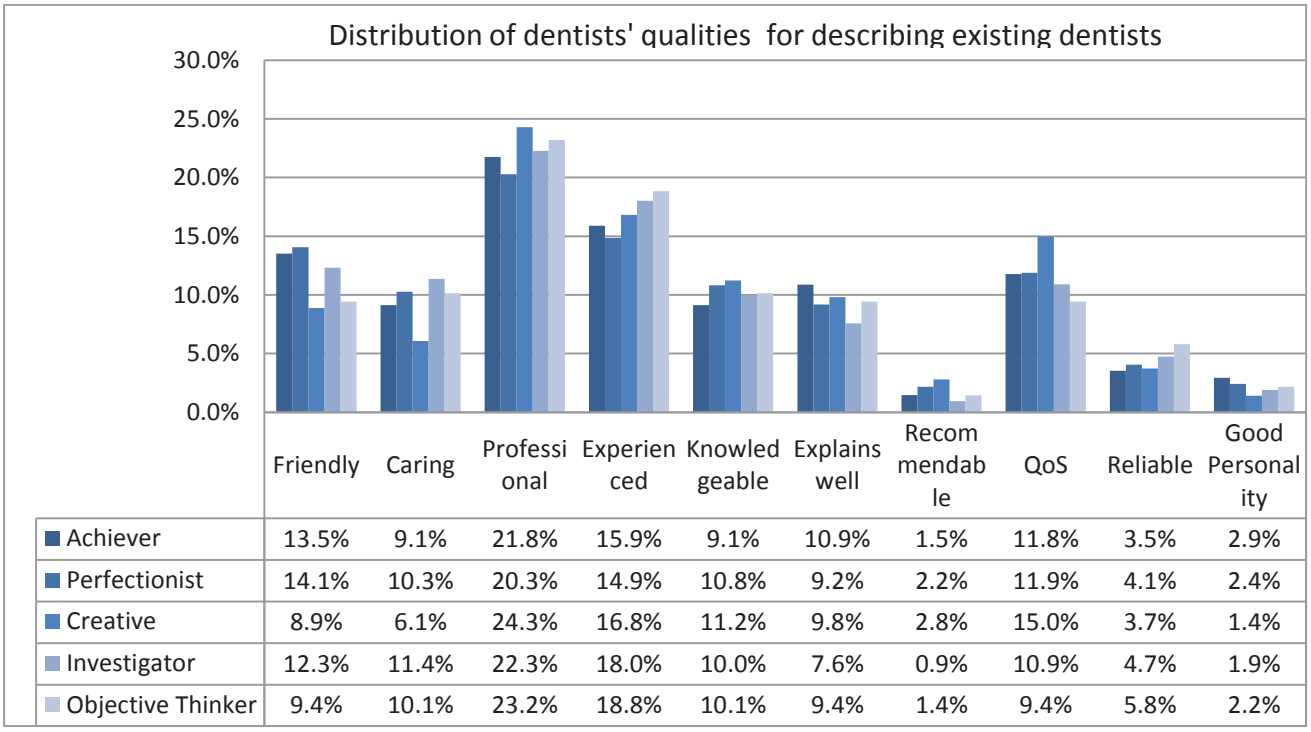
5.4.3.1. Based on 5 major Personalities Traits

The way the participants from the 5 major personality traits described their existing dentist and their future ideal dentist by using the 10 dentists' qualities are analysed to show discrepancies from each group of participants of the personality traits.

- *Description for existing dentists*

From the survey data, participants who belong to the 5 major personality traits showed that their existing dentist has the following dentists' qualities in order of ranking.

1st - Professional (22.0%), 2nd - Experienced (16.4%),
3rd - Friendly (12.3%), 4th - Quality of service (11.9%) and
5th - Knowledgeable (10.2%).



	Friendly	Caring	Professional	Experienced	Knowledgeable	Explains well	Recommendable	QoS	Reliable	Good Personality
Achiever	13.5%	9.1%	21.8%	15.9%	9.1%	10.9%	1.5%	11.8%	3.5%	2.9%
Perfectionist	14.1%	10.3%	20.3%	14.9%	10.8%	9.2%	2.2%	11.9%	4.1%	2.4%
Creative	8.9%	6.1%	24.3%	16.8%	11.2%	9.8%	2.8%	15.0%	3.7%	1.4%
Investigator	12.3%	11.4%	22.3%	18.0%	10.0%	7.6%	0.9%	10.9%	4.7%	1.9%
Objective Thinker	9.4%	10.1%	23.2%	18.8%	10.1%	9.4%	1.4%	9.4%	5.8%	2.2%

Figure 5.23: Dentists' Qualities described for existing dentists by 5 major participants

This result is summarised and drawn in a radar graph as shown below. Almost all participants described their dentists very similarly, with not much difference among the different groups of participants.

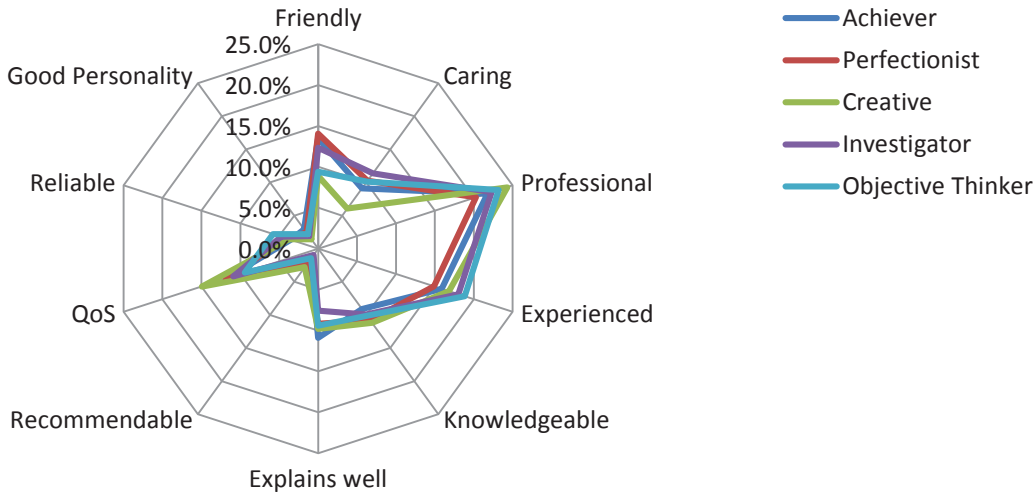
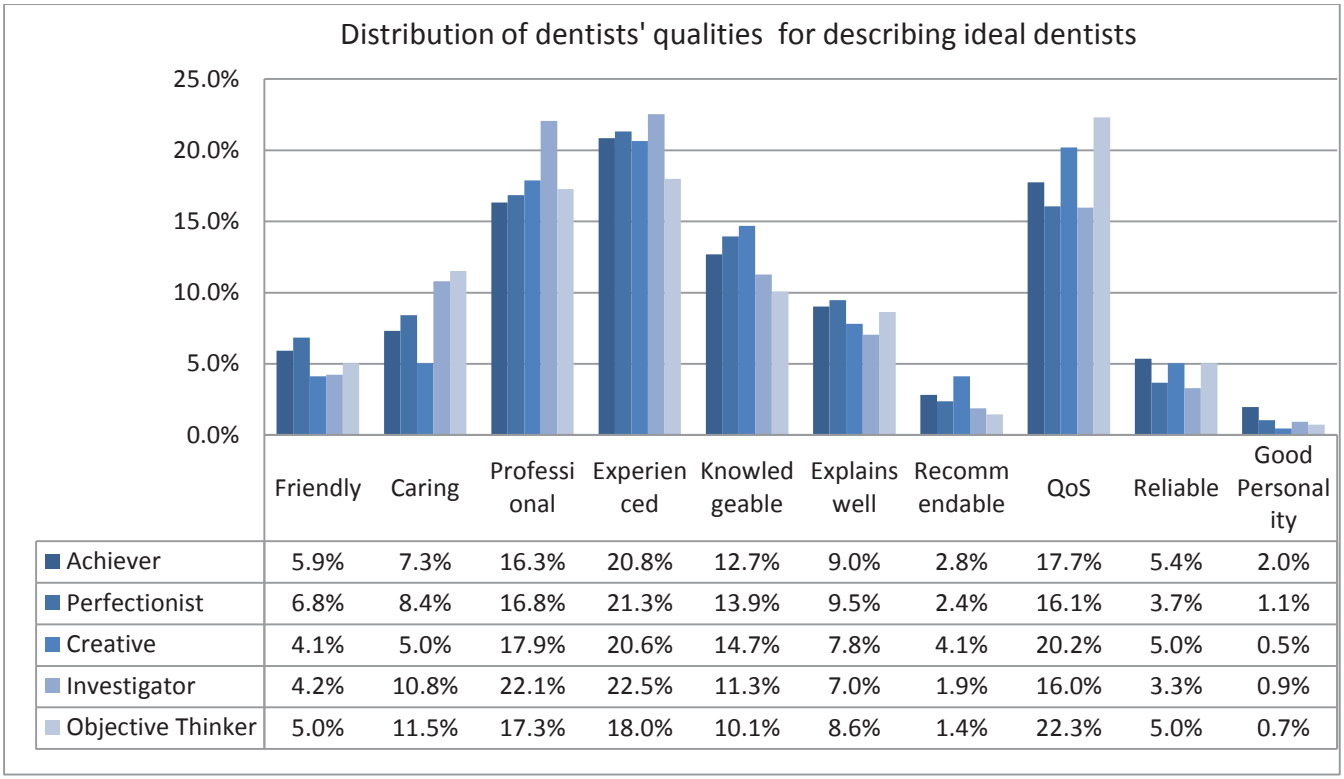


Figure 5.24: Dentists' Qualities described for existing dentists by 5 major participants

- *Description for ideal dentists*

When the same participants were asked to choose from the same list of dentists' qualities for their ideal dentist, they selected different dentists' qualities but only by a slight variation. The first 5 preferred dentists' qualities are shown below:

1st - Experienced (20.9%),
2nd - Quality of Service (17.9%),
3rd - Professional (17.8%),
4th - Knowledgeable (12.9%) and
5th – Explains well (8.6%).



	Friendly	Caring	Professional	Experienced	Knowledgeable	Explains well	Recommendable	QoS	Reliable	Good Personality
Achiever	5.9%	7.3%	16.3%	20.8%	12.7%	9.0%	2.8%	17.7%	5.4%	2.0%
Perfectionist	6.8%	8.4%	16.8%	21.3%	13.9%	9.5%	2.4%	16.1%	3.7%	1.1%
Creative	4.1%	5.0%	17.9%	20.6%	14.7%	7.8%	4.1%	20.2%	5.0%	0.5%
Investigator	4.2%	10.8%	22.1%	22.5%	11.3%	7.0%	1.9%	16.0%	3.3%	0.9%
Objective Thinker	5.0%	11.5%	17.3%	18.0%	10.1%	8.6%	1.4%	22.3%	5.0%	0.7%

Figure 5.25: Dentists' Qualities preferred with ideal dentist by 5 major groups of participants

The bar chart in Figure 5.25 above and the radar graph in Figure 5.26 below show the preferred dentists' qualities of ideal dentists as chosen by different groups of participants employing 5 major personality traits. The 1st preference for all groups was 'experienced dentists' except for the group belonging to 'Objective thinker'. 'Quality of Service' was the most preferred quality for the participants from that particular group. However, the 2nd preference for most of the groups was in between Quality of service and Professional as shown in the figures. But the groups from the 'Objective thinker' personality trait had 'Experienced' and 'Professional' as the 2nd and 3rd preferred qualities respectively. The fourth most preferred quality was 'Knowledgeable dentist' except for the 'Objective thinker' group. They chose 'Caring' as the fourth preferred quality. The participants from the same group described their existing dentists as being friendly by selecting the top three dentists' qualities as detailed in Figure 5.23 above. However, the data shows that they do not prefer friendly dentists that much because the quality of friendly dropped in ranking to almost the 3rd least preferred quality, as shown in these figures. Approximately 14% of participants expressed that their existing dentists are 'friendly' in Figure 5.23 and that ranking dropped to 5% in terms of ideal dentists.

These results are summarised and drawn as a radar graph, as shown below.

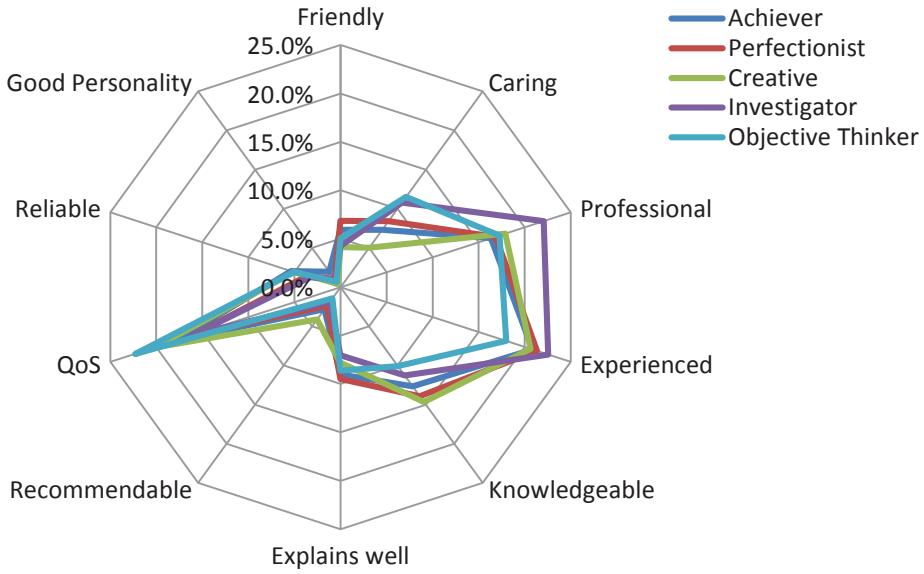


Figure 5.26: Distribution of Preferred Dentists' Qualities by 5 major participants

- **Comparison of dentists' qualities nominated for existing dentists versus ideal dentists**

The above two bar charts with table and radar graphs show that most of dental patients are comfortable and satisfied up to certain degree with their existing dentists. They described their dentists as 'Professional', 'Experienced' and 'Friendly'. As shown in the graphs in Figure 5.23 and 5.24, some of the participants described their dentist as someone who provides good 'Quality of service' and is 'Knowledgeable'. Meanwhile, graphs in Figure 5.25 and 5.26 captures a list of dentists' qualities that the participants from the 5 major personality traits prefer their dentists to have. There is not much difference in terms of the proportion of dentists' qualities that the existing dentists already have and the qualities that participants would prefer their ideal dentists to possess.

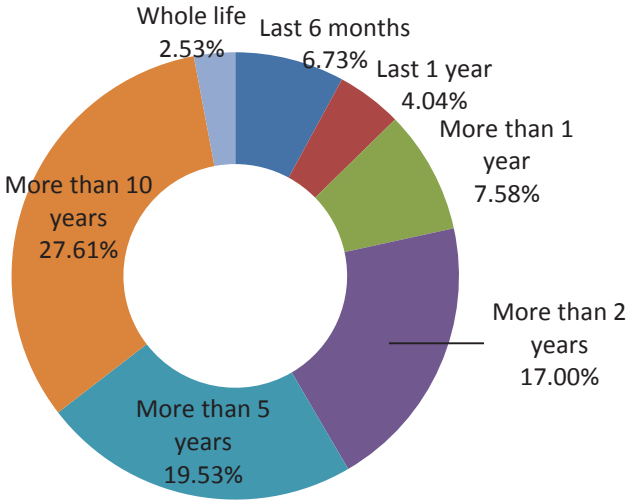


Figure 5.27: Length of time participants have been with existing dentists

This result proves why the majority of dental patients as participants in Australia, are staying with their dentists for a long period of time. First of all, 85% of the participants mentioned that they have their own dentists. 27.61% and 19.53% of those who have their own dentists have been visiting the same dentist for more than 10 and 5 years respectively. Figure 5.27 above shows how long the participants have been going to the same dentists.

When information from the above graph is delved into to investigate the personality traits level, the participants who belong to 'Objective thinker' personality traits had a bigger proportion (42%) who had been going to the same dentist for more than 10 years, in comparison with the other participants from different personality traits, as shown in Figure 5.28 below.

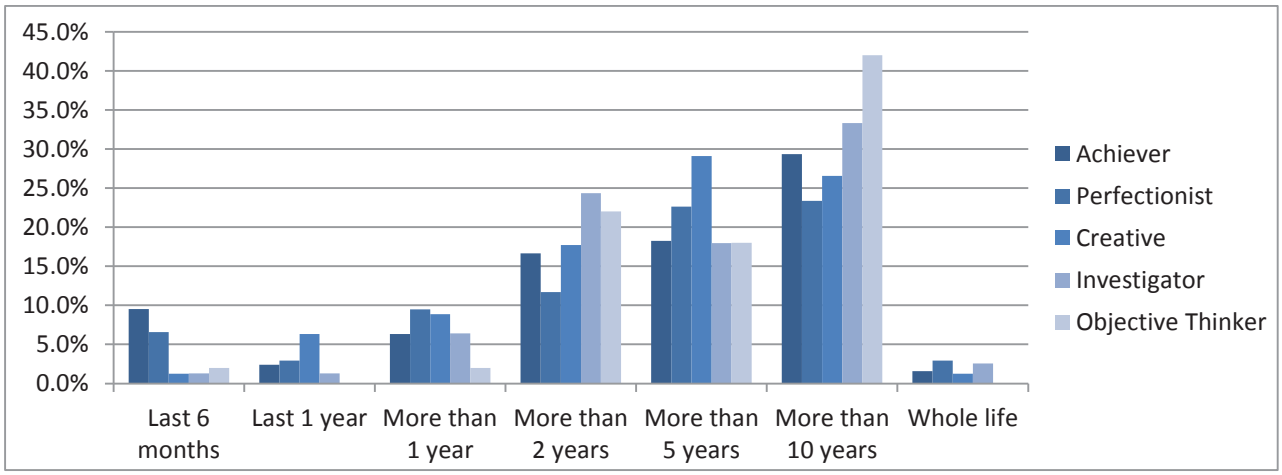


Figure 5.28: Length of time participants have been with existing dentists

In general, most of the participants have reported that they have been going to the same dentist for a comparatively long period of time. Therefore, it can be assumed that the majority of participants are satisfied with their existing dentists.

Further comparison of dentists' qualities between existing dentists and future ideal dentists, described by the 5 different groups of participants from personality traits, is conducted. For example, the first graph in Figure 5.29 shows that every participant group prefers to have more 'experienced dentists' than what they already have, except for the group who belong to 'Objective thinker' personality traits. The participants from 'Objective thinker' personality traits are happy with the level of experience that their existing dentist has. This information can be verified from Figure 5.28 above as it shows that most of the participants from that cohort have been going to the same dentist for a long period of time, being more than 10 years.

Figure 5.29 below shows how dentists' qualities are different to how participants describe their dentists and what qualities they would prefer their ideal dentist to possess. Similar results can be seen in relation to dentists' qualities of being 'professional'. The majority of participants from the survey indicated that their dentists are 'professional' but they would prefer them to be less professional. The exception was

for participants belonging to the personality traits of 'Investigator' who wanted the same level of professionalism as ideal dentists.

The line graphs in the figure below clearly show the variation in dentists' qualities, and the participants from each type of personality trait, with their existing dentists and ideal dentists. From these graphs below, participants who belong to the 'Objective thinker' personality traits out of 5 major traits, seem to prefer slightly different dentists' qualities. Their preference does not to any great degree change their view in regards to 'experienced' and 'knowledgeable' for existing and future dentists. They do not seem to worry about the amount of knowledge that their dentists have. Again, this argument is correlated with the number of years that they have been going to the same dentist.

Although only a small portion of participants described their existing dentists as 'caring', not many participants were concerned about the caring nature of their dentists. Only a few participants from 'Achiever' and 'Creative' personality traits wished that their dentists were more caring in nature. Despite former studies about the importance of a dentist's caring attitude (see Chapter 2), when we compare this with other qualities such as experienced, quality of service and professionalism, caring is not preferred that much in this study. Existing dentists of the participants seem to do enough caring of patients, as shown in the graph below.

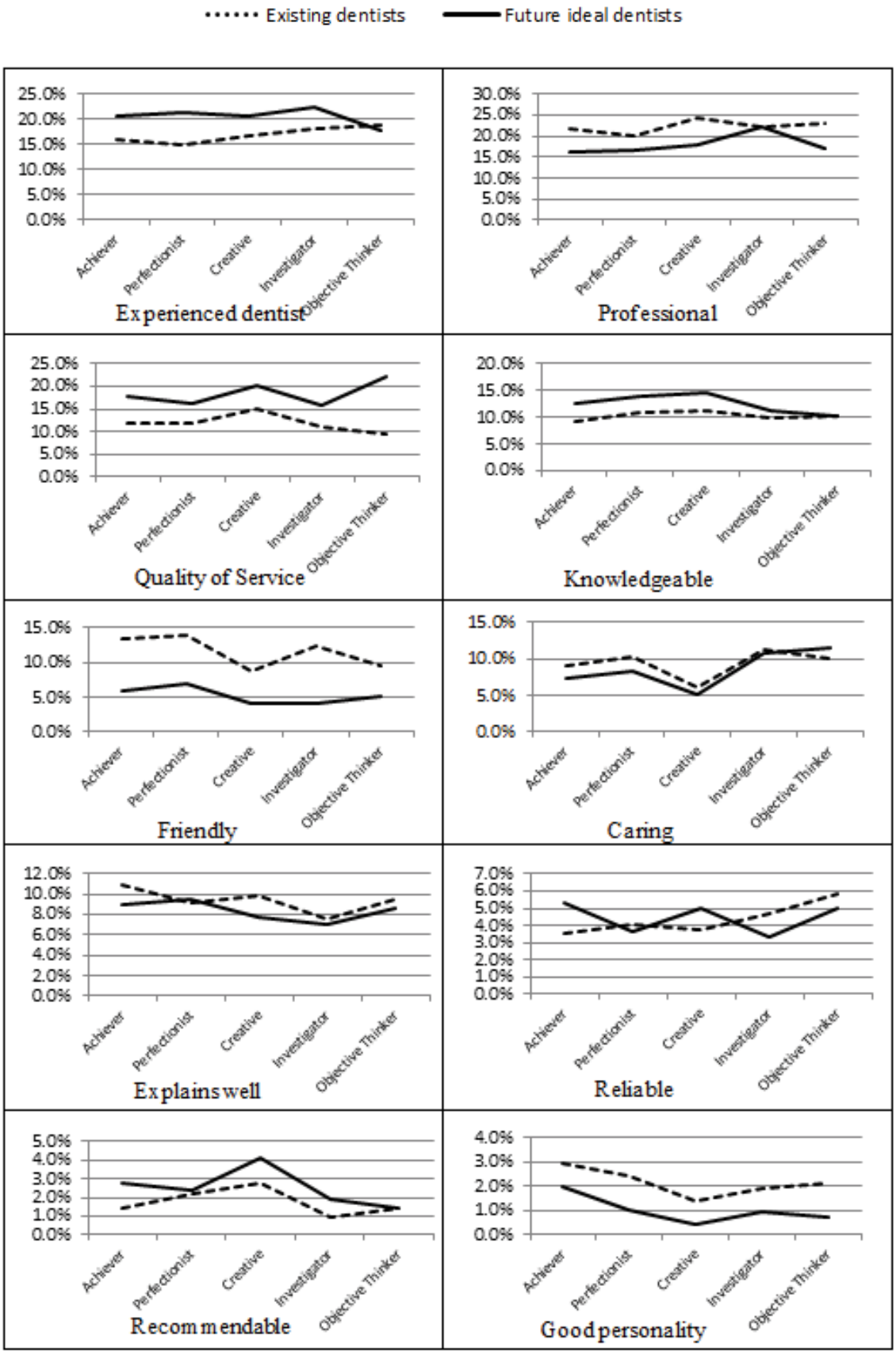


Figure 5.29: Dentists' qualities of existing dentists versus future ideal dentists

When the participants from the 5 major personality traits are further categorised by different levels of fear, the preferred dentists' qualities again change slightly in each category. The results based on groups of different levels of fear are discussed in the next section.

5.4.3.2. Based on Levels of dental fear

Like the way the participants were categorised based on different personality traits, they are classified in terms of different levels of dental fear in this section. For consistency of the results, only 470 records from the participants of the major 5 personality traits are selected for this analysis. Out of 470 participants, 194 (41%) of them stated that they have low to no dental fear, 104 (22%) only moderately fearful, 138 (29%) fearful and only 34 (7%) were highly fearful to visit dentists for a dental treatment. This is shown in the bar chart below.

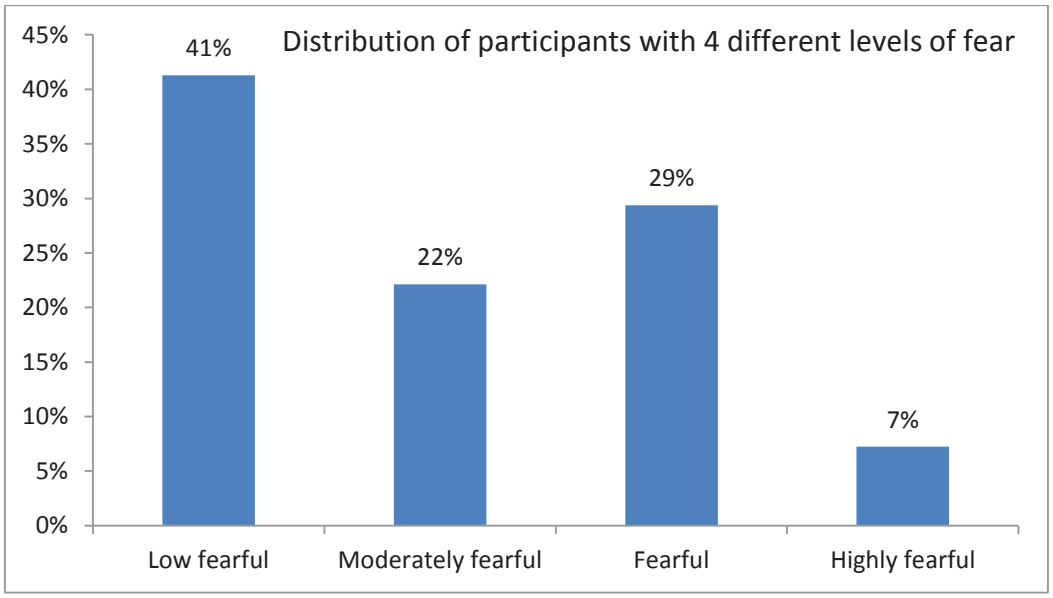
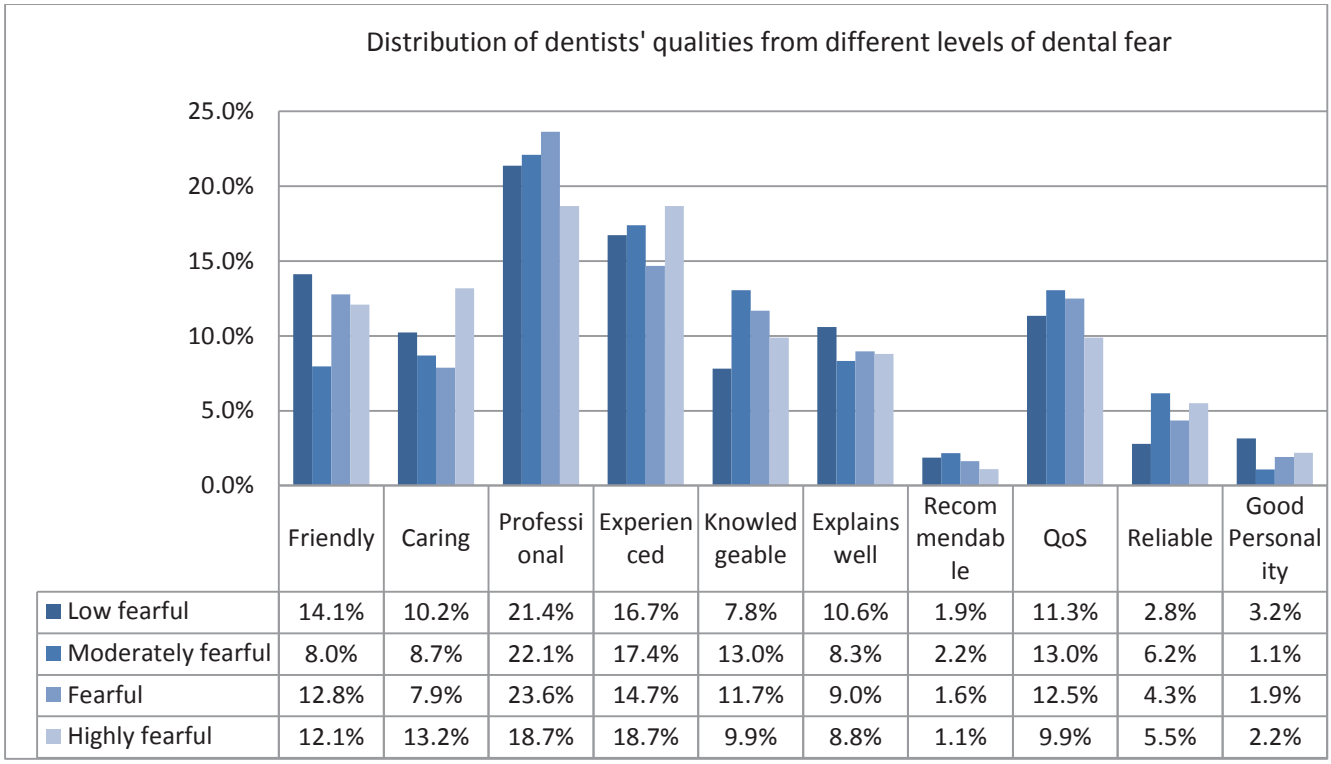


Figure 5.30: Distribution of participants from 5 major personality traits with levels of dental fear

The participants with different levels of dental fear described their dentists with similar dentists' qualities, as discussed above in Figure 5.23. Obviously, the total number for each dentists' quality would remain the same but there is a variation per group based on different levels of dental fear, as shown in Figure 5.31 below.



	Friendly	Caring	Professional	Experienced	Knowledgeable	Explains well	Recommendable	QoS	Reliable	Good Personality
Low fearful	14.1%	10.2%	21.4%	16.7%	7.8%	10.6%	1.9%	11.3%	2.8%	3.2%
Moderately fearful	8.0%	8.7%	22.1%	17.4%	13.0%	8.3%	2.2%	13.0%	6.2%	1.1%
Fearful	12.8%	7.9%	23.6%	14.7%	11.7%	9.0%	1.6%	12.5%	4.3%	1.9%
Highly fearful	12.1%	13.2%	18.7%	18.7%	9.9%	8.8%	1.1%	9.9%	5.5%	2.2%

Figure 5.31: Dentists' qualities described by participants from 4 groups based on levels of fear

This result is also summarised and drawn in the following radar graph.

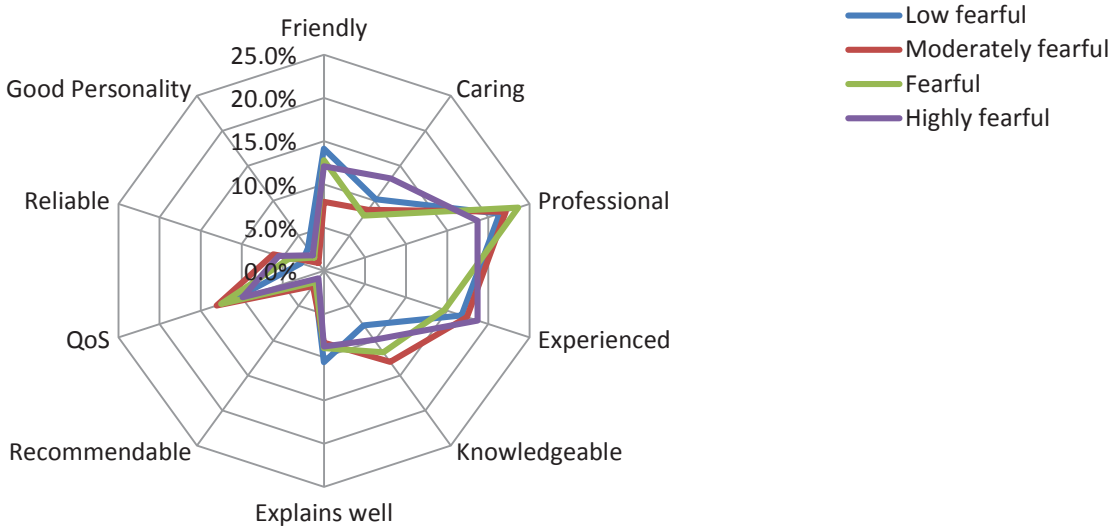
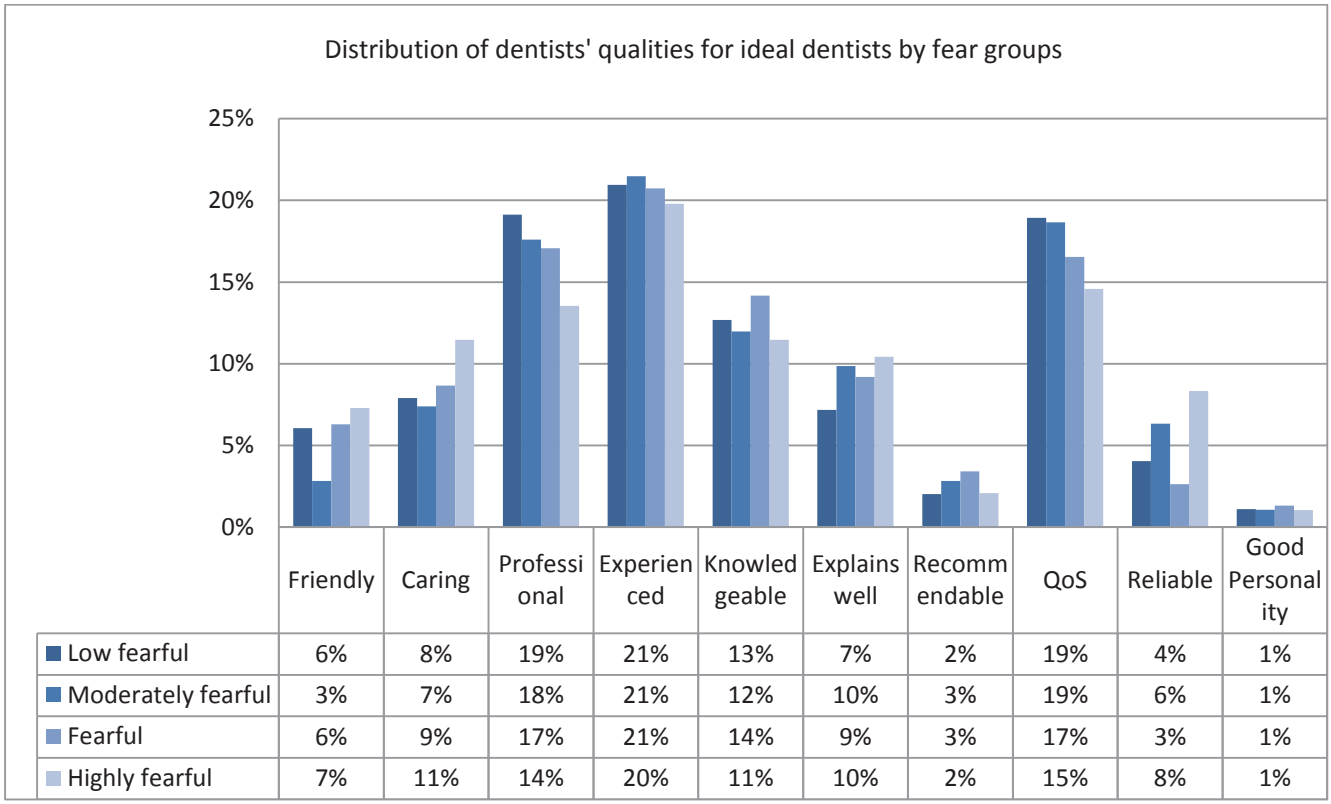


Figure 5.32: Dentists' qualities described by participants from 4 groups based on levels of fear

From the above bar chart and table, it is clear that existing dentists are more or less described as very similar by the cohorts of different levels of dental fear. Participants from low fearful groups found their existing dentists were friendly and good at explaining. This could be the reason why they are less fearful in the first place. Meanwhile, highly fearful participants found their existing dentists were more experienced and caring but they were still fearful.

Similar to the analysis from different personality traits, preferred dentists' qualities for the participants' ideal dentists are also analysed based on the 4 groups of participants with different levels of fear. The result is shown in Figure 5.33 and 5.34 below.



	Friendly	Caring	Professional	Experienced	Knowledgeable	Explains well	Recommendable	QoS	Reliable	Good Personality
Low fearful	6%	8%	19%	21%	13%	7%	2%	19%	4%	1%
Moderately fearful	3%	7%	18%	21%	12%	10%	3%	19%	6%	1%
Fearful	6%	9%	17%	21%	14%	9%	3%	17%	3%	1%
Highly fearful	7%	11%	14%	20%	11%	10%	2%	15%	8%	1%

Figure 5.33: Dentists' qualities preferred by 4 groups of participants based on level of fear

This result is also summarised and drawn in the following radar graph.

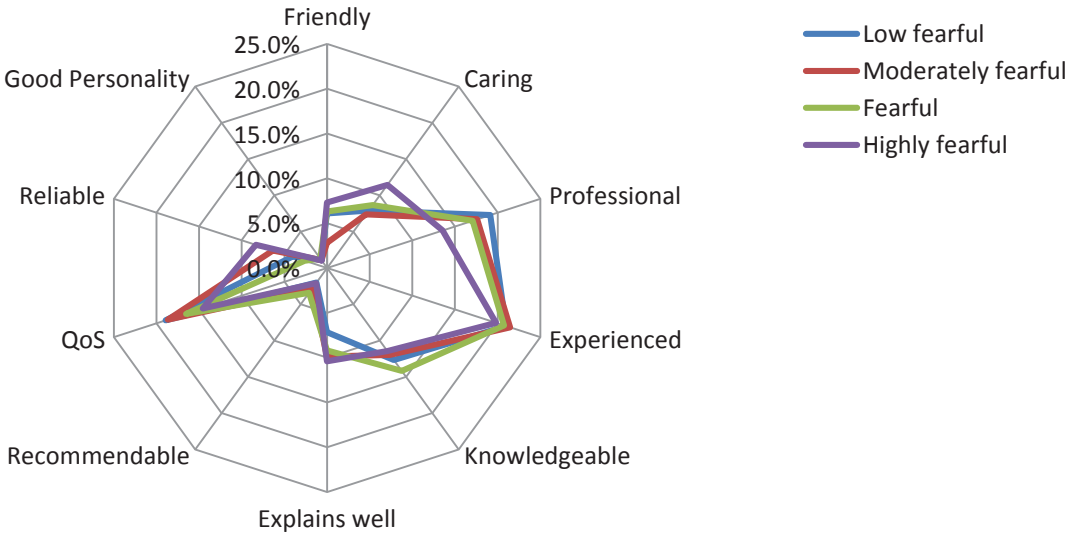


Figure 5.34: Dentists' qualities preferred by 4 groups of participants based on level of fear

Again, similar to the results of dentists' qualities preferred by different groups of personality traits, the preferred dentists' qualities by groups based on different levels of dental fear does not significantly change, as shown in the graph above. A comparison between the ways various groups of participants from levels of dental fear describe their existing dentists and ideal dentists is shown in the graphs below.

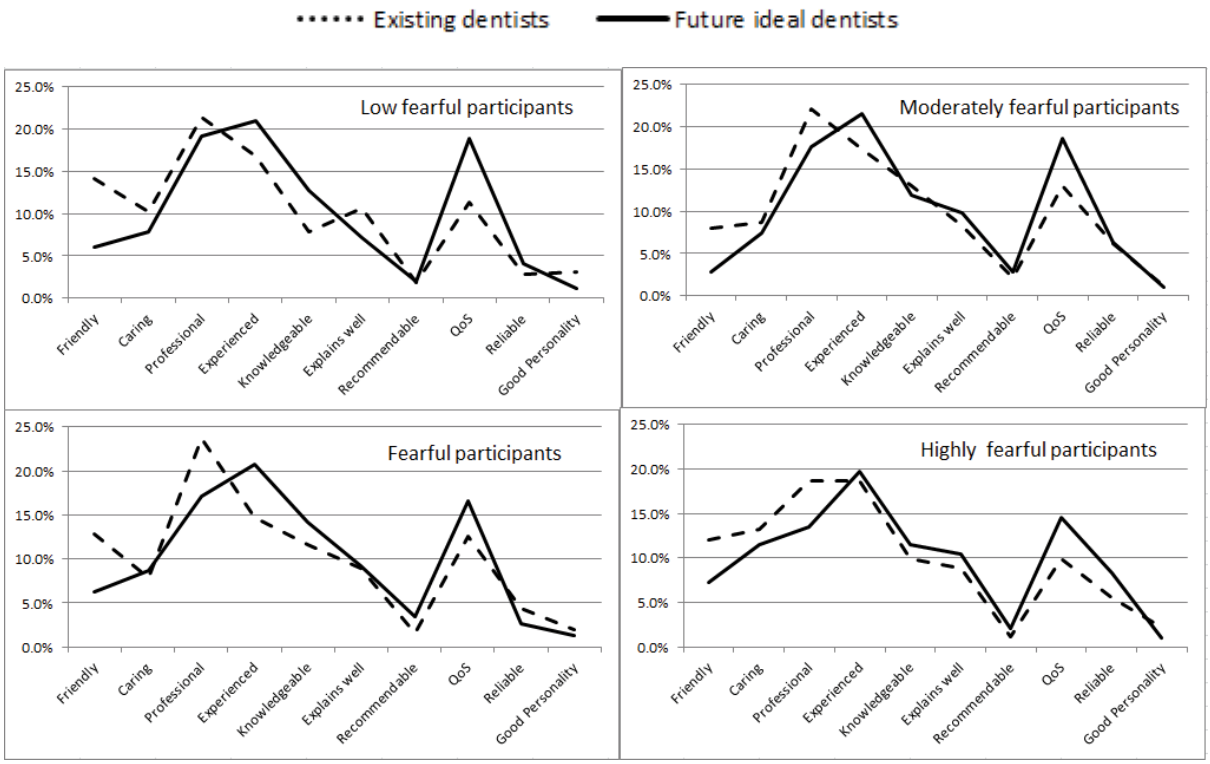


Figure 5.35: Comparison between dentists' qualities described for existing vs ideal dentists by fear groups

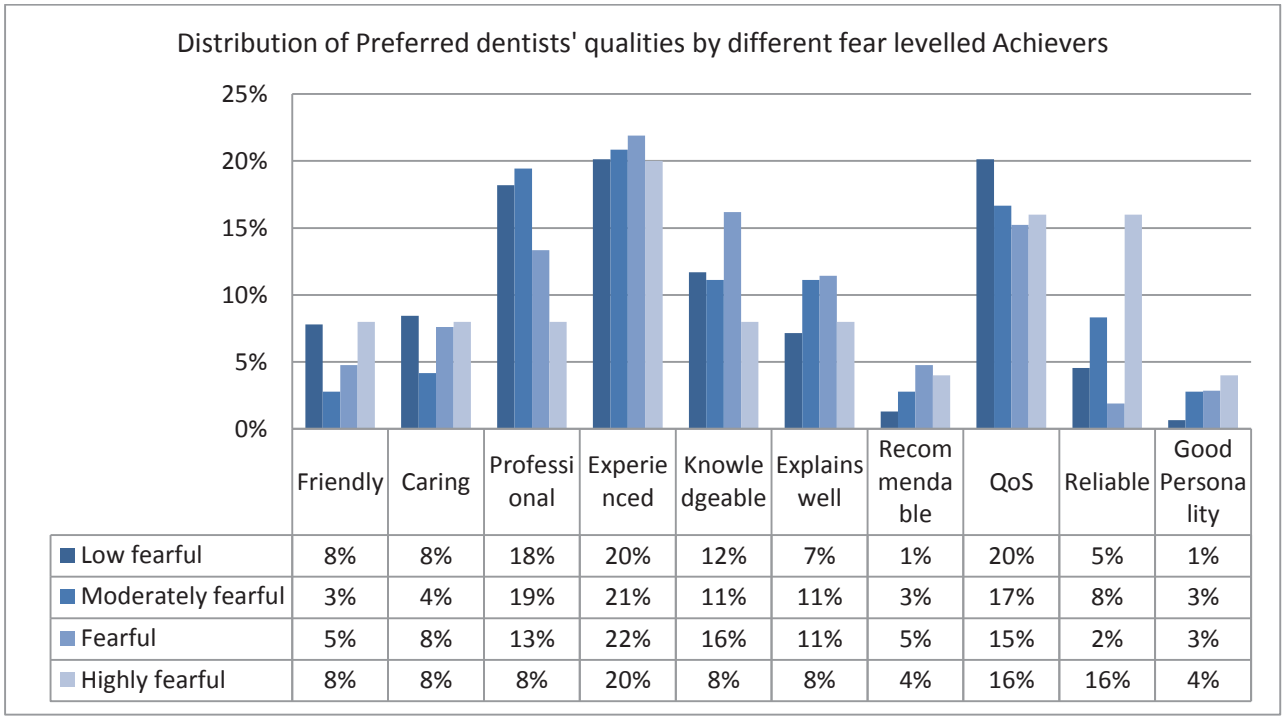
From the graphs in Figure 5.35 above, it can be seen that almost all participants preferred more quality of service from their ideal dentists. Apart from 'quality of service' as dentists' quality, the participants seem to be happy with their other dentists' qualities and hence they choose to stay with their regular dentist, as shown in Figure 5.28 above.

5.4.3.3. Based on both personality traits and dental fear

Preferred dentists' qualities by different groups of participants who are classified based on personality traits and levels of dental fear are discussed above. By combining both personality traits and dental fear, the participants can be further classified.

Only two groups of participants from the personality traits 'Achiever' and 'Perfectionist' are briefly discussed in this section. The top 3 most important dentists' qualities nominated by 'achiever' and 'perfectionist' are compared by segmenting the participants by their different levels of dental fear.

Experienced and professional dentists are the most important qualities of dentists but highly fearful achievers and perfectionists prefer to have reliable and friendly dentists respectively, as shown in the graphs below.



	Friendly	Caring	Professional	Experienced	Knowledgeable	Explains well	Recommendable	QoS	Reliable	Good Personality
Low fearful	8%	8%	18%	20%	12%	7%	1%	20%	5%	1%
Moderately fearful	3%	4%	19%	21%	11%	11%	3%	17%	8%	3%
Fearful	5%	8%	13%	22%	16%	11%	5%	15%	2%	3%
Highly fearful	8%	8%	8%	20%	8%	8%	4%	16%	16%	4%

Figure 5.36: Preferred dentists' qualities by Achievers with different level of fears.

This result is also summarised and drawn in the following radar graph.

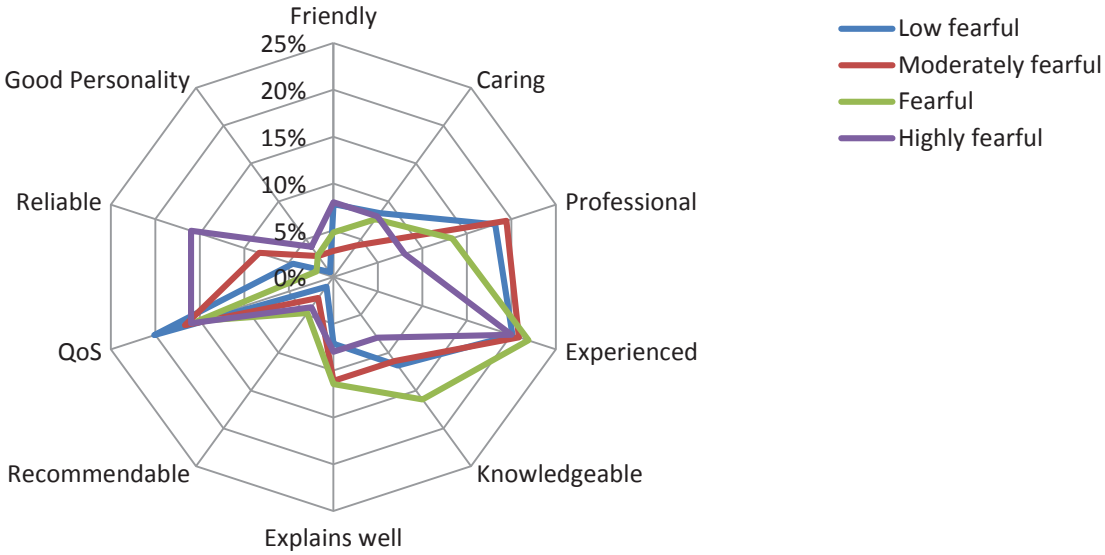
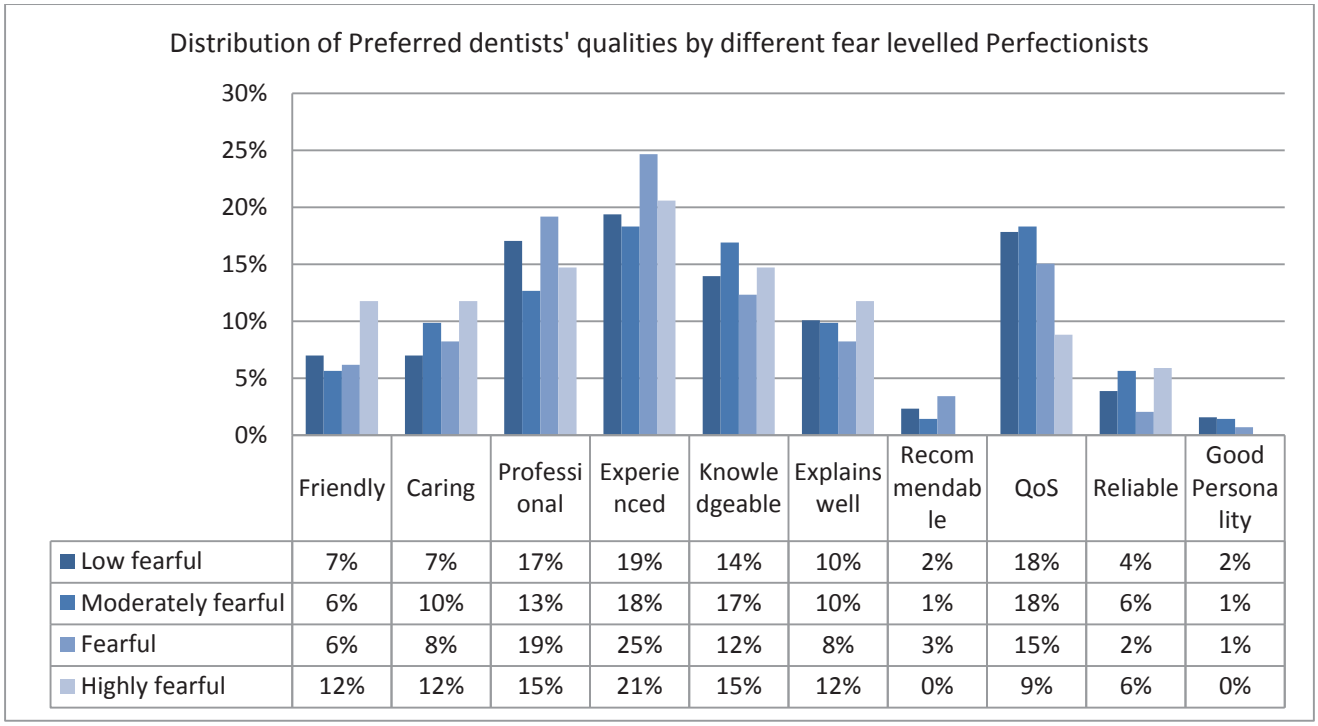


Figure 5.37: Preferred dentists' qualities by Achievers with different levels of fears.



	Friendly	Caring	Professional	Experienced	Knowledgeable	Explains well	Recommendable	QoS	Reliable	Good Personality
Low fearful	7%	7%	17%	19%	14%	10%	2%	18%	4%	2%
Moderately fearful	6%	10%	13%	18%	17%	10%	1%	18%	6%	1%
Fearful	6%	8%	19%	25%	12%	8%	3%	15%	2%	1%
Highly fearful	12%	12%	15%	21%	15%	12%	0%	9%	6%	0%

Figure 5.38: Preferred dentists' qualities by Achievers with different level of fears.

This result is also summarised and drawn in the following radar graph.

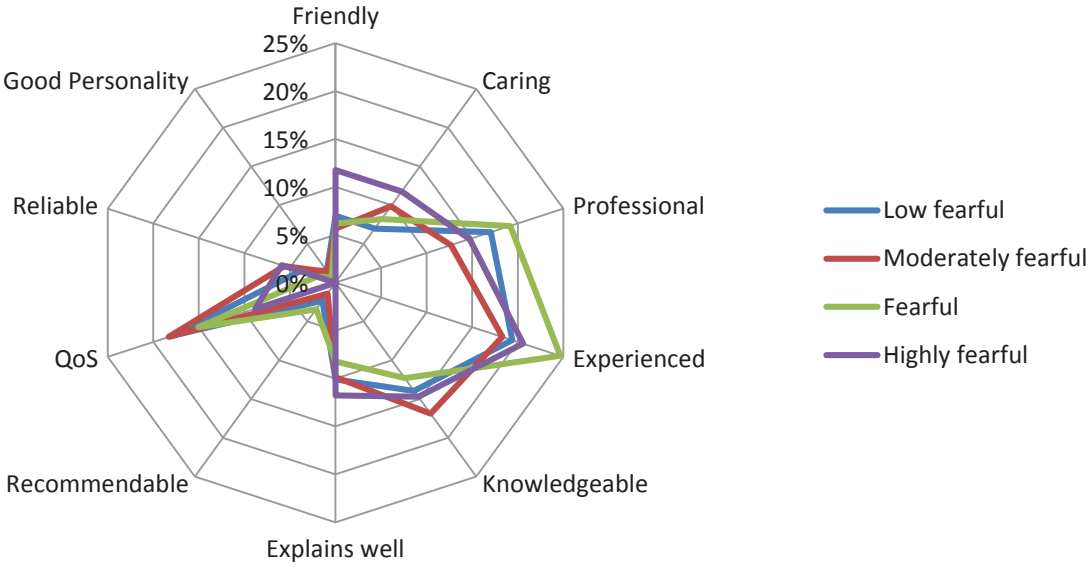


Figure 5.39: Preferred dentists' qualities by Achievers with different level of fears.

To a certain extent, there is not much difference between two different personality traits except for certain results for participants with certain levels of dental fear such as 'knowledgeable' dentists for fearful participants from the 'Achiever' personality trait.

Similarly, other variables can also be analysed by classifying the participants from different levels such as personality traits, levels of dental fear and others. The top 3 most important criteria patients consider

when searching for dentists are experienced dentists, location and cost from section 5.4.1. However, when the collected data is further analysed, it can be seen that the less fearful achievers and perfectionists also consider recommendations provided for the dentists as well. Similarly, highly fearful achievers recognise patients' reviews are important as shown in the graph below.

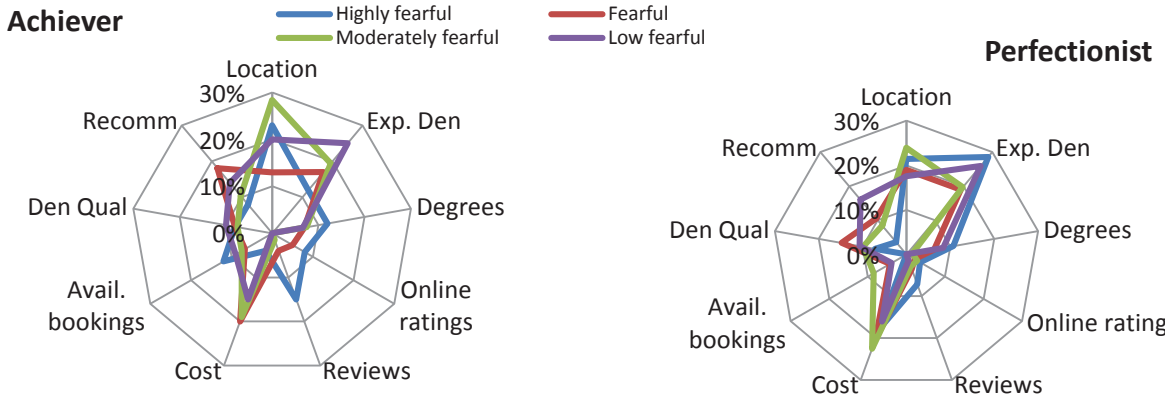


Figure 5.40: Most important criteria considered by Achiever and Perfectionist with different level of fears.

5.5. Matching Algorithm for dental care recommendation system

Dental care recommendation systems match dentists when patients are searching for a new dentist for specific dental treatments. Understanding interconnections between dentists and patients is critical for successful matching between two groups of people (Kutty et al. 2014) and it is possible through social networks. Usually, patients ask their friends and families which is a form of a social network when searching for a dentist. As discussed earlier, online platforms have been gradually replacing this phenomenon of sharing information with peers. In this study, the proposed trust-enhanced information model for dental care recommendation systems within the dental care social network has been discussed. This is where patients have their own profile. Through collaborating filtering (CF) the most suitable dentists would be recommended by analysing patients' profiles. Similar patients are determined not only from their similarity in terms of objective information but subjective criteria is emphasised and more importantly, personality traits are incorporated as well. User profiles of patients are anticipated to be enhanced by analysing their feedback and reviews collected from the social network and their involvement with other networks.

In this study, the matching process is enhanced by applying the 4 major trust components discussed in the model. As described in the previous chapters, subjective qualities are incorporated in both patients and dentists' profiles to improve the quality of recommendations. Then, the suitable dentists are recommended based on the information gathered from objective criteria selected by the patients and the information learnt from the network.

High level definition of the proposed matching algorithm after profiling both patients and dentists is shown below:

Input: Patients and Dentists profile

Output: List of dentists for each dental patient

Function: A simple loop

Get list of dentists based on criteria such as location, insurance provider, speciality, and so on

1. Cluster dental patients based on own attributes such as their personality types, age-group, treatments, frequency of visits, levels of dental fear and others $\{p_1, p_2, p_3, \ldots\ldots\ldots p_m\}$.
2. Cluster dentists with 10 dentists' qualities $\{d_1, d_2, d_3, \ldots\ldots\ldots d_n\}$ into y number of groups with various combinations of dentists' qualities.
3. For each cluster of patients with specific attributes $\{C_1, C_2 \ldots. C_x\}$

   Compare the patients' and dentists' profiles.

4. Sort the difference for each dentist and find the most suitable.
5. Present the top list of dentists as the recommended list.

Sample code:

```
for (int i = 0; i < PatientProfiles.Count; i++)
{
  // Get a single patient's profile {p1,p2,p3,...pm}
  var SinglePatientProfile = PatientProfiles[i];
  // Loop each dentist's profile and find the best match
  for (int j = 0; j < DentistProfiles.Count; j++)
  {
    // Get single dentist's profile {d1,d2,d3,...dn}
    var SingleDentistProfile = DentistProfiles[j];
    // compare dentist's profile and patient's profile
    listDifference.Add((double)Math.Abs(SinglePatientProfile -
SingleDentistProfile));
  }
  // sort the difference for each patient and find the suitable dentist
  listDifference.OrderByDescending(c => c);
  // return the top N dentists with the smallest difference
  listDifference.GetRange(0, N);
}
```

Figure 5.41: High level definition and sample code for the proposed matching algorithm

5.5.1. Comprehensive profiling of patients

As discussed in section 5.3.1 earlier in this chapter, patients are profiled from personality traits, levels of dental fear and other objective criteria that they select. Once the patients start interacting with the social network, similar patients can further be classified by understanding implicit information from the interactions within the network. These types of information can then be stored in the network and when the patient searches for a dentist when they move to new city or any other reason, the most suitable dentist may be recommended.

There are many types of patients which can be distinguished when profiling by combining personality traits and other variables. Specific rules for a particular type of patients can be constructed. Based on objective and subjective criteria selected at the time of a search and other information stored in the profile, the patient can be matched. From the survey, some other variables such as age group, frequency of visits, number of years has been visiting the same dentist, types of treatments and other are collected. These variables are added to filter and create new matching rules in this section.

For demonstration purpose, two types of patients are extracted from the survey. For example, patient type 'a' from the participants who belong to personality trait of 'Achiever' and 'b' from another group of personality traits of 'Perfectionist' with other variables selected by them in the survey as shown in the boxes below. Their preferred dentists' qualities for their ideal dentist are recorded and presented in a graph format below.

Patient type 'a':

Achiever → Gender Male → Age group (46-55) → Low fearful to visit dentist → Visits dentist annually → For regular check-up

Preferred dentists' qualities (weightings):

Experienced (0.286), Professional (0.143), Friendly (0.143), Knowledgeable (0.143), QoS (0.143), Reliable (0.143).

Distribution of preferred dentists' qualities by the patient type 'a' is represented by a line graph below:

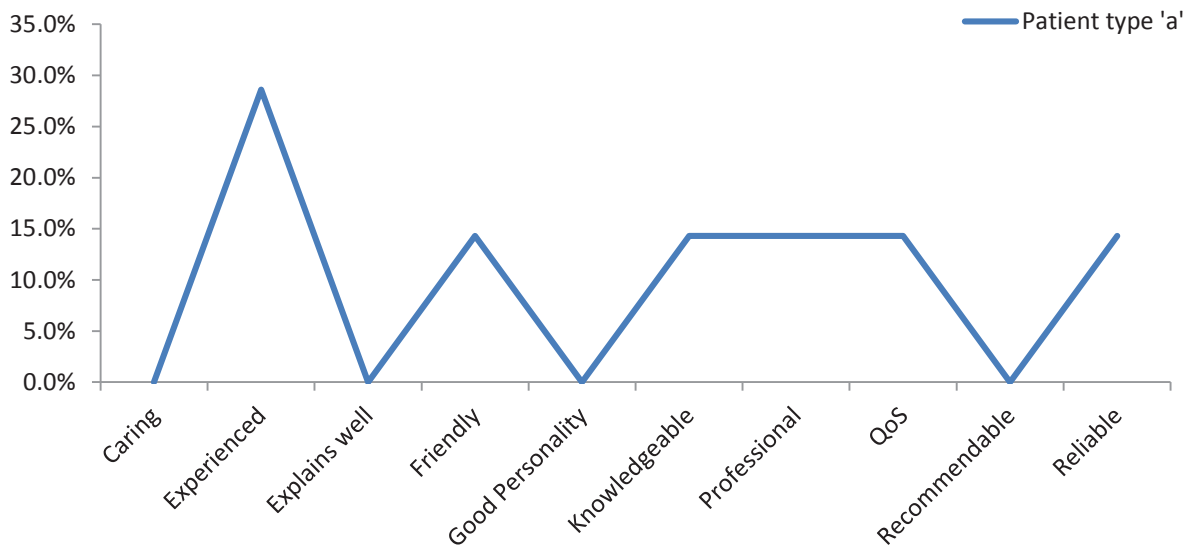


Figure 5.42: An example of dentists' qualities preferred by a patient type 'a'

Patient type 'b':

Perfectionist → Age group (26-35) → fearful → visits for scaling → visits annually

Preferred dentists' qualities (weightings):

Experienced (0.288), Professional (0.22), QoS (0.136), Knowledgeable (0.119), Caring (0.068), Friendly (0.051), Reliable (0.051), Explains well (0.051), Recommendable (0.017) and Good personality (0.00)

Distribution of preferred dentists' qualities by the patient type 'b' is represented by a bar chart below:

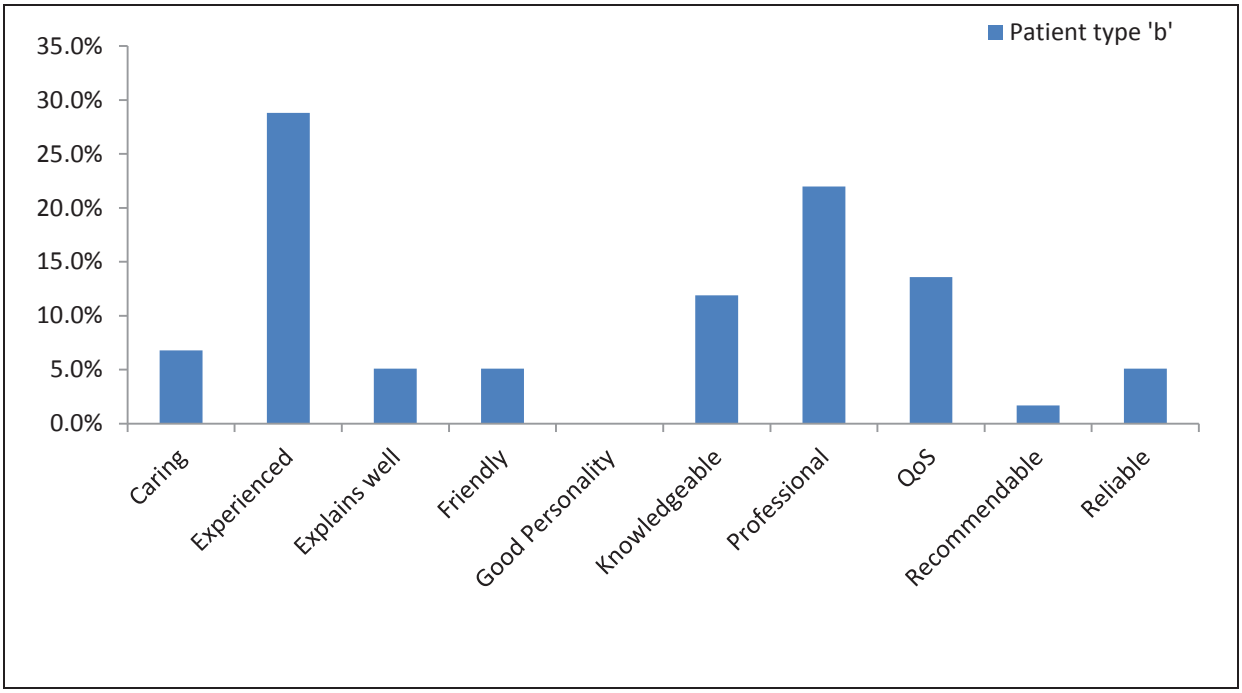


Figure 5.43: An example of dentists' qualities preferred by a patient type 'b'

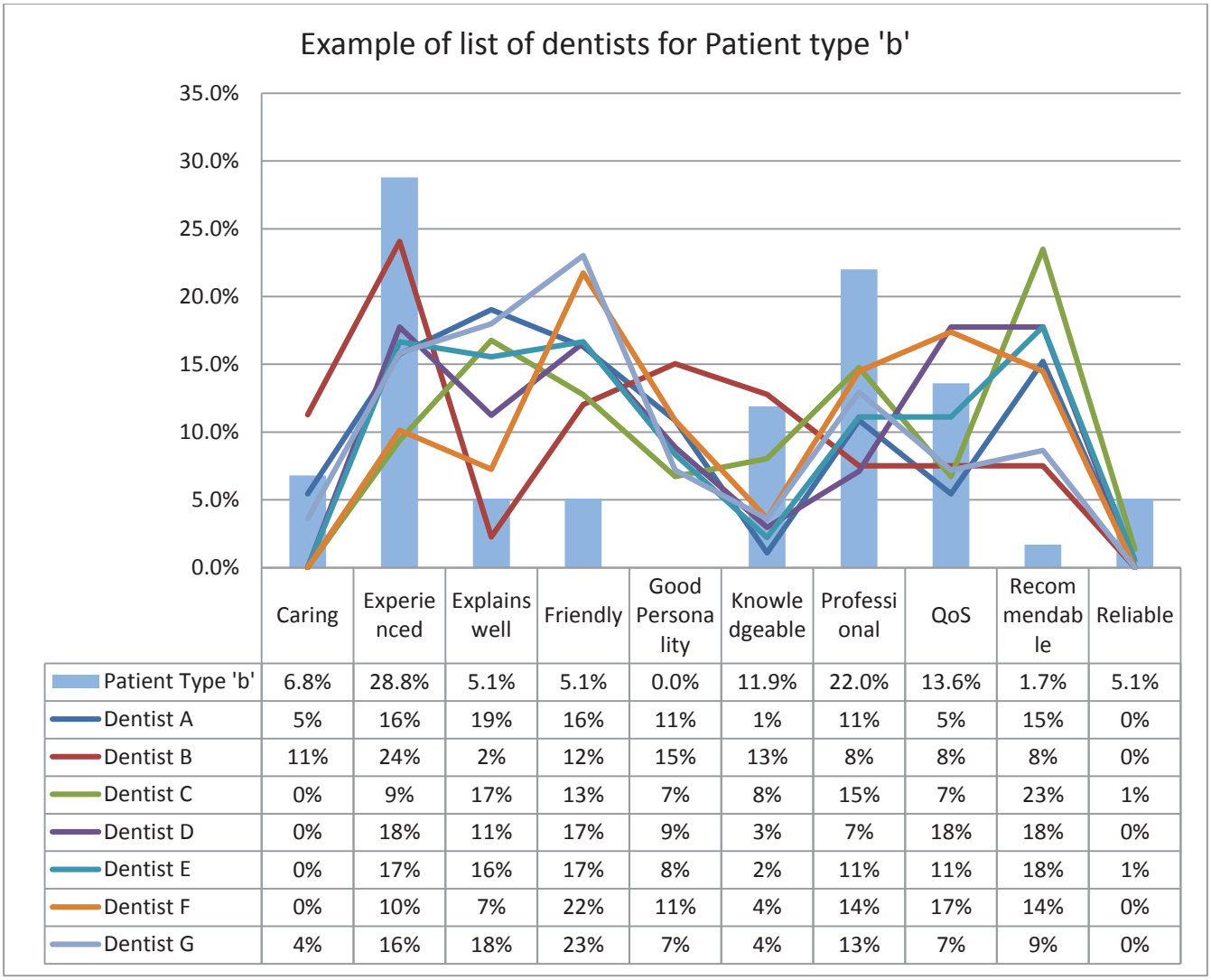
5.5.2. Matching algorithms

The aim of this study is to improve the quality of recommendation of dentists to patients by analysing subjective information available for both patients and dentists in the network. Matching algorithms are formulated by integrating the subjective qualities in their profiles. For the above mentioned types of patients, the most suitable dentist is recommended by the following methods:

5.5.2.1. Nearest neighbour classification

Dentists are profiled from dental crowdsources as described earlier in section 5.3.2. They have been categorised from their subjective dentists' qualities and are shown in Figure 5.12 and 5.13 earlier in this chapter. The same list of dentists is taken for an example in this section. Let's say from the list of 7 dentists in the graph (Dentist A to Dentist G), if the patient type 'b' from needs to be matched, the dentists' qualities will be compared with each dentist in the list and shown in Figure 5.44 below. The dentist with the lowest difference between dentists' qualities will be listed first in the result and consecutively other dentists with minimum difference in dentists' qualities will be listed.

The recommended list is created by combining the graph from the figure 5.13 for dentists and the figure 5.43 for the patient type 'b' and shown in Figure 5.44 below.



	Caring	Experienced	Explains well	Friendly	Good Personality	Knowledgeable	Professional	QoS	Recommendable	Reliable
Patient Type 'b'	6.8%	28.8%	5.1%	5.1%	0.0%	11.9%	22.0%	13.6%	1.7%	5.1%
Dentist A	5%	16%	19%	16%	11%	1%	11%	5%	15%	0%
Dentist B	11%	24%	2%	12%	15%	13%	8%	8%	8%	0%
Dentist C	0%	9%	17%	13%	7%	8%	15%	7%	23%	1%
Dentist D	0%	18%	11%	17%	9%	3%	7%	18%	18%	0%
Dentist E	0%	17%	16%	17%	8%	2%	11%	11%	18%	1%
Dentist F	0%	10%	7%	22%	11%	4%	14%	17%	14%	0%
Dentist G	4%	16%	18%	23%	7%	4%	13%	7%	9%	0%

Figure 5.44: Comparison of what Patient Type 'b' prefers and the list of dentists available in the location

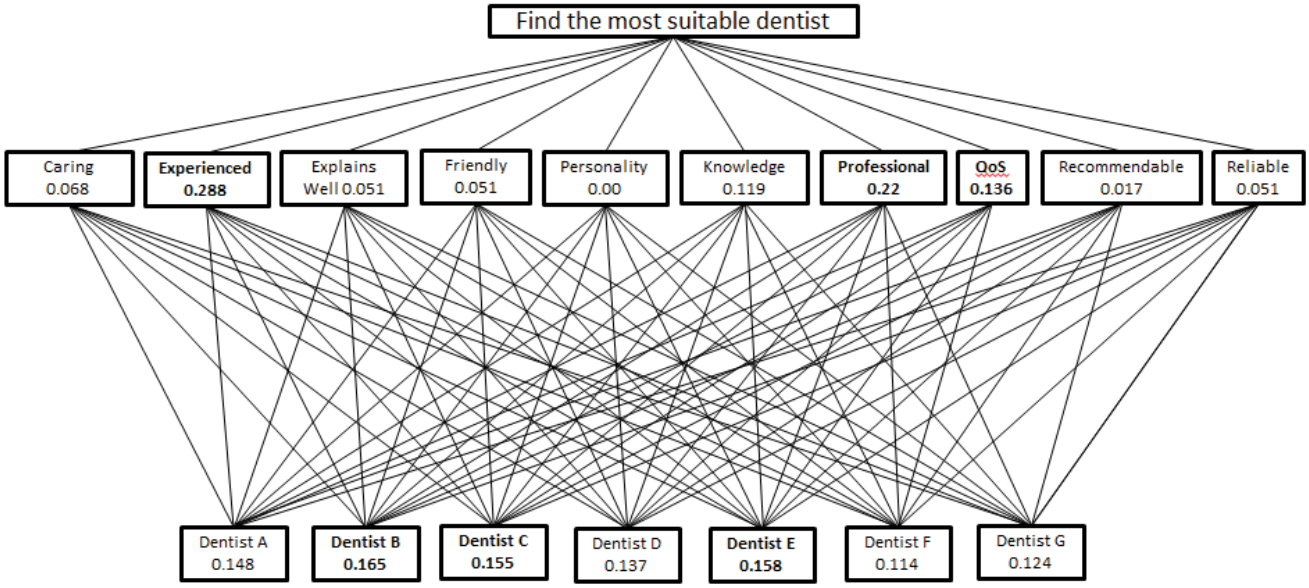
Taking all dentists' qualities into consideration, the list is filtered by finding out the difference between the weightings of the dentists and the preferred dentists' qualities by the patient 'b'. The following list of dentists is recommended as the descending order.

Table 5.8: List of recommended dentists from the example by using nearest neighbours

Order	List of dentists	Nearest distance
i.	Dentist B	0.66
ii.	Dentist G	0.90
iii.	Dentist D	0.93
iv.	Dentist E	0.93
v.	Dentist F	0.93
vi.	Dentist C and	0.96
vii.	Dentist A	0.99

5.5.2.2. Analytical hierarchy process (AHP)

The same list of dentists and the patient are used to analyse another matching technique called AHP. The prefered dentists' qualities derived for the patient type 'b' from the Figure 5.43 is used as the criteria in the AHP to filter the list of 7 dentists in the example.



Caring	0.33	0.50	0.00	0.00	0.00	0.00	0.17
Experienced	0.17	0.19	0.08	0.18	0.18	0.08	0.13
Explains well	0.24	0.02	0.17	0.13	0.19	0.07	0.17
Friendly	0.16	0.09	0.10	0.15	0.16	0.16	0.17
Good Personality	0.19	0.19	0.10	0.14	0.14	0.14	0.10
Knowledgeable	0.04	0.34	0.24	0.10	0.08	0.10	0.10
Professional	0.16	0.08	0.18	0.10	0.16	0.16	0.15
QoS	0.09	0.09	0.09	0.26	0.18	0.21	0.09
Recommendable	0.17	0.06	0.21	0.18	0.19	0.12	0.07
Reliable	0.00	0.00	0.67	0.00	0.33	0.00	0.00

Figure 5.45: Applying AHP to rank the list of dentists for the patient type 'b'

Seven dentists who are profiled from ten dentists' qualities are arranged in [10 x 7] matrix and it is multiplied by [7 x 1] matrix as the preferred dentists' qualities preferred by the patient. The outcome of [10 x 1] matrix shows the preferred alternatives or dentists. The list is organised in ascending order so that the first in the list ise the most suitable dentist. From figure 5.45 above, the weights are shown in the table below:

Table 5.9: Recommended list of dentists from the example by using AHP

Order	List of dentists	Weights
i.	Dentist B	16.5%
ii.	Dentist E	15.8%
iii.	Dentist C	15.5%

iv.	Dentist A	14.8%
v.	Dentist D	13.7%
vi.	Dentist G and	12.4%
vii.	Dentist F	11.4%

The list of suitable dentists out of seven dentists are compared between the two above tables. The order of dentists are different in those tables. The nearest neightbour matching technique measures the nearest distance of each preferred dentists' qualities of the patient with all seven dentists. However, through AHP, the weights are magnified based on the weightings of the criteria for the patient 'b'.

5.5.2.3. Comparison of two matching algorithms

The results from the two matching techniques used above are compared. Although Dentists D, E and F have the same absolute value of 0.93 from the first algorithm, distance function, they are ranked differently from the second method, AHP. Therefore the relationship between two sets of ranks are measured by Spearman's rank correlation.

Spearman's correlation coefficient between two ranks ρ(rho) = + 0.178571

Table 5.10: Correlation coefficient between two ranks

Correlations

			RankDistance	RankAHP
Spearman's rho	RankDistance	Correlation Coefficient	1.000	.179
		Sig. (2-tailed)	.	.702
		N	7	7
	RankAHP	Correlation Coefficient	.179	1.000
		Sig. (2-tailed)	.702	.
		N	7	7

A small positive correlation between two ranks shows that the ranks are correlated with each other but only with a linear margin. Only the first rank from both techniques are the same and the rest are not in this case. Only seven dentists are selected for the purpose of this demonstration.

The distance function only calculates the distance between the preferred dentists' qualities by the patient versus dentists' qualities of each dentist available. However, the AHP method multiplies the weightings and therefore the figures are magnified based on the preferred dentists' qualities by the patient.

5.5.3. Summary

Aligned with the increased number of people using social media, more dental patients are using online platforms than ever before to search for a dentist. Although, the main source of finding a dentist is either a friend or a family member, an increasing number of people are using online searching or recommendation systems to find their new dentists. The results from both surveys showed that the participants are willing to use online recommendation systems to find new dentists.

Recommendation systems are gaining popularity and performing well in the online world to recommend different items. User profiling is the backbone for any recommendation system. The user profile generally intends to capture related knowledge from the user to understand the context so that a reliable recommendation can be provided. In this study, patients are profiled not only by their objective preferences for choosing a dentist, but also from their subjective qualities such as level of dental fear and personality traits determined by the personality test. Learning subjective information implicitly from OSNs to profile patients may be possible but due to some challenges like privacy and identification, the process is not carried out in this study.

Dentists are in general, classified with their speciality for different dental treatments and number of years of experience. In this study, we have recognised the importance of the subjective qualities of dentists to patients. Patients usually describe their dentists subjectively by using certain terminologies when they write reviews or feedback after their dental treatments. The terminologies are categorised in terms of ten dentists' qualities and the dentists are profiled based on these qualities. Thus, an aggregation of previous patients' perceived behaviour is used to describe and profile a dentist.

The subjective aspects of the trust components from the proposed model are captured and used in profiling both patients and dentists. Preferred criteria, search methods and dentists' qualities are analysed from the survey data to further classify the patients and derive matching rules for recommendations. Participants from the survey are further classified with different variables to differentiate between them. When the participants are classified based on levels of dental fear and personality traits, a slight variation of their preferences is noted and discussed.

For demonstration purposes, two types of participants from the survey are randomly selected and analysed for their preferred dentists' qualities based on all the responses. A list of seven dentists is also randomly chosen from New York to find out which one would be the most suitable dentist for the patient. Results from the two matching techniques are compared to show how they differ. The ranking of dentists are positively correlated from those two matching techniques to show that they are somewhat related to each other. The result from the AHP method is taken as the better rankings of dentists as the recommended list.

5.5.3.1. Related work

The online world has been continuously evolving and most of the online shops now apply some type of product recommendation system (Heimbach et al. 2015) by capturing users' preferences and interests. Good user profiles need to be constructed for reliable recommendations to the users. Schiaffino & Amandi (2009) mentioned various types of content for user profiles and how they could vary in different areas of application. Besides, users' preferences and interests, much more information can be added such as background knowledge, skills, behaviour, individual characteristics, interactions and feedback to improve the accuracy of recommendations.

There have been several studies recently done for recommendation systems in the social network environment but there is not much focus on social relationships within the network. With the growing trend of social media usage, social information has been increasingly present in OSNs (Heimbach et al. 2015) which can be used for profiling users. Li et al. (2014) have also reinforced that there is a significant relationship between users, which is usually hidden, and which provides a great opportunity to profile users. Social connections among users in the network have a significant influence when recommending an item or a professional to other users. The same phenomenon can be derived for better recommendations by understanding the relationships online (Guo et al. 2015) because there are massive amounts of data available.

Some other researchers have been focussing their studies in the health area. Batool et al. (2012) and Zhang et al. (2013) have examined social media posts to profile patients. But they have only considered explicit information from the posts in Facebook and Twitter. We have used dental reviews to classify dentists subjectively because most of the reviewers describe their dentists subjectively and provide implicit information about their dentists. For patients, we have added personality traits to describe patients subjectively in their profiles.

Hu & Pu (2010) have explored the similarity of users based on personality from social networks. Facial expressions have been suggested to identify personality besides popular personality tests (Schiaffino & Amandi 2009). These studies are done to acknowledge the similarity and differences between users with different personality traits.

5.5.3.2. Challenges and Limitations

In this chapter, patients and dentists are first profiled from subjective criteria. A suitable match between them is explored by analysing survey data collected during the study. However there are many challenges and limitations. These are listed below:

Despite our attempt to profile dentists based on subjective qualities described by previous patients of the dentists, there are some other challenges in the process. They are summarised below:

- Satirical or ironical views in the reviews are difficult to be recognised in the text mining to analyse the terminologies used to describe dentists.
- Only a few reviews per dentist make it infeasible because the reviews may be biased or they could even be coming from someone the dentist knows personally (schilling attack). Hence, we have only analysed the reviews for a dentist who has a minimum of 10 reviews.
- Online reviews are still not widely accepted or used by the public for dental reviews.
- Due to privacy and identity issues, it is not possible to find out the source of the reviews and the same person may have multiple identities to write reviews.
- Some sites may filter the reviews before publishing online which creates challenges to find out if the patients are actually expressing their feelings about their experiences.

Patients are classified subjectively from the questionnaires publicly available for the DISC personality test. Matching rules are prescribed by analysing results from the main survey. Some of the challenges and limitations are mentioned as below:

- Dentists are extracted from dental crowdsources in the USA. The list of dentists used in the analysis in this chapter is from New York City. However, the participants of the survey were considered as dental patients for matching and they were limited to Australia only. The matching algorithm is created for Australian patients with US dentists due to the limitations in the number of dental reviews available in Australia.
- Although the total number of participants is 580 for this survey, when grouped from 15 different personality traits from the DISC personality test, only 5 groups of participants have 50 or more participants. The other 10 groups are not analysed because there is not enough participants for further analysis.
- In fact, requesting patients to do a personality test before searching for a dentist, may not be a practical approach. In the future, patients will be profiled automatically similar to the dentists.
- Analysis is relying on the questionnaires from the personality test and the matching rules are also heavily dependent on the results from the personality test used.
- Not every participant nominated their 3 most preferred dentists' qualities when they were asked to choose the 3 most important dentists' qualities. Some of the participants chose less than the 3 which was instructed to them; hence the responses were not equally distributed.
- There is no consistency on questions and choices of answers between 2 surveys run for dental patients and hence they cannot relate to each other.
- The survey was run anonymously through a third party provider but the participants are only from Australia in the second survey.
- For experimental purposes, it is not practical to send one patient to a number of dentists to compare the dentists' qualities.

5.5.3.3. Open issues

There are many open issues in improving dental care recommendations:

- There is no clear explanation on how dental treatments are different to other healthcare treatments. Many sites combine dentists with other health professionals.
- One of the popular sites, Yelp combines Dentists reviews with other general businesses.
- The privacy rules impose challenges for the users who share information in the networks.
- Users are able to create their own profile for the site and hence it is difficult to determine the authenticity of their profiles.
- There is no system in place to stop people posting fake or wrong information about dentists on review sites.
- A regulatory body such as the Australian Dental Association (ADA) is not in favour of review sites. This is another challenge to get approval for the proposed system. For example, one of the health insurance companies, NIB in Australia had difficulty to get acceptance from ADA a few years ago. Hopefully, the experience with NIB now makes it easier for the regulatory body to approve the proposed model as there is a benefit to all parties involved.
- Dental practices can implement the proposed model to their system to understand how dentists within the practice are performing. This tool can be used to understand performance and provide necessary training to the dentists who are falling behind in terms of looking after their patients because of their behaviour towards the patients.

5.5.4. Future work

Both patients and dentists can be further classified based on many other criteria to find out the correlation between which attribute and criteria combination is common or what is preferred by a particular type of patient group. In the future, it is anticipated that the patients' profiles can be done more efficiently through their involvement in social networks. Dental patients have not been sharing enough information regarding dental issues online to be able to profile the patients based on the information available online whether this is reviews or feedback or just comments.

In order to profile patients, other reviews and posts review sites like Yelp can be analysed to understand what type of patients they are. The analysis can be based on the language that is used by analysing their overall reviews for other businesses, for example, positive, excited, concerned, friendly, easy to please, hard to please, hate everything, asking many questions, etc. If these types of information can be verified with other information available about them online such as other social media sites like Facebook and Twitter, the information will be more accurate and reliable for profiling purposes. It is anticipated that

profiling of patients will continue to be improved by using information from reviews posted about dentists and other businesses in general.

The matching algorithms for dental care recommendation systems are anticipated to be verified from many other matching techniques in the future. As long as profiles for both dental patients and dentists are done properly to include more information on subjective aspects, the recommended list will be improved. However, results from different matching techniques will be tested.

A dental social network where all the identities are known to the system and the reviews are collated from other sources in one place would reduce some of the challenges mentioned above. However, an approval from regulatory bodies and related parties will remain a challenge in terms of establishing such a network.

Accepted papers from this chapter:

Pradhan, S., Gay, V and Nepal, S. (2014) "Improving dental care recommendation systems using patient and dentist profiling", The 25th Australasian Conference on Information Systems (ACIS 2014), Auckland, New Zealand, December 8-10 2014. <Online: http://hdl.handle.net/10292/8053>

Pradhan, S., Gay, V and Nepal, S. (2015) "Analysing and using subjective criteria to improve dental care recommendation systems", The 19th Pacific Asia Conference on Information Systems (PACIS 2015), Singapore, 6-9 July 2015. <Online: http://aisel.aisnet.org/pacis2015/99>. (Nominated for the Best Paper)

Chapter 6

6. Conclusion and Future Directions

Finding a dentist has become easier with the growing popularity of online recommendation systems and social media. Emerging social media and other technologies have provided a means to make recommendations readily available for internet users. However, due to the invasive nature of dental treatments, trust is an important issue for patients to determine the suitability of a dentist. Traditionally, the most trusted people in a person's life, such as friends and family, are the major sources for dental referrals. Since the number of social networking users is growing, the level of trust in online information has been increasing. This inherent trust can assist users when filtering a list of dentists to identify a suitable dentist for a particular need.

In this study, we have found that trust can be acquired from both offline and online social networks. Trust is analysed from multiple perspectives in relation to its impact on the quality and effectiveness of recommendations in dental care recommendation systems.

The steps followed in this study are summarised below:

- First, the study considered the preferred criteria of dental patients when they were searching for a dentist. Apart from location and cost, the subjective qualities of dentists such as their quality of service, experience, reliability, etc. were the most important criteria for patients.
- Second, online dental reviews were examined to extract the most commonly used words to describe dentists. The subjective characteristics of the dentists were found to be the mostly frequently used terminologies to describe a dentist. This outcome coincided with the results from the preference criteria survey conducted previously. These subjective qualities were then used to profile dentists.
- Third, the study recognised that patients are also an important element of recommendation systems as they can be profiled according to subjective information. However, there is currently a lack of information in dental reviews sites about patients. Indeed, there are no specific social networking sites which provide personal information about dental patients. In order to address the deficit in terms of the subjective information about dental patients, this study analyses the use of a personality test and levels of dental fear to classify dental patients subjectively. This test is in addition to the objective criteria which is employed for selecting a dentist.
- Finally, this study discusses the use of matching algorithms to enhance the quality of recommendations by taking into account the newly constructed profiles which include the subjective qualities of both dentists and patients.

6.1. Contributions

The main purpose of this study was to enhance the quality of dental recommendations for patients by incorporating trust within dental care recommendation systems. This study makes the following contributions:

- **Proposal of a trust-enhanced information model for dental care recommendation systems**

This study proposes a model that incorporates trust from multiple standpoints to enhance the quality of recommendations. The element of trust is evaluated from the following four trust components:

- **Context analysis** of situations where patients search for and visit a dentist, as well as the conditions under which dentists treat patients. Analysing patients' information in detail helps to profile patients as well as filtering the qualities of dentists preferred by them. The more situational variables that are available on patients' information, the better it is to classify patients. This, in turn, helps us to evaluate their preferences in terms of finding a suitable dentist. For example, identifying similarity of information such as symptoms, age groups, treatments, adverse reactions, etc. assists in making better associations with other users who are experiencing similar issues.
- **Relationship analysis** is one of the important components to measure trust between a) patients and dentists; b) patients and recommendation systems; c) new patients and existing patients of the same dentist. Most people find their dentists by consulting their family or friends, which is a major type of referral trust. The success of referrals is dependent on the strength of the relationship. The same mechanism of trust defines the type of referral of a dentist by previous patients to a new patient. A layer of complication is added when referrals from online media are used. A trust relationship between dentists and patients starts only after a dental visit, and depending on the success of the visit, the relationship continues or ceases. This is often revealed and expressed by the patients in dental reviews. The scope of these reviews can be expanded to include an evaluation of the relationships between existing as well as new patients and the effectiveness of the recommendation systems. When existing patients genuinely share their experience, the new patients are more likely to find the most appropriate dentists to choose from. Hence the relationship between patients as users and their relationship with dentists as well as with the system can improve the quality of recommendations.

- **Reputation analysis** of recommendation systems, dentists and other users in the systems. Sharing quality information in social networks determines the social network users' reputation whereas the patients' perception and ratings help shape the dentists' reputation. Dentists' reputation is based on a multitude of factors like professional accreditation, quality of service, behavioural approach to dental patients, recommendations, treatment skills etc. Rating scores on dental reviews are taken into consideration to profile dentists in this study. The scores are based on subjective variables such as patients' perceived experience and satisfaction from the dental treatment that they received from a particular dentist or dental practice.
- **Personality analysis** of both patients and dentists to identify their subjective characteristics. Whilst the subjective qualities of dentists are derived from dental crowdsources which profile dentists, the subjective qualities of patients are not yet available. A personality test is therefore used to profile patients in order to enhance the quality of recommendations and improve the effectiveness of the matching process.

Due to the increasing usage of social media, more information is accessible online to evaluate the trust components related to dental care recommendations. Consequently, the effectiveness and quality of the recommendations is enhanced by increasing the quality of information available. This makes it easier to choose a suitable dentist for a patient at any given time based on their individual preferences.

- **Profiling of dentists from dental crowdsources**

Dental patients search, filter and visit a particular dentist for their specific dental treatment. They choose their dentists based on how dentists are described by the trusted people in their life. This phenomenon has gradually transitioned from offline to online due to the growth of social media. Dentists are reviewed and described by their patients in dental reviews with star-rating scores. The most frequently used words to describe dentists subjectively are extracted from dental reviews to classify dentists in this study. The trust derived from the reputational rating (in the form of star-ratings) and subjective qualities sourced from dental reviews have been combined to profile dentists.

In this information age, dental patients find their dentists through social networks consisting of their friends, families or peers whether it is online or offline. Since social media has been dominating the online world and internet users are interacting daily with their friends, conversations about dentists and dental treatments are also appearing in social media. This argument is supported by two surveys conducted in this study. Nearly 50% of the participants in the first survey that sought to determine preference criteria used online dental recommendation systems if they were known to them. Similarly, although only 10% of the participants in the second survey used online search methods to find their

dentists, more than double the participants (23%) indicated that they would use online search methods to find their next dentist.

- **Profiling of patients from personality traits**

Dental patients are usually classified by their preferences when searching for a dentist such as their age group, location, type of dental treatments etc. Similar treatments by different patients are perceived differently because they have their own subjective qualities in terms of behaviour, attitude and understanding. This study recommends the inclusion of these subjective qualities to enhance the quality of recommendations. However, these qualities are not attainable due to privacy and identification challenges in the online platforms. Therefore for the purposes of this study, one of the popular personality tests was used to determine the personality traits of patients. Patients were classified into 15 personality traits from the DISC personality test. They were further classified based on age-groups, dental treatments, frequency of dental visits, level of dental fear, etc. to examine whether the preferred dentists' qualities varied for different categories of patients.

- **Matching rules to enhance the quality of dental recommendations**

In this study, we analysed how the subjective qualities of both patients and dentists could provide guidance to improve the matching of patients with dentists. Matching based on the profiles with subjective qualities enhances the quality of recommendations.

From analysing the responses of the 580 participants of the survey, no significant difference was found in the types of preferred dentists' qualities for different categories of patients with various personality traits. The most preferred dentists' qualities by patients with the most personality traits are experience, professionalism and quality of service. When the personality traits were combined with the relevant level of fear and objective criteria, their calculated preferences varied slightly, although not to a significant degree. It is therefore important to consider more subjective patient criteria in addition to their personality traits and objective criteria such as frequency of dental visits, types of dental treatments, hygienic dental behaviour, etc. Adding more criteria makes it easier to filter the patients' preferences. As patients' dental habits, hygienic behaviour, and other conditions are quite challenging to estimate even when they are available online, using a combination of other criteria such as dental treatments, frequency of visits, fear and types of personality traits have been useful in terms of identifying and filtering the preferred qualities of dentists in this study.

The proposed new trust-enhanced information model for dental care recommendation systems can be applied to unknown environments where patients have inadequate knowledge of the availability of dental care services (for example, while travelling overseas).

6.2. Future work and directions

Potential future work and research directions are summarised below:

- Profiling of patients from social networks. Based on reviews and posts on social media, we are hopeful that there will be enough information to understand a person's dental habits and attitude towards dental treatments.
- With the increased number of reviewers and users in social networks, it will be easier to see the relationships between users to measure the social influence on dental recommendations. This influence factor can be added to enhance the recommendations of dentists.
- It is envisaged that context analysis of patients or reviewers will help us to understand the specific situations of patients who have recommended or rated the same dentist. This work will determine the guidelines for the ratings and reviews written by the patients for specific types of dentists.
- It is recommended that all four trust components from the proposed trust model be combined to profile dentists and patients so that the quality of recommendations will be enhanced further.

Reference:

1. Adams, S.A. (2010). 'Revisiting the online health information reliability debate in the wake of "web 2.0": An inter-disciplinary literature and website review', *International Journal of Medical Informatics*, vol. 79, no. 6, pp. 391-400.
2. Aggarwal, C.C. (2011). *Social Network Data Analytics*, Springer, New York.
3. Ajzen, I. (2005). "Attitudes, personality and behavior. McGraw-Hill Education, Bershire, UK
4. Alsaleh, S., Nayak, R., Xu, Y. and Chen, L., (2011). "Improving matching process in social network using implicit and explicit user information," in Du. X et a. (eds) APWeb 2011, LNCS 6612, Pp. 313-320.
5. Anderson, R.M., Borgs, C.H., Chayes, J.T., Feige, U.M., Flaxman, A., Kalai, A.T., Mirrokni, S.V. and Tennenholtz, M. (2011). "Trust-based recommendation systems," United States Patent. Aug 2, 2011, Patent No. 7,991,841 B2.
6. Arazy, O., Kumar, N. and Shapira, B. (2010). "A Theory-driven design framework for social recommendation systems," Journal of the Association for Information Systems, September 2010, Vol. 11, Issue 9, Pp. 455-490
7. Armitage, C. J. and Reidy, J.G. (2012). "Evidence that process simulations reduce anxiety in patients receiving dental treatment: randomized exploratory trial," Anxiety, Stress & Coping: An International Journal, 25:2. pp. 155-165.
8. Armfield, J.M. (2010). "The extent and nature of dental fear and phobia in Australia," Australian Dental Journal, Vol. 55. Issue 4. pp. 368-377.
9. Avesani, P., Massa, P. and Tiella, R. (2005). "A trust-enhanced recommender system application: Moleskiing," ACM Symposium on Applied Computing,
10. Baden, R., Bender, A., Spring, N., Bhattacharjee, B., & Starin, D. (2009). Persona: an online social network with user-defined privacy. In ACM SIGCOMM Computer Communication Review Vol. 39, No. 4, pp. 135-146).
11. Balduzzi, M., Platzer, C., Holz, T., Kirda, E., Balzarotti, D. and Kruegel, C. (2010). "Abusing social networks for automated user profiling", in Jha, S., Rommer, S. and Kreibich, C. (eds.) Recent Advances in Intrusion Detection, LNCS 6307, Springer, pp. 422-441.
12. Batool, R., Khan, W. A., Maqbool, J., Afzal, M and Lee, S. (2012). Towards personalized health profiling in Social Network,
13. Beirne and et al (2008). 'Recall intervals for oral health in primary care paitents (Review)', The Cochrane Collaboration, Cochrane Oral Health Group, Wiley Publishers, Issue 4
14. Belkin, NJ and Croft, WB, (1992). "Information filtering and information retrieval: two sides of the same coin," Communications of the ACM, December 1992, Vol 35. No. 12. Pp. 29-38.
15. Bharadwaj, K.K. and Al-Shamri, M.Y.H. (2009). 'Fuzzy computational models for trust and reputation systems', Electronic Commerce Research and Applications, vol. 8, no. 1, pp. 37-47.
16. Bhuiyan, T., Xu, Y., Jøsang, A., Liang, H. and Cox, C. (2010). Developing trust networks based on user tagging information for recommendation making. Web Information Systems Engineering–WISE 2010, pp. 357-64.
17. Bhuiyan, T., Xu, Y. and Josang, A (2009). State-of-the-Art Review on Opinion Mining from Online Customer's Feedback. In: the 9th Asia-Pacific Complex Systems Conference, Tokyo, Japan, November 4 -7.

18. Bisgin, H., Agarwal, N., and Xu, X. (2012). A study of homophily on social media. World Wide Web. Vol. 15. Pp. 213-232. DOI 10.1007/s11280-011-0143-3.
19. Bliemel, M. and Hassanein, K. (2007). Consumer satisfaction with online health information retrieval: a model and empirical study. E-service Journal, 5, 55-83.
20. Boutet, A., Frey, D., Guerraoui, R., Kermarrec, A and Patra, R. (2014). "HyRec: Leveraging browsers for scalable recommenders," MIDDLEWARE'14, December 8 – 12 , France.
21. Boyer, C., Baujard, V. & Geissbuhler, A. (2011). 'Evolution of Health Web certification, through the HONcode experience', *Studies in health technology and informatics*, vol. 169, p. 53
22. Breen, K.J. and Greenberg, P.B. (2010). "Ethics in medicine – A clinical perspective Difficult physician-patient encounters", Internal Medicine Journal, Vol 40 pp. 682-688. Doi: 10.1111/j.1445-5994.2010.02311.x
23. Brownlie, J. (2008). "Conceptualizing trust and health", in Brownlie, J. Greene, A and Howson, A. (eds.) Researching Trust and Health, Routledge, Taylors & Francis Group, New York.
24. Brusilovsky, P. and Millan, E. (2007). User models for adaptive hypermedia and adaptive educational systems," in Adaptive Web by Brusilovsky, P., Kobsa, A. and Nejdl, W. (eds.), Pp. 3-53.
25. Burke, R. (2007). " Hybrid web recommender systems," in Brusilovsky, P., Kobsa, A. and Nejdl, W. (Eds.), The Adaptive Web, LNCS 4321, Pp. 377-408
26. Calisir, F., Gumussoy, C.A., Bayraktaroglu, A.E. and Karaali, D. (2014). "Predicting "Predicting the Intention to Use a Web-Based Learning System: Perceived Content Quality, Anxiety, Perceived System Quality, Image, and the Technology Acceptance Model." *Human Factors and Ergonomics in Manufacturing & Service Industries* Vol. 24 No.5. Pp.515-531.
27. Campos-Castillo, C. and Anthony, D. L. (2015). The double-edged sword of electronic health records: implications for patient disclosure. Journal of the American Medical Informatics Association, 22(e1), e130-e140.
28. Carmona, C.J., Ramírez-Gallego, S., Torres, F., Bernal, E., del Jesus, M.J. and García, S. (2012). Web usage mining to improve the design of an e-commerce website: OrOliveSur. com. Expert Systems with Applications,39(12), pp.11243-11249.
29. Carritore, C., Wiedenbeck, S. Kracher, B. and Marble, R.P. (2012). "Online trust and health information websites, *International Journal of Technology and Human Interaction,* Vol. 8(4), Pp. 92-115.
30. Carter, A.E., Carter, G., Boschen, M. AlShwaimi, E. and George, R. (2014). "Pathways of fear and anxiety in dentistry: A review." World J Clin Cases. 2014 Nov 16; 2(11): 642–653. Published online 2014 Nov 16. doi: 10.12998/wjcc.v2.i11.642 <http://www.wjgnet.com/2307-8960/full/v2/i11/642.htm>
31. Castellucia, C. (2012). "Behavioural tracking on the Internert: A technical perspective" in Gutwirth, S., Leenes, R. de Hert, P. and Poulletg, Y.(eds.), European Data Protection: In Good Health?, Springer Science+Business Media, DOI: 10.1007/978-94-007-2903-2_2.
32. Chamoro-Premuzic, T. and Funham, A. (2009). "Personality and intellectual competence," Lawrence Erlbaum Associates, New Jersey, USA
33. Chang, E., Dillon, T. and Hussain, F. (2006). Trust and Reputation for Service-Oriented Environments. pp. 110-118
34. Chiravirakul, P. and Payne, S.J. (2014), "Choice overload in search engine use?" CHI 2014, April 26 – May 1, Toronto, Canada, Pp. 1285-1294.

35. Chirita, P.A., Nejdl, W. and Zamfir, C., (2005). November. Preventing shilling attacks in online recommender systems. In Proceedings of the 7th annual ACM international workshop on Web information and data management (pp. 67-74). ACM.
36. Chung, T.S., Wedel, M. and Rust, R.T. (2015). Adaptive personalization using social networks. Journal of the Academy of Marketing Science 2015, Pp. 1-22
37. Clarkson J et al. (2010), 'The translation research in a dental setting (TRiaDS) programme protocol', *Implementation Science,* 5:57
38. Connelly, T.P. (2011) "Flawed: Consumer reviews sites for dentists and physicians", Huffingtonpost.com, posted on 15/12/2011.
39. Coreil, J. (2008). "Behavioural and Social Science Theory" Available online: https://au.sagepub.com/sites/default/files/upm-binaries/26637_Chapter4.pdf
40. Costa, P. T., Jr., & McCrae, R. R. (1998). Six approaches to the explication of facet-level traits: Examples from Conscientiousness. European Journal of Personality, 12, 117–134.
41. Crandall, D., Cosley, D., Huttenlocher, D., Kleinberg, J. & Suri, S. (2008). 'Feedback effects between similarity and social influence in online communities', ACM, pp. 160-8.
42. Dasgupta, S. and Ng, V. (2009). Mine the easy, classify the hard: A semi-supervised approach to automatic sentiment classification. Proceedings of the Joint Conference ACL-IJCNLP, Singapore. Pp. 701-709
43. Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Quarterly, 13(3), 319–339
44. Delbanco, T.L. (1992). "Enriching the doctor-patient relationship by inviting the patient's perspective," Annals of Internal Medicine, 1 March 1992, Vol 116, No. 5, Pp. 414-418, DOI: 10.7326/0003-4819-116-5-414
45. Deng, S., Huang, L. Yin, Y. and Tang, W. (2015). "Trust-based service recommendation in social network," *International Journal Applied Mathematics and Information Science,* Vol. 9. No. 3. Pp. 1567-1574.
46. Deshpande, A. & Jadad, A.R. (2009). 'Trying to measure the quality of health information on the internet: is it time to move on', *Journal of Rheumatology*, vol. 36, no. 1, pp. 1-3
47. Doyle, P. and Sixsmith, J. (2008). Exploring the feasibility of developing internet based health promotion materials for third level students. Health Promotion Research Centre, Galway.
48. Ellison B.N. and Boyd. D. (2013). Sociality through Social Network Sites. The Oxford Handbook of Internet Studies. Dutton, W. H. (ed.). pp. 151-172.
49. Elgin, C.R. (2012). 'Factors Affecting Patient Selection of an Orthodontic Practice' [Accessed online: http://etd.ohiolink.edu/view.cgi/Elgin Craig Ross.pdf]
50. Emmert, M., Sander, U., & Pisch, F. (2013). Eight questions about physician-rating websites: a systematic review. Journal of medical Internet research,15(2).
51. Eriksen H.M., Bergdahl, J. and Bergdahl M. (2008). 'A patient-centred approach to teaching and learning in dental student clinical practice', *European Journal of Dental Education,* 12, pp. 170-175.
52. Euzenat, J., and Shvaiko, P. (2007). Ontology matching (Vol. 333). Heidelberg: Springer.
53. Eytan, T., Benabio, J., Golla, V., Parikh, R. and Stein, S. (2015). "Social media and the health system," The Permanente Journal, Winter 2011, Vol. 15. No. 1.

54. Fang, H., Guo, G. and Zhang, J. (2015). “Multi-faceted trust and distrust prediction for recommendation systems, Decision Support Systems, Vol. 74, Pp. 37-47. DOI :10.1016/j.dss.2015.01.005
55. Fernandez-Luque L, Karlsen R, Melton GB (2012). HealthTrust: A Social Network Approach for Retrieving Online Health Videos, J Med Internet Res 14(1):e22, DOI: 10.2196/jmir.1985.
56. Filieri, R. (2015). “Why do travelers trust TripAdvisor? Antecedents of trust towards consumer-generated media and its influence on recommendation adoption and word of mouth,” Tourism management, Vol 51, Pp. 174-185
57. Fox, S. and Duggan, M. (2013). Health online 2013, Pewinternet.org << http://www.pewinternet.org/2013/01/15/health-online-2013/>>
58. Flick, U. (2015). Introducing research methodology: A beginner's guide to doing a research project, 2nd edition Sage, Los Angeles.
59. FutureDontics (2014). “Whitepaper: Dealing with patient reviews, the dental guide to online reputation,” FutureDontics.com, Parent company of 1800-Dentist.
60. Gawronski, B. and De Houwer, J. (2014). “Implicit measures in social and personality psychology,’ in Reis, H.T and Judd, C.M. (ed.) Handbook of research methods in social and personality psychology, 2nd edition, Cambridge university press. CHAPTER3
61. Gay, V. & Leijdekkers, P. (2011). 'The Good, the Bad and the Ugly About Social Netwoks for Health Apps', paper presented to the *9th IEEE/IFIP EUC Embedded and Ubiquitous computing*, Melbourne, Australia, October 2011.
62. Giustini, D. (2012). Social media and clinical trial recruitment: Potential benefits and challenges. Journal of Canadian Health Libraries Association (JCHLA), Vol. 33. Pp. 140-145.
63. Golbeck, J.A. (2005). “Computing and applying Trust in web-based Social Networks”. University of Maryland, Maryland, USA
64. Golbeck, J.A. (2006). "Generating Predictive Movie Recommendations from Trust in Social Networks," vol. 3986, pp. 93-104.
65. Goudge, J. and Gilson, L. (2005). How can trust be investigated? Drawing lessons from past experience. Social science & medicine, vol. 61, no. 7, pp. 1439-51
66. Govoni, M. and Leeuw, W. (n.d.). “Designing a comprehensive health history” <http://www.dentalcare.com/en-US/dental-education/continuing-education/ce76/ce76.aspx?ModuleName=coursecontent&PartID=5&SectionID=-1>
67. Gray, E., Seigneur, J.M., Chen, Y. & Jensen, C. (2003). 'Trust propagation in small worlds', *Trust Management*, pp. 1072
68. Gritzalis, D., Kandias, M., Stavrou, V., & Mitrou, L. (2014). “History of information: The case of privacy and security in social media.” In Proc. of the History of Information Conference Pp. 283-3.
69. Gummerus, J., Liljander, V., Pura, M. & van Riel, A. (2004). 'Customer loyalty to content-based web sites: the case of an online health-care service', *Journal of Services Marketing*, vol. 18, no. 3, pp. 175-86
70. Guo, L., Ma, J., Chen, Z., & Zhong, H. (2015). Learning to recommend with social contextual information from implicit feedback. Soft Computing, Vol. 19(5), 1351-1362.DOI: 10.1007/s00500-014-1347-0

71. Guo, G., Zhang, J., Thalmann, D., Basu, A. and Yorke-Smith, N. (2014). “From ratings to trust: An empirical study of implicit trust in recommender systems,” In *Proceedings of the 29th Annual ACM Symposium on Applied Computing*, pp. 248-253. ACM, 2014.
72. Hackworth, B.A. & Kunz, M.B. (2010), 'Health care and social media: Building relationships via social networks', *Academy of Health Care Management Journal*, vol. 6, no. 1, pp. 55-68.
73. Hall, M.A., Dugan, E., Zheng, B. and Mishra, A.K., (2001) “Trust in physicans and medical institutions: What is it, can it be measure, and does it matter?” The Milbank Quarterly, Vol. 79, No. 4. Pp. 613-639.
74. Hedman, E., Ringberg, K., and Gabre, P. (2009). Oral health education for schoolchildren: a qualitative study of dental care professionals’ view of knowledge and learning. International journal of dental hygiene, 7(3), 204-211.
75. Heimbach, I, Gottschlich, J and Hinz, O. (2015). The value of user’s Facebook profile data for product recommendation generation. Electron Markets, Vol. 25, Pp. 125-138: DOI: 10.1007/s12525-015-0187-9
76. Hernández-Ortega, B. (2011). 'The role of post-use trust in the acceptance of a technology: Drivers and consequences', *Technovation*
77. Holme, P., and Newman, M. E. (2006). Nonequilibrium phase transition in the coevolution of networks and opinions. Physical Review E, 74(5), 056108.
78. Hou, J. and Shim, M. (2010).: The Role of Provider–Patient Communication and Trust in Online Sources in Internet Use for Health-Related Activities. In: Journal of Health Communication. vol. 15, no. S3, pp. 186-99
79. Howe, J. (2006). The rise of crowdsourcing. Wired magazine, 14(6), 1-4.
80. Hu, R., & Pu, P. (2010). Using personality information in collaborative filtering for new users. Recommender Systems and the Social Web, 17.
81. Hu, C., Zhao, L., and Huang, J. (2014). Exploring online identity re-construction in social network communities: A qualitative study. PACIS 2014 Proceedings. Paper 36.
82. Ickman, S.W., Kinsel, P.A. and Roberton, N.P., (2014) “Extracting facts from social network messages,” Patent US8775400 B2.
83. Ito, A., Hayashi, M., Hamasaki, T., and Ebisu, S. (2012). How regular visits and preventive programs affect onset of adult caries. Journal of dental research, 91(7 suppl), S52-S58.
84. Jannach, D., Karakaya, Z. and Gedikli, F. (2012). “Accuracy improvements for multi-criteria recommender systems,” in Proceedings of the 13th ACM Conference on Electronic Commerce (EC 2012), 2012, pp.674–689.
85. Jiang, W., Wang, G., & Wu, J. (2014). Generating trusted graphs for trust evaluation in online social networks. Future generation computer systems, 31, 48-58.
86. Johnson, F. Rowley, J. and Sbaffi, L. (2015). “Modelling trust formation in health information contexts,” Journal of Information Science, Pp. 1-15. DOI: 10.1177/0165551515577914
87. Josang, A. and Pope, S. (2005). Semantic constraints for trust transitivity, Australian Computer Society, Inc., pp. 59-68
88. Josang, A., Ismail, R. and Boyd, C., (2007). ‘A survey of trust and reputation systems for online service provision’, Decision Support Systems, 43(2007), pp: 618-644
89. Kazienko, P. and Musial, K. (2006). “Recommendation framework for online networks,” in Mark Last et al. (eds.) Advances in Web Intelligence and Data Mining, SCI 23, Pp. 111-120.

90. Kim Y. (2014). “Trust in health information websites: A systematic literature review on the antecedents of trust,” Health Informatics Journal, 1-14. DOI: 10.1177/1460458214559432
91. Kim Y.A. and Ahmad, M.A. (2013). “Trust, distrust and lack of confidence of users in online social media-sharing communities,” Knowledge-Based Systems, Vol. 37, Pp. 438-450
92. Kim, Y.A., Eisenberg, M.E., Ahmad, M.A. and Srivastava, J. (2010). “ Modeling trust in online social networks to improve adolescent health behaviours,” Available Online << https://www.cs.umn.edu/sites/cs.umn.edu/files/tech_reports/10-018.pdf>>
93. Kim, Y.A. and Phalak, R. (2012). “A trust prediction framework in rating-based experience sharing social networks without a Web of Trust,” Information Science, Vol 191, pp.128-145.
94. Kitchens, B., Harle, C. A., & Li, S. (2014). Quality of health-related online search results. Decision Support Systems, 57, 454-462.
95. Kosala, R. and Blockeel, H., (2000). Web mining research: A survey. *ACM Sigkdd Explorations Newsletter*, *2*(1), pp.1-15.
96. Klein, R. (2007). 'Internet-Based Patient-Physician Electronic Communication Applications: Patient Acceptance and Trust', *e-Service Journal*, vol. 5, no. 2, pp. 27-51.
97. Kutty, S., Nayak, R. and Chen, L. (2014). A people-to-people matching system using mining techniques, World Wide Web, Issue 17. Pp. 311-349. DOI: 10.1007/s11280-013-0202-z
98. Kwan, M. and Ramachandran, D. (2009). Trust and online reputation systems. Computing with Social Trust, pp. 287-311.
99. Lai, LSL and Turban E, (2008). “Group formation and operations in the Web 2.0 environment and social networks,” Group Decision and Negotiation, 17 No. 5, Pp. 378-402.
100. Li, N., Orrange, S., Kravitz, R.L. and Bell, R.A. (2014). “Reasons for and predictors of patients’ online health information seeking following a medical appointment”, Oxford Journals in Medicine & Health, Family Practice, Vol. 31 (5), Pp. 550-556.
101. Li, R., Wang, C., & Chang, K. C. C. (2014). User profiling in an ego network: co-profiling attributes and relationships. In Proceedings of the 23rd international conference on World Wide Web (pp. 819-830). ACM. DOI: 10.1145/2566486.2568045
102. Libert, T. (2015). Privacy implications of health information seeking on the web. Communications of the ACM, 58(3), 68-77.
103. Linington, P.F., Milosevic, Z., Tanaka, A. and Vallecillo, A., (2011). Building enterprise systems with ODP: an introduction to open distributed processing. CRC Press.
104. Liu, B. and Chen-Chuan-Chang, K., (2004). Editorial: special issue on web content mining. *Acm Sigkdd explorations newsletter*, *6*(2), pp.1-4.
105. Linoff, G.S and Berry, M.J.A. (2011). “Data Mining ad Techniques for marketing, sales and customer relationship management, (3rd Edition), Wiley Publishing
106. Lober, W.L. and Flowers, J.L, (2011). ‘Consumer Empowerment in Health Care Amid the Internet and Social Media’, Seminars in Oncology Nursing, Vol 27, No.3 (August), 2011, pp: 169-182
107. Lopez-Nores, M., Blanco-Fernandez, Y., Pazos-Arias, J.J., Garcia-Duque, J. and Martin-Vicente, M.I. (2011). “Enhancing Recommender Systems with Access to Electronic Health Records and Groups of Interests in

Social Networks," 7th International Conference on Signal Image Technology & Internet Based Systems, IEEE, pp. 105-110.

108. Lopez-Nores, M., Blanco-Fernandez, Y., Pazos-Arias, J.J., Diaz-Redondo, R. (2010). "Property-based collaborative filtering: A new paradigm for semantics-based, health-aware recommender systems," 5th International Workshop on Semantic Media Adaptation and Personalisation, IEEE, pp. 98-103.
109. Luna, V., Quintero, R., Torres, M., Moreno-Ibarra, M., Guzmán, G., & Escamilla, I. (2014). An ontology-based approach for representing the interaction process between user profile and its context for collaborative learning environments. Computers in Human Behavior, Vol 51, Pp. 1387-1394. doi:10.1016/j.chb.2014.10.004
110. Luo, L., Kannan, P.K. and Ratchford, B.T. (2008). Incorporating subjective characteristics in product design and evaluations. Journal of Marketing Reasearch, vol. XLV, American Marketing Association, pp. 182-194
111. Luo, J.S. and Smith, B.N. (2011). Social Networking, Health 2.0, and Beyond. Information Technology Essentials for Behavioral Health Clinicians, pp. 119-31
112. Ma, L., Krishnan, R. and Montgomery, A.L. (2014). "Latent homophily or social influence? An empirical analysis of purchase within a social network," *Management Science*, Vol. 61, No. 2. Pp. 454-473.
113. Malamed, S. F. 2015, "Medical emergencies in the dental office", 7th edition, Elsevier Mosby, Canada. ISBN: 978-0-323-17122-9
114. Malik, Z. and Bouguettaya, A. (2009): RATEWeb: Reputation assessment for trust establishment among web services. The VLDB Journal, vol. 18, no. 4, pp. 885-911
115. Massa, P. and Avesani, P. (2004). "Trust-Aware Collaborative Filtering for Recommender Systems," vol. 3290, pp. 492-508.
116. Matsuo Y. and Yamamoto, H. (2009), "Measuring bidirectional effects on trust and rating on online social networks," The 18th International Conference on World Wide Web, Madrid, Spain, April 20-24, pp. 751.760
117. McNeil, D.W., Helfer, A.J., Weaver, B.D., Graves, R.W., Kyle, B.N. and Davis, A.M. (2011). "Memory of Pain and Anxiety Associated with Tooth Extraction," Journal of Dental Research. Vol. 90. pp. 220-224.
118. McCrae, R. R. and John, O.P. (1991). An introduction to the Five-Factor Model and its applications. Journal of Personality, 60: pp. 175-215
119. Mehta, S. and Banati, H. (2012). "Trust aware social context filtering using Shuffled frog leaping algorithm," pp. 342-347.
120. Meyer, E. (2012). "Meeting the needs of difficult dental patients, clear communication and careful preparation can help moderate stressful situations," Inside Dental Assisting, vol.10, no.5, Sep/Oct.
121. Merijohn, G.K., Bader, J.D., Frantsve-Hawley, J. and Aravamudhan, K. (2008). Clinical decision support chairside tools for evidence-based dental practice, Journal Evid Base Dent Pract, vol. 8, pp. 119-132
122. Mezgar, I. and Grabner-Kauter, S. (2015). "Privacy, trust and business ethics for mobile business social networks," Handbook of Research on Business Ethics and Corporate Responsibilities. 390
123. Mohammad, S.M and Turney. P. D. (2011). Crowdsourcing a Word-Emotion Association Lexicon, Computational Intelligence, Wiley Blackwell Publishing Ltd.
124. Moick, M., and Terlutter, R. (2011). Physicians' motives for professional internet use and differences in attitudes toward the internet-informed patient, physician-patient communication, and prescribing behavior. Medicine 2.0,1(2), e2-e2.

125. Montazemi, R., Pittaway, J. J., & Cocosila, M. (2009). Toward a deeper understanding of drivers and enablers of transformational e-government: a multilevel perspective.
126. Morri, K. (2008)., Trust-networks in recommender systems," San Jose University Master's projects. Paper 99.
127. Morris, M.R., Teevan, J. and Panovich, K. (2010). "What do people ask their social networks, and why?: a survey study of status message q&a behavior. CHI 2010, Using your Social Network, April 10-15 2010, Atlanta, USA, Pp. 1739-1748.
128. Moturu, S. & Liu, H. (2010). Quantifying the Trustworthiness of Social Media Content: Content Analysis for the Social Web, LAP Lambert Academic Publishing
129. Musacchio, E., Perissinotto, E., Binotto, P., Sartori, L., Silva-Netto, F., Zambon, S, Manzato, E., Corti, M.C., Baggio, G. and Crepaldi, G. (2007). "Tooth loss in the elderly and its association with nutritional status, socio-economic and lifestyle factors," Vol. 65, No. 2, Pp. 78-86. (doi:10.1080/00016350601058069) < http://informahealthcare.com/doi/abs/10.1080/00016350601058069>
130. Nepal, S., Paris C., Pour, P.A., Freyne, J. and Bista, S. (2013). "Interaction based content recommendation in online communities," in Careberry, S. et al. Advances in User Modeling. UMAP 2013 LNCS 7899, Pp. 14-24.
131. Nepal, S., Sherchan, W. and Paris C. (2012). Building trust communities using social trust. Advances in User Modeling. UMAP 2012 Workshops. Spain July 11-15.
132. Ngai, E.W.T, Tao, S. S.C and Moon, K.K.L., (2015). "social media research: theories, constructs and conceptual frameworks," International Journal of Information Management, Vol. 35 (1), February 2015, Pp. 34-44
133. O'Doherty, D., Jouili, S. and Roy P. V. (2012). "Trust-based recommendation: an empirical analysis," The 6th SNA_KDD Workshop, Aug 12, 2012, Beijing, China.
134. Osterwalder, A. and Pigneur, Y. (2010). Business Model Generation. John Wiley and Sons, Inc
135. Perea-Pérez, B., Santiago-Sáez, A., García-Marín, F., Labajo-González, E., and Villa-Vigil, A. (2011). Patient safety in dentistry: dental care risk management plan. Med Oral Patol Oral Cir Bucal, 16(6), e805-9.
136. Pfeffer, G.B., (2015). "Raising the bar for online physician review sites" The American Journal of Orthopedics, Vol 44 (1), pp. 11-12.
137. Pickard, K.T. and Swan, M. (2014). "Big desire to share big health data: A shift in consumer attitudes toward personal health information," AAAI 2014 Spring Symposia: Big Data Becomes Personal: Knowledge into Meaning, Association for the Advancement of Artificial Intelligence, 2014.
138. Pletneva, N., Cruchet, S., Simonet, M.A., Kajiwara, M. & Boyer, C. (2011). 'Results of the 10 th HON survey on health and medical Internet use'.
139. Raymond, K. (2006). Reference model of open distributed processing (RM-ODP): Introduction. Open Distributed Processing: Experiences with distributed environments.
140. Ratzan, S.C. (2011). Our New "Social" Communication Age in Health. Journal of Health Communication. vol. 16, no. 8, pp. 803-4.
141. Ricci, F., Rokach, L. and Shapira, B. (2011). "Chapter 1: Introduction to Recommender Systems Handbook," in Ricci, F. et al (eds.), Recommender Systems Handbook, Springer Science+Business Media, pp. 1-35.

142. Riley, K. (2013). Business model innovation for healthcare, modelH update: Healthcare customer segmentation – Users, buyers and intermediaries, available http://www.innovationexcellence.com
143. Rodriguez-Vazquez, L. M., Lopez, E. R., Centelles, A. V., Otero, A.I.B. Otero, F. V. and Centelles, P. V. (2008). "Stress amongst primary dental care patients," Med Oral Patol Oral Cir Buscal, Vol.13 (4), E:253-6.
144. Rolfe, A., Cash-Gibson, L., Car, J., Sheikh, A. and McKinstry, B. (2014). "Interventions for improving patients' trust in doctors and groups of doctors (Review)", The Cochrane Library 2014, Issue 3. http://www.thecochranelibrary.com
145. Rosaci, D. (2012). "Trust measures for competitive agents," Knowledge-based systems, Vol 28, Pp. 36-46, doi:10.1016/j.knosys.2011.11.011
146. Rosak-Szyrocka, J., Rados, A. and Wawrzak, A. (2013). "CRM concept as patients' relations management in dentistry," < https://depot.ceon.pl/handle/123456789/3476>
147. Rossi, P.H., Wright, J.D. and Anderson, A.B. eds., (2013.) *Handbook of survey research*. Academic Press
148. Rowley, J. and Johnson, F. 2013, "Understanding trust formation in digital information sources: The case of Wikipedia," *Journal of Information Science*, Vol. 39(4), Pp. 494-508
149. Salton, G. and Buckley, C. (1988). Term-weighting approaches in automatic text retrieval. Available on < http://www.cs.odu.edu/~jbollen/IR04/readings/article1-29-03.pdf>
150. Sarda, K., Gupta, P., Mukherjee, D., Padhy, S. and Saran, H. (2009). "A distributed trust-based recommendation system on social networks," Proc. IEEE 10th Second Workshop Hot Topics in Web Systems and Technologies.
151. Saif, H., He, Y. and Alani, H. (2012). Semantic sentiment analysis of twitter. In The Semantic Web–ISWC 2012 (pp. 508-524). Springer Berlin Heidelberg.
152. Sbaraini, A., Carter, S.M., Evans, W. and Blinkhorn, A. (2012). "Experiences of dental care: What do patients value?" BMC Health Services Research. 12:177.
153. Schiaffino, S. and Amandi A. (2009). "Intelligent User Profiling", in Branner, M. (Ed.), Artificial Intelligence, LNAI 5640, pp. 193-216.
154. Siegrist, M., Gutscher, H. and Earle, T.C. (2005), "Perception of risk: influence of general trust and general confidence," Journal of Risk Research, Vol. 8(2), Pp. 145-156
155. Sillence, E., Briggs, P., Harris, P., Fishwick, L. (2006): A framework for understanding trust factors in web-based health advice. *International Journal of Human-Computer Studies*, vol. 64, no. 8, pp. 697-713
156. Skopik, F., Truong H. and Dustdar, S. (2009) "Trust and reputation mining in professional virtual communities," The 9th International Conference on Web engineering, San Sebastian, Spain, June 22-26, pp. 751-760.
157. Smyth, B. and O'Donovan, J. (2005). "Trust in recommender systems," 10th international conference on intelligent user interfaces, 2005, pp. 167-174.
158. Song, J. & Zahedi, F.M. (2007), 'Trust in health infomediaries', Decision Support Systems, vol. 43, no. 2, pp. 390-407
159. Spencer, J. and Harford, J. (2008), "Improving oral health and dental care for Australian", National Health and Hospitals Reform Commission, University of Adelaide. December 2008.
160. Su, X. and Khoshgoftaar, TM. (2009). A Survey of Collaborative Filtering Techniques. Hindawi Publishing. Advances in Artificial Intelligence.

161. Sun, J. & Tang, J. 2011, A Survey of Models and Algorithms for Social Influence Analysis, Springer.
162. Louis, B. L. S., Firestone, A. R., Johnston, W., Shanker, S., & Vig, K. W. (2011). Prospective patients rate practice factors: Development of a questionnaire. American journal of orthodontics and dentofacial orthopedics, 139(2), 235-241.
163. Swan, M. (2009). 'Emerging patient-driven health care models: an examination of health social networks, consumer personalized medicine and quantified self-tracking', International journal of environmental research and public health, vol. 6, no. 2, pp. 492-525
164. Swan, M. (2012). Crowdsourced health research studies: an important emerging complement to clinical trials in the public health research ecosystem. Journal of Medical Internet Research, Vol 14, No.2
165. Swearingen, K. and Sinha, R. (2001). "Beyond algorithms: an HCI perspective on recommender systems," ACM SIGIR 2001, Workshop on Recommender Systems, Vol 13. No. 5-6, Pp. 1-11
166. Teddlie, C. and Tashakkori, A. (2003). "Major issues and controversies in the use of mixed methods in the social and behavioural sciences", in Tashakkori and Teddlie (eds.), Handbook of Mixed Methods in social & behavioural research, Sage Publications, California.
167. Thiede, M. (2005). Information and access to health care: is there a role for trust? Social science & medicine, vol. 61, no. 7, pp. 1452-62
168. Thirunarayan, K., Anantharam, P. Henson, C. and Sheth, A. (2014) "Comparative trust management with applications: Bayesian approaches emphasis," Future Generation Computer Systems, Vol 31, Pp. 182-199.
169. Tsai, T., Orav, E.J. and Jha, A.K., (2015). "Patient satisfaction and quality of surgical care in US hospitals," Annals of Surgery, Jan 2015, Vol. 261 (1), pp2-8 DOI: 10.1097/SLA.000000000765
170. Tschannen-Moran, M. (2014). "Trust matters, Leadership for successful schools", 2nd edition Jossey-Bass, A Wiley Brand. San Francisco. ISBN: 978-1-118-83437-4
171. Tselenti, P. and Danas, K., (2014). "A review of trust-aware recommender systems based on graph theory", Proceedings of International Conference on Computer Science, Computer Engineering, and Social Media, Greece, 2014.
172. Tustin, N. (2010). "The role of patient satisfaction in online health information seeking," Journal of Health Communication, Vol. 15, No. 1, 2010, pp. 3-17.
173. Vallecillo, A. (2006), UML for ODP System specification, WODPEC 2006, Hong Kong
174. Vani et al (2010). "Toothpaste Brands –A Study of consumer behavior in Bangalore city," Journal of Economics and Behavioral Studies Vol. 1, No. 1, pp. 27-39, Dec 2010.
175. Vayena, E., Mastroianni, A. and Kahn, J. (2012). Ethical issues in health research with novel online services. American Journal of Public Health. Public Health Ethics. Vol. 102 (12). Pp. 2225 – 2230.
176. Victor, P, Cornelis, C. and De Cock, M. (2011). "Chapter 2: Trust models" in Trust networks in recommender systems, Atlantis Press, ISBN: 978-94-91216-07-7.
177. Victor, P, Cornelis, C., De Cock, M. and da Silva, P.P. (2009). "Gradual trust and distrust in recommender systems" Fuzzy Sets and Systems, Vol. 160, Pp. 1367-1382.
178. Volkman, J.E., Luger, T.N., Harvey, K.LL. Hogan, T.P. Shimada, S.L., Amante, D. , McInnes, D. K., Feng, H. and Houston T.K. (2014). "The national cancer institute's health information national trends survey (HINTS): a national cross-sectional analysis of talking to your doctor and other health care providers for health information," Bio Med Central (BMC) Family Practice, Vol 15:111, DOI: 10.1186/1471-2296-15-111

179. Walter, F.E., Battiston, S. and Schweitzer, F. (2008). “A model of a trust-based recommendation system on a social network,” Auton Agent Multi-Agent Syst, Vol 16, Pp. 57-74. DOI 10.1007/s10458-007-9021-x
180. Wang, J. Yin, J., Liu, Y. and Huang, C. (2011). “Trust-based collaborative filtering,” The 8th International Conference on Fuzzy Systems and Knowledge Discovery, Shanghai, China, July 26-28, pp. 2650-2654.
181. Watanabe, N. (2008). 'Role of trust in cross-cultural adaptation: the perspective of international degree students at a Finnish university', University of Jyväskylä.
182. Waylan, A., Makoul, G. and Albeyatti, Y. (2015). “Patient-clinician communication in a dental setting: a pilot study,” British Dental Journal, Vol 218, 22 May 2015, Pp. 585-588.
183. Webster, Y.W., Dow, E.R., Koehler, J., Gudivada, R.C. & Palakal, M.J. (2011). 'Leveraging health social networking communities in translational research', Journal of biomedical informatics.
184. WeKnowIT (2011). “D1.4 User profiling and personalization tools,” Weknowit, FP7-215453.
185. Wei, C., Chen, H. and L. M. (2011). Estimating trust strength for supporting effective recommendation services. PACIS 2011 Proceedings, Paper 212.
186. Weitzel, L., Quaresma, P. and de Oliveira, J.P.M. (2012). Evaluating quality of health information sources. 26th IEEE Intl’ Conference on Advanced Information Networking and Applications (AINA), Fukuoka, Japan. Pp. 655 -662.
187. Wiesner, M. and Pfeifer, D. (2014). “Health Recommender Systems: Concepts, Requirements, Technical Basics and Challenges,” Int. J. Environ. Res. Public Health, March, pp. 2580-2607.
188. Williams, J. (2010): Social networking applications in health care: threats to the privacy and security of health information. ACM, pp. 39-49
189. Wilson, P. (2002) “How to find the good and avoid the bad or ugly: a short guide to tools for rating quality of health information on the internet,” BMJ 324 Pp.598–602
190. Xiao, B. and Benbasat, I. (2013). “Research on the Use, Characteristics, and Impact of e-Commerce Product Recommendation Agents: A Review and Update for 2007-2012,” Handbook of Strategic e-Business Management, Progress in IS 2014, pp. 403-431.
191. Yarascavitch, C., Regehr, G., Hodges, B. and Haas, D.A. (2009). “Changes in Dental Student Empathy During Training,” Journal of Dental Education Vol. 73. No. 4. pp. 509-517.
192. Ye, Y. (2011) “Correlates of consumer trust in online health information: Findings from the Health Information National Trends Survey, *Journal of Health Commnunication,* Vol. 16(1), Pp. 34-49.
193. Young, K. (2011). Social ties, social networks and the Facebook experience.International Journal of Emerging Technologies and Society, 9(1), 20.
194. Zahedi, F.M. and Song, J. (2008)., 'Dynamics of trust revision: Using health infomediaries', Journal of Management Information Systems, vol. 24, no. 4, pp. 225-48.
195. Zahedi, F.M., Song, J. and Jarupathirun, S. (2008). Web-based decision support', Handbook of Decision Support Systems, Chapter 16.
196. Zhang, B., Huang, Z., Yu, J. and Xiang, Y. (2014)., “Trust computation for multiple routes recommendation in social networking sites,” *Security and Communication Networks*, Vol. 7. No. 12. Pp. 2258-2276. DOI: 10.1002/sec.935.
197. Zhang, Y., He, D. and Sang, Y. (2013). “Facebook as a platform for health information and communication: A case study of a diabetes group”, J Med System, Vol 37, 9942, DOI 10.1007/s10916-013-9942-7

198. Zhang, Y. and Yu, T. (2012). “Mining trust relationships from online social networks,” Journal of computer science and technology, Vol 27, No. 3, May 2012, pp. 492-505.
199. Zhou, X., Xu, Y., Li, Y., Josang, A. and Cox, C. (2012). “The state-fo-the-art in personalized recommender systems for social networking,” Artificial Intelligence Review, Vol. 37. Pp. 119-132. DOI 10.1007/s10462-011-9222-1
200. Ziegler, C. N. (2005). Towards decentralized recommender systems (Doctoral dissertation, Institut für Informatik).

Websites:

201. Better health channel (2015). Potential risks for health website: https://www.betterhealth.vic.gov.au/
202. DentalFearCentral (2012). The world’s biggest dental phobia, Dental fear and anxiety resource, website: http://www.dentalfearcentral.org/
203. Dentistreviews (2015). Compare Dentist Review Sites website: http://www.dentistreviews.com/sites/
204. DentistDig (2012). website: http://www.dentistdig.com/
205. DISCInsights, (2015). DISC Personality test, Website: https://www.discinsights.com
206. Discprofiles4u (2015). Disc Classic 2.0, website: http://www.discprofiles4u.com/blog/2012/disc-profile-test-1 classical-patterns-1-of-20
207. Doctoroogle (2015). Doctor Oogle Good Dentist Guide, Online: http://www.doctoroogle.com
208. General Dental Council (2010). “Patient and Public Attitudes to Standards for Dental Professionals, Ethical Guidance and Use of the Term Doctor” George Street Research, November 2010
209. Healthgrades (2015). website: http://www.healthgrades.com/
210. McKinsey&Company. (2011). “Big Data: The next frontier for innovation, competition and productivity,” McKinsey Global Institutue.
211. NationalDentalReviews (2015). website: https://nationaldentalreviews.org/
212. RateaDentist (2015). website: https://www.rateadentist.com/
213. RateMDs (2015). Doctor reviews and ratings, website: https://www.ratemds.com
214. Statista (2016). Leading social networks worldwide as of January 2016, website: http://www.statista.com/
215. Yelp (2015). website http://www.yelp.com/