CHAPTER 1

General introduction
In dental care, rapid developments are taking place in areas such as the administration of patient care, innovations in diagnostic procedures and imaging, as well as in practice management and organizational modernization. Digital technologies form a substantive part of such developments. This leads to changing the ways of carrying out diagnostic procedures, performing treatments, gathering and integrating information into practice processes, as well as communication. Using digital technologies has a strong impact on oral health care. Dental practices, dental professionals, and patients’ experiences with oral care influence whether and how digital technologies are used. And, in turn, by using digital technologies dental practices and dental professionals’ work environments change.

Such changes reflect developments in wider society. In our daily activities, many digital technologies are used for all sorts of purposes. The role of technological change and the increasing role of digital forms of information in modern societies has received ample attention within the social sciences and in science and technology studies. In these studies, the links between technology and society are central. Firstly, in one area of social studies of technology, technologies and how they are developed and implemented is seen as fundamentally social rather than technical (Bijker & Law 1992). From this perspective, both the functioning and the dysfunctions of a technology is seen as due to how they have been constructed and how they fit in with social aspects. Technology use, then, is inseparable from political, economic, social, and cultural realms. Secondly, more recent social studies of technology have emphasised not so much how they are socially shaped, but how technology and users shape one another, seeing this as a dialectic relationship (Timmermans & Berg 2003). These more recent approaches point out that technologies are more than socially shaped (Mol 2002b; Timmermans & Berg 2003; Orlikowski 1992). Those who use technologies are then seen as active agents who influence technologies and social structures and are in turn influenced by them (Orlikowski 1992).

Studying technologies and users, then, involves more than looking at people and machines. It involves looking at more than one domain, and more than individuals or groups of people. Instead, in this thesis I depart from perspectives that study how technologies, users, and the context in which they are situated mutually shape each other and become intermingled (Timmermans & Berg 2003). Political and social contexts shape which technologies get used, and this reinforces or transforms political and social structures (Webster 2007). Furthermore, different users inevitably do different things with technologies, and various forms of use - including non-use and resistance - influence a technology’s trajectory (Oudshoorn & Pinch 2003). This wider context can be brought into focus in several ways. For example, by studying the ways in which they construct and relate to different ways of seeing human bodies in medical practice (Mol 2002b), or by tracing their role in professional practice and in workplaces (Star 1995).
In this thesis, I study ensembles of innovations that are used in dental practices. An innovation is “An idea, practice, or object that is perceived as new by an individual or other unit of adoption” (Rogers 2003), adoption being a (decision to) use an innovation. Specifically, digital technologies are the subject of this thesis. This term refers to specific types of innovation, those that are digital and often computer-linked, and which lead to digital information, in the form of images, texts, numbers, links, and stored or exchanged information. In what follows, some background on digital technologies in health care is provided, followed by a discussion of digital technologies in dental practices and the way in which this topic has been delimited in this thesis. This is followed by a discussion on the topic of studying users and technologies in (dental) practices. Finally, the aims and structure of this thesis are presented at the end of this introduction.

Digital technologies in health care
Technologies in health care have been of a varied nature; some large and used in a clinic, such as MRI scanners or X-ray devices, some information-related, such as electronic patient records or clinical decision support systems, and some used in the body such as genetic technologies (Webster 2007). These have had an impact not only on health care practices, but also in the ways in which human bodies are conceptualized (Casper & Morrison 2010). In recent decades, many technologies of a specific type have been developed in health care, namely digital technologies. They are used by patients, health care professionals and have been presented as ‘solutions’ to achieve better health care delivery and health monitoring (Lupton 2014). Innovations are thus often presented as increasing effectiveness and quality of health care.

Whereas some innovations have been shown to improve health care, others have not yielded improvements (Prasad et al. 2013). The same can be said, more specifically, about digital technologies. Moreover, their effects on health care often reaches further than expected effectiveness or clinical outcomes: “Discussion of digital health in the popular media and the medical and public health literature has rarely addressed the broader implications for how understanding and knowledge of the body, health, disease and illness are developed and for issues relating to medical and public health practice, power relations and the doctor–patient relationship” (Lupton 2014, p. 1347). In medical sociology (Casper & Morrison 2010) and in science and technology studies (Timmermans & Berg 2003), such broader implications have been focused on. These studies have looked at the changes occurring around the rise and use of digital health technologies as dynamic and interrelated changes in health, technology and society (Webster 2007). For example, changes in the body and the way the body is monitored, treated, embodied and conceptualized has been addressed here (Mol 2002b), as well as patients’ involvement in health and health care practices as digital technologies distribute more of the practices around maintaining health to patients (Lupton 2014; Blume 2013).
Digital technologies have not only impacted health and the body, but have similarly had an impact in health care practices. One of the main areas in which this is the case is in the amount and means by which information is gathered and the ways in which it is handled (Mort & Smith 2009). The use of other technologies has also led to changes in relations between colleagues, and changes in power distribution (Barley 1986). Furthermore, digital technologies have contributed to transforming professional roles and the development of new professions, for example those focused on dealing with digital technologies in health care (Masys 2002).

**Digital technologies in dental practices**

The ensemble of technologies that are used in dental practices has changed over time. Many of the most recent innovations in dental practices have been digital technologies. Digital technologies in dental practices include on the one hand computer-based information and communication technologies, such as digital patient records, teledentistry, social media use by dental practices, and digital management techniques such as practice supply management. On the other hand, many digital technologies for diagnosis and treatment are used in dental practices. This includes digital radiography devices, intra oral scanners, tooth colour determination devices, and software for designing restorations digitally.

In this thesis, the use of digital technologies in dental practices is the central topic. These were studied as examples of innovations used in dental practices. Digital technologies were defined for the purpose of the studies presented in chapters two through four as newer technologies, which are computer-linked. Thus, devices such as electronic apex locators, or rotary files were not specifically addressed in these chapters, where digital technologies were the main focus. Furthermore, we used a definition of clinical digital technologies – those that are used for diagnosis or treatment – defining these as all digital technologies that are devices or machines in themselves. Thus, clinical digital technologies were defined in these chapters as devices that are distinct from computer or mobile applications or software systems. Two of the chapters in this thesis used a different definition. In chapter five, newer technologies were studied. These were clinical technologies, which included digital technologies in addition to other devices. In chapter six, respondents were asked what they defined as digital technologies, and their definitions were used throughout that chapter.

In this thesis I look at a large number of digital technologies used by dentists in dental practices. Studying one technology at a time would have led to a more in-depth perspective, but does not necessarily lead to more insight in what changes in dental practices. Focusing on the ensemble of digital technologies mainly in use by dental practitioners, a broader perspective is taken that allows for more understanding of changes in the profession, and in oral health care. This approach is somewhat akin to studying infrastructure and
how different technologies in one setting are evaluated (Star 1999). Besides the digital technologies used in dental practices, those in other places or organizations also play a role in the developments in oral health care and in the profession of dentists. Digital technologies used in dental laboratories, in dental education, by health insurance organizations, and in patient’s homes, for example, all have an effect on dental practices.

Most current research in digital dentistry focuses on technologies’ technical properties or clinical performance. Few studies were found that explore dentists’ attitudes to specific technologies (Bauer and Brown 2001; Parashos and Messer 2006). The available studies found (Molander, Reit & Dahlen 1996; Flores-Mir, Neal G Palmer, et al. 2006; Rindal et al. 2008; Parashos & Messer 2006; Matthews et al. 2016) mainly use the approach of diffusion of innovations (which will be explained below). A few studies have investigated the use of a number of digital technologies by dentists (Tay et al. 2008; Flores-Mir, Neil G Palmer, et al. 2006; John et al. 2003). In addition, the impact of digital transformations on the profession of dentistry has been addressed to a limited degree, mainly in exploratory and opinion pieces and in the context of dental education (Bauer and Brown 2001; Baum 1996; Eaton et al. 2008; Esfandiari and Feine 2011b; Knösel et al. 2011; Schleyer 2003). Empirical research on this subject, however, is scarce. And the available literature leaves the question what effects the use of digital technologies may have on dentists, patients, and in dental practices largely unanswered.

When writing about technology use in dental practices, users and technologies can not really be separated: when one thinks of a dentist at work, all sorts of physical objects are part of dentistry, to the point that a dentist working without any techniques does not give a full picture of the profession. And yet all these tools without an oral health professional using them would be no more than objects sitting in a room. The effects technologies have in dental practices thus come about when, and while, dentists are using technologies: the whole is more than the sum of its parts. Thus, technology use and the effect of technology use on people result from the interactions between users, and technology.

**On using digital technologies**

Digital technologies’ effects on health care come about when they are used, which leads to the question why some people use them and others do not. Often several alternatives are weighed at the same time. In addition, technologies that one already uses play a role in decision-making. Yet comparing different technologies involves weighing many aspects, which are often difficult to foresee. In the first place, new digital technologies have often not been used extensively, let alone, researched extensively. Thus, decisions about them are made in the absence of evidence regarding their effects. And even if more would be known about their effects, establishing the effect that a technology has on a given dental practice, or on outcomes of dental treatment, would still be less than straightforward, as a lot depends...
on how exactly they are used and in what setting. Comparing various digital technologies, or comparing these with analogue techniques, then, entails simplifying a range of complex variables (Mol 2002a). Dentists’ and patients’ preferences for methods, existing and new skills, infrastructure and computer networks available in a practice, attended courses and education, legal requirements and insurance policies, and ideas about what is important in the profession of dentistry, all play a role in how technologies are perceived and evaluated.

The body of work that developed around Rogers’ (Rogers 2003) seminal study of the diffusion of innovations presents innovation as an individual decision-making process influenced by the decision-making of others. This process starts with knowledge of the innovation, continues through persuasion and gathering information, to a decision whether to use or not to use the innovation. This is then followed by implementation and furthering knowledge about the innovation for others. Rogers distinguishes between five groups, ranging from innovators and early adopters to the middle groups of early and late majorities followed lastly by laggards. These groups are distributed as in a bell-curve, thus the innovators and early adopters, as well as the laggard group are composed of few individual adopters, and the majority are in the two middle groups. The likelihood of acceptance of an innovation is dependent, in this model, on inherent characteristics of the innovation and its adopters, as well as on the degree to which others accept the innovation. An innovation that is accepted by many usually gets more attention – leading others to adopt as well – and gets developed and promoted more. Only when a sizeable number of users adopt the innovation (moving beyond the innovative first category), the spread of a technology takes off and becomes used widely. This has often been referred to as the ‘adoption gap’, namely the gap between the first few users and the larger majority who are needed for an innovation to get more and more used and thereby more and more developed and promoted. In more recent studies this approach has been criticized. In these more recent approaches, the diffusion of innovations is not seen as a linear process of increasing technological change, but as one subject to ‘reinvention’, with increasing and decreasing use for individual practitioners over time. Thus, this perspective stresses that an innovation often does not remain the same while it is being developed and used. It is then a multidirectional, not a unidirectional process (Singhal 2011).

Furthermore, economic studies and the field of technology assessment show that the stockpile of available technologies makes strong demands on professionals’ decision-making, in keeping up with information on new technologies, and balancing the willingness to innovate with rising costs and time investments (Esfandiari & Feine 2011; Webster 2002). Furthermore, changes arise between generations active in the field, ranging from those for whom digital technologies form part of their upbringing and education, and those for whom this mode of working and thinking is less intuitive. Especially in the context of education this has been discussed extensively (Bennett et al. 2008; Morris & Venkatesh 2000; Prensky 2001a; Prober & Heath 2012).
In information systems research, social sciences, and health care studies, a substantial amount of research has been done on the barriers and facilitators of technology acceptance. These studies focus mainly on the question what hinders the acceptance of technologies by users, even if they offer proven benefits (Greenhalgh et al. 2004; Fleuren et al. 2004; Boonstra & Broekhuis 2010). In this literature, barriers are identified on different levels of analysis, which can be grouped together as aspects of an innovation, personal factors of the user, organizational factors, and socio-political factors (Fleuren et al. 2004). In addition, it was shown that the barriers that play a role for users are not the same as those that play a role for non-users of an innovation (Lapointe & Rivard 2005). This implies that for digital technologies to be effectively used, efforts need to be tailored to each user group.

Science and technology studies, as well as organization studies and medical sociology, have addressed overall changes that happen in a profession alongside digital technology use. This body of research shows the intertwined relations between technological and social changes (MacKenzie & Wajcman 1999; Oudshoorn & Pinch 2003). They address, for instance, changes in professional values (Berg et al. 2000; Timmermans & Berg 2003) and far-reaching changes in cooperation and professional roles that may occur within a short time after introduction of a technology (Barley 1986; Dopson 2005; Lehoux et al. 2002). Changes taking place around technology introduction and use are highly influenced by the organizational and social context in which they take place. In many of the studies in these fields, this is seen as an unpredictable process best studied for each case separately.

In this thesis, I describe the ways in which dental practitioners use the ensemble of technologies that are available for their workplace. Both the practice of dentistry and dental technologies are viewed as dynamic in what follows: they are in a process of change and they intersect in different ways. I investigated how technologies are used in dental practices, delimiting it by focusing on a professional group and not a technology. This means bringing into focus that technology use does not necessarily happen in a linear way – some technologies may not become used or become left aside, and earlier experiences may inform subsequent experiences and actions.
General introduction

Aims and overview of this thesis
The studies presented in this thesis were conducted with the aim to investigate the impact of digital innovations on the practice of dentistry, by focusing on three key research questions:

1. Which promoting and constraining characteristics can be identified in dentists’ adoption and rejection of digital developments?
2. Which changes impacting on the dental workforce can be expected to develop alongside the increasing role of digital techniques in the field of dentistry?
3. How do dentists and dental practices adapt to these changes, and what are the consequences of these adjustments?

Barriers and incentives to technology adoption among dental practitioners were investigated in an exploratory study, which is presented in Chapter 2. It identified factors that influence adoption of digital dental technologies. These factors include attributes of a technology, of dentists, of dental practices, and of the socio-political context. A questionnaire was developed on the basis of the study described in Chapter 2, and used in a study of general dental practitioners in the Netherlands. The first part of this study is described in Chapter 3, which discusses the extent of use of various types of digital technologies among general dental practitioners. In addition to this, Chapter 3 describes the association between personal and practice characteristics and the level of use of digital technologies among dentists in the Netherlands. In Chapter 4, a study using data from the same questionnaire is presented, but focusing on opinions about technology use and motivating aspects of work. It describes the relation between the number of technologies dentists use, when taking dentist and dental practice characteristics, and motivating work aspects into account. Chapter 5 describes the use of newer technologies among dentists in New Zealand, and compares dentists’ technology use across various studies. It looks at the use of various specific new technologies by dentists in New Zealand, describes how these were associated with dentists’ and dental practices’ characteristics, and which factors dentists indicated were most important in their decision-making regarding the use of a new technology. Chapter 6 describes a grounded theory study using semi-structured interviews, aimed at gaining an in-depth understanding of what happens when dentists use digital technologies in the dental practice. It describes this as a process, involving five phases dentists go through when using digital technologies. Chapter 7 discusses what was learned through the investigations and ideas that form the building blocks of this thesis. It presents ideas that connect the preceding chapters, discusses the various methods used and what they offered, looks back on the journey involved in doing this thesis, and finally closes off with recommendations.