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# Impact of time pressure, as a stressor, on dentist's diagnostic decision making.

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**UNIVERSITY OF  
PLYMOUTH**

**IMPACT OF TIME PRESSURE, AS A STRESSOR, ON  
DENTIST'S DIAGNOSTIC DECISION MAKING**

by

**ANASTASIOS PLESSAS**

A thesis submitted to the University of Plymouth

in partial fulfilment for the degree of

**RESEARCH MASTERS**

School of Dentistry

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## Author's Declaration

At no time during the registration for the degree of Doctor of Philosophy has the author been registered for any other University award without prior agreement of the Doctoral College Quality Sub-Committee.

Work submitted for this research degree at the University of Plymouth has not formed part of any other degree either at the University of Plymouth or at another establishment.

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# Abstract

**Background:** Growing evidence from the wider healthcare and psychology literature support the notion that stress may affect an individual's decision making, technical and non-technical skills. Stress amongst dentists is prevalent and different stressors have been described in the dental literature. In dentistry, although extensive research has been conducted on dentists' well-being and mental health, little is known about how different stressors may affect dentists' performance.

**Aim:** The current work aimed to examine the effect of stress, if any, on dentists' decision making and performance.

**Methods:** This ResM project was divided into three parts: a systematic review examining the impact of stress on dentists' performance (Chapter 2), a systematic mapping review to identify dental decision making models and factors that may influence dental decision making (Chapter 3), and lastly an experimental study on the impact of time pressure, as a stressor, on dentists' diagnostic performance when examining dental bitewing radiographs (Chapter 4).

**Results:** The systematic search yielded 3535 citations, of which twelve were eligible for inclusion but they did not answer the research question; thereby demonstrating a gap in the research base. The mapping review identified the different study designs and methods used in evaluating dental decision making. It also offered a taxonomy of factors which may potentially influence dentists' decisions based on previously described decision-making models. The identified factors were taxonomised as dentist, patient and environmental factors. Following an iterative process, factors that are

perceived as influential by dentists but not evaluated in experimental studies (e.g. time pressure) were identified and informed the development of the subsequent experimental study of the ResM project. The experimental study demonstrated a statistically and clinically significant deterioration in dentists' median diagnostic sensitivity of 30% when examining bitewing radiographs under time pressure. By contrast, median diagnostic specificity was 100% under both conditions.

**Conclusions:** This work, following a comprehensive evidence based approach, identified a gap in the literature which warranted further exploration. It showed that time pressure, a frequently reported stressor in dental practice, has a negative impact on dentists' diagnostic performance which could potentially have an adverse effect on the quality of patient care delivery and patient safety. Future studies are warranted to explore a) the mechanism(s) underlying the observed deterioration in performance, b) the impact of time pressure on different aspects of dentists' performance c) the role of other stressors on dentists' performance and d) approaches to minimising or mitigating the risk of diagnostic errors from occurring.

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# **Chapter 1: Background**



## **Stress in Dentistry**

Dentists' stress has been described in the literature as early as 1978 (Cooper, Mallinger & Kahn, 1978). Dentistry is recognised as a stressful profession (Blinkhorn, 1992; Myers & Myers, 2004; National Clinical Assessment Service, 2011; Wilks, 1995; Wilson *et al.*, 1998), and dentists perceive their profession to be more stressful than other healthcare professions (Gale, 1998; Moore & Brodsgaard, 2001). In the UK, a British Dental Association (BDA) survey suggested that 57.1% of the community dentists and 72.9% of those working in general dental practice reported high work-related stress (BDA, 2015). These figures are in line with the international literature (Ayers *et al.*, 2008; Gerschman & Burrows, 1998; Gorter *et al.*, 1999a; Shelly, Wong & Rackcliffe, 1989).

## **Conceptualisation of stress**

In order to understand how stress may affect decision making and performance, it is important to first discuss the different conceptualisations and definitions of stress. Stress has been viewed as a stimulus, a response, and a transaction (Colligan and Higgins 2005). Originally, stress was conceived as pressure from the environment and then as a strain within the person. In contrast, nowadays stress is viewed as a result of interaction/transaction between the situation, the environment and the individual. Stress, therefore, is the psychological and physical state that results when the resources of the individual are not sufficient to cope with the perceived demands and pressures of the situation (Colligan and Higgins 2005).

### **Stress as a stimulus**

Stress as a stimulus is perceived as comprising the characteristics of the environment that are considered disturbing and have the effect of causing strain reactions in the individual exposed to them (time pressure for example). The individual is a passive recipient of stress and plays no role in determining the degree and intensity of the

stressor. The stimulus theory of stress, therefore, ignores important variables such as prior learning, environment, support networks, personality, and life experience (Colligan and Higgins, 2005; Holmes and Rahe, 1967).

### **Stress as a response**

On the contrary, stress as a response mainly considers stress from an individual's physiological reactions to stressors. The response model was introduced by Hans Selye (Selye 1983). Selye 's model suggested that the stress response could result in positive or negative outcomes based on cognitive interpretations of the physical symptoms or physiological experience. In this way, stress could be experienced as eustress (positive) or distress (negative) (Selye 1983). Thus, the focus of the model is the physiological/psychological manifestation of stress.

The notion of stress as a physiological response has emerged from the general adaptation syndrome (GAS) model (Selye, 1983). This model describes stress as a dependent variable and includes three components:

1. Stress is a defensive mechanism.
2. Stress follows the three stages of alarm, resistance, and exhaustion.
3. If the stress is prolonged or severe, it could result in disease or adaptation.

When confronted with a negative stimulus, the alarm response initiates the sympathetic nervous system to combat or avoid the stressor (e.g. increased heart rate). Thereafter the resistance response initiates physiological changes (e.g., fight or flight), and the system returns to homeostasis, only when the person has dealt with the stressor or the stressor has been removed. The third stage (exhaustion) maintains that when a stressor persists, it could lead to a depletion of a person resources (Colligan and Higgins, 2005; Selye 1983).

## **Stress as a transaction**

In attempting to explain stress as more of a dynamic process, the transactional theory of stress was developed. Two variations of the transactional models of stress have been suggested, namely Lazarus's and Folkman (1987) and Cox's and MacKay (1981) models.

Lazarus and Folkman (1987) suggest that stress occurs when there are demands on the person that exceed their adjustment resources. Thus, if the individual views the situation as stressful it is due to his or her appraisal of the environment (Lazarus and Folkman, 1987). According to the transactional model an individual's appraisal of a stressor is at the centre of the stress experience (Lazarus and Folkman, 1987). An individual's appraisal of a stressor determines how he or she copes with, or responds, to the stressor. There are three stages of appraisal described in the model; namely primary, secondary and reappraisal. Primary appraisal consists of the judgment that an encounter is irrelevant, benign-positive, or stressful; secondary appraisal refers to a judgment concerning what might and can be done; and reappraisal is when the appraisal is changed based on new information from the environment and/or the person. The process of appraisal explains why some individuals are better able to cope under potentially stressful conditions, whereas others cannot (Lazarus and Folkman, 1987; Michie, 2002).

Within the context of the transactional model, Cox and MacKay (1981) define stress as an individual phenomenon and the result of a transaction between the person, the environment and the situation. The term transaction emphasises the active and adaptive nature of the process (Cox and McKay, 1981). Thus, stress is described as part of a complex and dynamic system of transactions between the person and his environment.

This model includes both the response-and stimulus-based definitions of stress and suggests that stress is an individual perceptual phenomenon rooted in psychological processes. Stress process is viewed as cyclical rather than linear. The process consists of five stages. The first stage represents the sources of demand relating to the person and it forms part of the individual's environment. These demands are either external, derived from the environment, or internal in the form of psychological and physiological needs, the fulfilment of which determines the individual's behaviour. The second stage consists of the individual's perception of the demands and his or her ability to cope with the demand. Stress may arise when there is an imbalance between the perceived demand and the person's perception of their capability to meet the demand. Interestingly, the important balance or imbalance is between the perceived demand and the individual's perceived capability and not between the demand and the individual's actual capability. When a high demand is made on an individual, he or she will not experience stress until he or she has reached his or her physical, mental or emotional limitations. At this point, the individual realises that he or she cannot cope anymore and then experiences stress due to the recognition of his or her limitations and the imbalance between the demand and capability. This imbalance will be experienced on a subjective or emotional level, coupled with changes on a physiological level as well as cognitive and behavioural attempts to reduce the stressful nature of the demand. The third stage is associated with the psychophysiological stages, which correspond to the response to stress. The fourth stage is concerned with the consequences of the coping responses, whether actual or perceived. The fifth and last stage of the model revolves around feedback, which also occurs in all of the other stages determining the outcome at each of the stages (Colligan and Higgins, 2005; Cox and McKay, 1981).

## **Aetiology and consequences of occupational stress**

The degree of stress experienced depends on the functioning of two protective physiological mechanisms: the “alarm reaction” and the “adaptation”. Stress is experienced when either of these mechanisms are not functioning properly or when we find it difficult to switch appropriately from one to another (Michie 2002). Michie (2002) provided a framework of sources of occupational stress. According to this framework, factors related to occupational and workplace stress may fall in one of the following five categories of: (1) factors unique to the job, (2) role in the organisation, (3) career development, (4) interpersonal work relationships, and (5) organisational structure/climate. Each of the five categories demonstrates that stress can occur specifically when there is a conflict between the worker and the job demands placed on him or her. In fact, when the worker has little control over the situation, the tolerable challenging stress becomes distress (Michie 2002).

Factors which are intrinsic to the job include long hours, work overload, time pressure, difficult or complex tasks, lack of breaks, lack of variety, and poor physical work conditions (for example, space, temperature, light) (Michie 2002). Factors related to the social and organisational context of work include, workload, types of hours worked, a toxic work environment, role conflict, role ambiguity, lack of autonomy, isolation, career development barriers, difficult relationships with administrators and/ or co-workers, managerial bullying, harassment, and organizational climate (Michie 2002).

Acute responses to stress may be in the areas of feelings (e.g., anxiety, depression, irritability, fatigue), behaviour (e.g., becoming withdrawn, aggressive, tearful, unmotivated), thinking (for example, difficulties of concentration and problem solving)

or physical symptoms (e.g., palpitations, nausea, headaches). If stress persists, it can lead to changes in neuroendocrine, cardiovascular, autonomic and immunological functioning, that could lead to mental and physical ill health (e.g., anxiety, depression, heart disease). In cases where the stressors are prolonged, the employee is at significant risk of developing physiological and psychological disorders that can lead to increased absenteeism, organisational dysfunction, and decreased work productivity (Colligan and Higgins, 2005; Mitchie 2002).

## **Stress and Dentists Well-being**

A growing body of evidence highlights the issues of mental ill health, burnout and work related stress amongst dentists in the UK and internationally. The prevalence of burnout amongst the profession varies amongst the studies globally with some reporting that 2.5% of the dental workforce is severely burnt-out (Gorter *et al.*, 1999b) and others indicating that 26% of the dentists are in high risk of both emotional exhaustion and depersonalisation (Gorter & Freeman, 2011). Signs of burnout, interestingly, may appear as early as the undergraduate years and the first years of clinical practice (Alzahem *et al.*, 2011; Gorter *et al.*, 2007). Amongst the factors younger age, male gender, high job-strain/working hours, as well as qualification level have been identified as factors to be associated with an increased prevalence of burnout in dental professionals (Singh *et al.*, 2016).

In the UK, the British Dental Association carried out qualitative research on mental health and well-being of UK dentists (Larbie, Kemp & Whitehead, 2017). Participants described feelings of stress as the main problem for them in relation to burnout and mental health issues. Working conditions, working environment, regulators (including

the GDC) and the NHS were reported as significant factors hindering the dentists' mental health and well-being (Larbie, Kemp & Whitehead, 2017).

A review commissioned by the UK Department of Health proposed that mental disorders such as depression and anxiety may hinder clinicians' performance in a number of ways including poorer time management and productivity, reduced concentration and attention, and fatigue (Harvey *et al.*, 2000). The National Clinical Assessment Service (NCAS) is an NHS organisation set up to understand, manage and prevent performance concerns. In a recent NCAS review, approximately 22% of the cases involving dentists that have been referred to NCAS were due to health concerns, including mental health problems (National Clinical Assessment Service, 2009). The NCAS review was unable to identify any research that investigated how dentists' ill health, including stress and related mental health states affects patient care (National Clinical Assessment Service, 2009; NHS National Patient Safety Agency, 2011).

## **Stressors in Dentistry**

Dental stressors have been well researched internationally. Dental professionals encounter numerous sources of stress beginning in dental school (Alzahem *et al.*, 2011) and postgraduate training (Divaris *et al.*, 2012) and escalating during their practicing lives. They affect not only general dentists but also dental hygienists (Lang, Gilpin & Gilpin, 1990) and specialist dentists such as orthodontists (Pirillo, Caracciolo & Siciliani, 2011), paediatric dentists (Davidovich *et al.*, 2015) and oral surgeons (LaPorta, 2010; Marrelli *et al.*, 2014). Data on the role of gender on levels of stress, its' perceived impact and coping strategies is conflicting. Some studies suggest that female dentists suffer more from stress-related symptoms than their male colleagues (Azad *et al.*, 2013; Boran *et al.*, 2012; Pozos Radillo *et al.*, 2008) when others indicate the

opposite (Cooper *et al.*, 1988) or did not identify any differences (Rankin & Harris, 1990). Most studies demonstrate an inverse relationship between practicing years and experience and levels of stress (Brand & Chalmers, 1990; Marrelli *et al.*, 2014; Moore & Brodsgaard, 2001; Ronneberg *et al.*, 2015). Practitioners working in a private practice report less stress and higher well-being than NHS practitioners (Bhugra, Bhui & Gupta, 2008; Brand & Chalmers, 1990; Denton, Newton & Bower, 2008; Myers & Myers, 2004). The same pattern has been supported to exist for part-time practitioners working 40 or less hours a week (Azad *et al.*, 2013; BDA, 2015).

The most often reported stressors are dealing with difficult and demanding patients, running behind schedule and time pressures followed by staff problems and relationship and pressures from third parties (Ayers *et al.*, 2008; Bhugra, Bhui & Gupta, 2008; Boran *et al.*, 2012; Brand & Chalmers, 1990; Broomfield, Humphris & Kaney, 1995; Chapman, Chipchase & Bretherton, 2015b; Cooper, Mallinger & Kahn, 1978; Cooper *et al.*, 1988; DiMatteo, Shugars & Hays, 1993; Gorter *et al.*, 1999b; Heering-Sick & Tönnies, 1989; Johns & Jepsen, 2015; Kay & Lowe, 2008; Moore & Brodsgaard, 2001; Myers & Myers, 2004; O'Shea, Corah & Ayer, 1984).

Treating anxious patients and preschool children seems to be a prevalent stressor amongst dentists regardless of their level of experience (Davidovich *et al.*, 2015). Dentists' fear of causing pain has also been described (Cooper, Mallinger & Kahn, 1978; Moore & Brodsgaard, 2001; O'Shea, Corah & Ayer, 1984) especially when administering local anaesthesia (Davidovich *et al.*, 2015; Peltier *et al.*, 1995; Rasmussen *et al.*, 2005; Simon *et al.*, 1994). Furthermore, dealing with uncooperative (Boran *et al.*, 2012; O'Shea, Corah & Ayer, 1984), difficult (Cooper, Mallinger & Kahn, 1978; Johns & Jepsen, 2015), non-compliant (O'Shea, Corah & Ayer, 1984) and demanding patients

(Gorter *et al.*, 1999b), the fragility of this relationship (Brand & Chalmers, 1990; DiMatteo, Shugars & Hays, 1993; Gorter *et al.*, 1999b; Myers & Myers, 2004) especially in the case of a complaint (Chapman, Chipchase & Bretherton, 2015b; Holden, 2014; Kay & Lowe, 2008; Stuart & Cunningham, 2015) and the way that the dentist is perceived by their patients and the public (DiMatteo, Shugars & Hays, 1993; Johns & Jepsen, 2015) appear to be important stressors in a dentist's professional life. Other stressors, include economic pressures, work overload, practice management, striving for technical perfection, private life and personal time balance, breaking bad news and dealing with medical emergencies (Azad *et al.*, 2013; Boran *et al.*, 2012; Brand & Chalmers, 1990; Chapman, Chipchase & Bretherton, 2015b; DiMatteo, Shugars & Hays, 1993; Gorter *et al.*, 1999b; Guneri, Epstein & Botto, 2013; Moore & Brodsgaard, 2001; Myers & Myers, 2004; O'Shea, Corah & Ayer, 1984). A summary of the identified stressors in the international literature are depicted in Table 1 below.

Table 1: Dentists' stressors as identified in the literature

Author/ Date	(Ayers et al., 2008)	(Azad et al., 2013)	(Bhugra, Bhui & Gupta, 2008)	(Boran et al., 2012)	(Brand & Chalmers, 1990)	(Broomfield, Humphris & Kaney, 2008)	(Chapman, Chipchase & Cooper et al., 1988)	(Davidovich et al., 2015)	(DiMatteo, Shugars & Hays, 1993)	(Gorter et al., 1999a)	(Gureri, Epstein & Baffo, 2013)	(Heering-Sick & Tönnies, 1989)	(Holden, 2014)	(Johns & Jepsen, 2015)	(Kay & Lowe, 2008)	(Moore & Brodsgaard, 2001)	(Myers & Myers, 2004)	(O'Shea, Corah & Aver, 1984)	(Palliser et al., 2005)	(Peltier et al., 1995)	(Rasmussen et al., 2005)	(Ronneberg et al., 2015)	(Simon et al., 1994)	(Stuart & Cunningham, 2015)
Stressors	Breaking bad medical news										X													
	Causing pain						X	X								X		X		X				X
	Complaints/ Litigation						X					X		X										X
	Dentist- patient relationships					X	X		X	X							X							
	Income/ economic pressures					X	X		X	X								X						X
	Medical emergencies																		X					
	Patients (anxious, difficult, demanding)				X		X	X		X		X		X	X	X		X						
	Practice Management						X	X		X				X	X									
	Private life/ personal time								X	X														
	Public/ patient perceptions					X	X	X		X				X										
	Staff problems/ relationships						X	X		X	X			X	X			X						
	Technical perfection	X					X			X								X	X					
	Third Parties			X		X	X			X								X	X					X
	Time and scheduling pressures	X				X	X	X						X		X	X	X						
	Treating children	X							X												X	X		
Workload/ long hours		X		X			X									X	X							

## **Stress, Decision Making and Performance in Healthcare**

Clinical performance consists of different areas that require different skills sets; These comprise of diagnostic skills (including information gathering and interpretation), treatment planning and decision making skills, technical operative skills and non technical skills such as leadership and communication skills. Looking at the broader healthcare literature, there are studies supporting the hypothesis that stress negatively impacts on healthcare workers' performance.

### **Diagnostic skills and decision making**

Time constraints appears to affect doctors' diagnostic accuracy and skills (ALQahtani *et al.*, 2016; Tsigas *et al.*, 2013). ALQahtani *et al.* (2016), in a randomised controlled experiment, observed that the participants in the time-pressure condition made on average 37% more errors than the control group (ALQahtani *et al.*, 2016). Similarly, in an experimental study, 34 Greek general medical practitioners (GPs) were presented with two scenarios involving virus respiratory tract infections and their responses were compared to national guidelines (Tsigas *et al.*, 2013). The GPs asked significantly fewer questions concerning presenting symptoms, conducted a less-thorough clinical examination, and they gave less advice on lifestyle, when they were exposed to the time-pressure condition (Tsigas *et al.*, 2013).

An early longitudinal US-based study using data from 67 hospitals and recruiting 12,000 hospital healthcare workers investigated the correlation between job strain and medication errors, the possible association between malpractice claims and levels of on-the-job stress and finally the effects of an organization-wide stress management programme on the above (Jones *et al.*, 1988). Statistically significant correlations were found between stress, medication errors and malpractice claims, whereas a decrease in

the reported medication errors and the number of malpractice claims was observed upon the implementation of the stress management programme (Jones *et al.*, 1988).

Furthermore, several studies have implemented simulation scenarios to test participants' performance and decision making in critical situations. A crossover study testing paramedics' performance in simulated critical events demonstrated that high-stress scenarios lead to more commission errors (reporting information not present in the scenario) (Leblanc *et al.*, 2012). On the other hand, in a similar prospective crossover study, no difference in the performance of fifty-four Canadian hospital doctors in a resuscitation simulation scenario was found in the addition of acute stressors (Piquette *et al.*, 2014). In contrast, medical students' resuscitation performance was negatively affected by stress and mental overload (Hunziker *et al.*, 2011).

### **Technical skills**

Arora *et al.* (2010), in a systematic review, concluded that excessive stress impairs surgical technical performance; but its effect is more profound in novice surgeons than their experienced peers (Arora *et al.*, 2010). In contrast, the results of a later experimental study on the effect of different stressors on psychomotor performance were not in line with the conclusions of the above systematic review (Poolton *et al.*, 2011). It was only time pressure which caused a significant increase in stress levels, but it did not influence completion time or the outcome of a laparoscopic simulation task (Poolton *et al.*, 2011).

### **Non technical skills**

Arora *et al.* (2010) suggested that non-technical skills such as leadership and communication may well be hindered during stressful surgical crises (Arora *et al.*, 2010). Brown *et al.* (2009) assessed the communication skills of novice and expert

medics in a simulated breaking bad news consultation observed that poor performance was related to high stress and fatigue levels (Brown et al., 2009). Empathy among medical students has been found to be inversely associated with high levels of stress (Park *et al.*, 2015). Stress also appears to affect the memory of healthcare personnel. Namely, increased stress in NHS-24 helpline nurses has been correlated with more frequent failures of attention and memory concentration (Allan *et al.*, 2014). Vuori *et al.* (2014), similarly, found an inverse association between job strain of hospital ward personnel and speed of memory retrieval (Vuori *et al.*, 2014).

The above may well apply to the practice of dentistry however there is paucity of primary evidence exploring the effects of stress on dentists performance. Therefore, the aim of this ResM project was to evaluate the impact of stress and anxiety on dentists' clinical performance. The term stress relates to the intra and/or perioperative stress induced by different stressors and emotions that a dentist may experience. This project did not attempt to prove causality between dentists' ill mental health (such as depression, burnout, or anxiety as a clinical condition) and poor performance.



## **Chapter 2: Impact of Stress on Dentists' Clinical Performance: a Systematic Review**



## **Background and Aim**

As discussed previously a variety of stressors can affect healthcare personnel's decision making, attention, memory, diagnostic, technical and non-technical skills. Thus, it is plausible that the stress experienced by dentists can affect their clinical performance.

In an online survey of UK general dental practitioners, 84% of the dentists who participated felt that various occupational pressures and fears can negatively influence their decision-making (GDPUK 2008). In a subsequent research priority setting exercise, the question: "does dentists' fear have an adverse effect on clinical decision making?" was voted highly by members of the Primary Care Dentistry Research forum as a question that needed to be answered (Fox, 2010). This led to an evidence summary sponsored by the Shirley Glasstone Hughes Trust, which was published in 2010 (Fox, 2010). This rapid review failed to identify any relevant literature on the topic and suggested that this is a novel territory for primary research (Fox, 2010). Since the scope of the rapid review was limited to fear and decision making, we assumed that studies exploring the effect of other stressors in different aspects of clinical performance would not have been included in Fox's review. In addition, since the call for primary research in 2010, studies answering the above question regarding fear and decision making may have been published. Therefore, this systematic review aimed to answer the question: how does stress impact on dentists' clinical performance?

Aim: to review the empirical evidence on the impact of stress in dentist's performance

Objectives: To identify studies that evaluated the impact of stress or different stressors on different aspects of dentists' performance (technical and non-technical).

## **Methods**

This review used systematic review methodology and adhered to the preferred reporting items for systematic reviews and meta-analysis statement (PRISMA). A systematic review protocol was registered with the International Prospective Register of Systematic

Reviews (PROSPERO) under the registration number CRD42016045756 (Appendix 1).

The PECO framework was used to structure the research question and search strategy.

**P:** (population): dentists, general dental practitioners

**E:** (exposure): stress

**C:** (comparison): no stress

**O:** (outcome): decision making, diagnosis, treatment planning, performance, clinical performance, clinical competence, psychomotor performance, communication skills

Studies were selected based on the criteria stated below.

**Type of studies:** Primary prospective empirical studies either observational (in a practice or clinical setting) or experimental (in a simulated environment) were included. Both randomised and non-randomised studies were considered for inclusion. Retrospective studies, non-empirical studies and opinion pieces were excluded. Both experimental and observational prospective comparative studies (e.g. clinical trials, cohort studies) were included to explore both the impact of stress in real life and in experimental settings. In observational studies, we expect the condition is more similar to what dentist's experience, however, measuring the existence or level of stress is difficult. In experimental studies, measuring the existence and level of stress (and its impact) is likely to be more accurate, but it might not directly reflect the real-life working environment.

**Types of participants:** Studies recruiting dentists were considered for inclusion. Any studies involving solely other healthcare professionals were excluded.

**Types of exposure:** Studies that reported stress using validated self-report or physical measures were considered for inclusion. Studies reporting only participants' perceptions were excluded.

**Types of outcome measures:** Relevant outcome measures included measurable changes in different aspects of performance (decision making, diagnosis, treatment planning, performance, clinical performance, clinical competence, psychomotor performance, communication skills). Studies reporting only participants' perceptions were excluded.

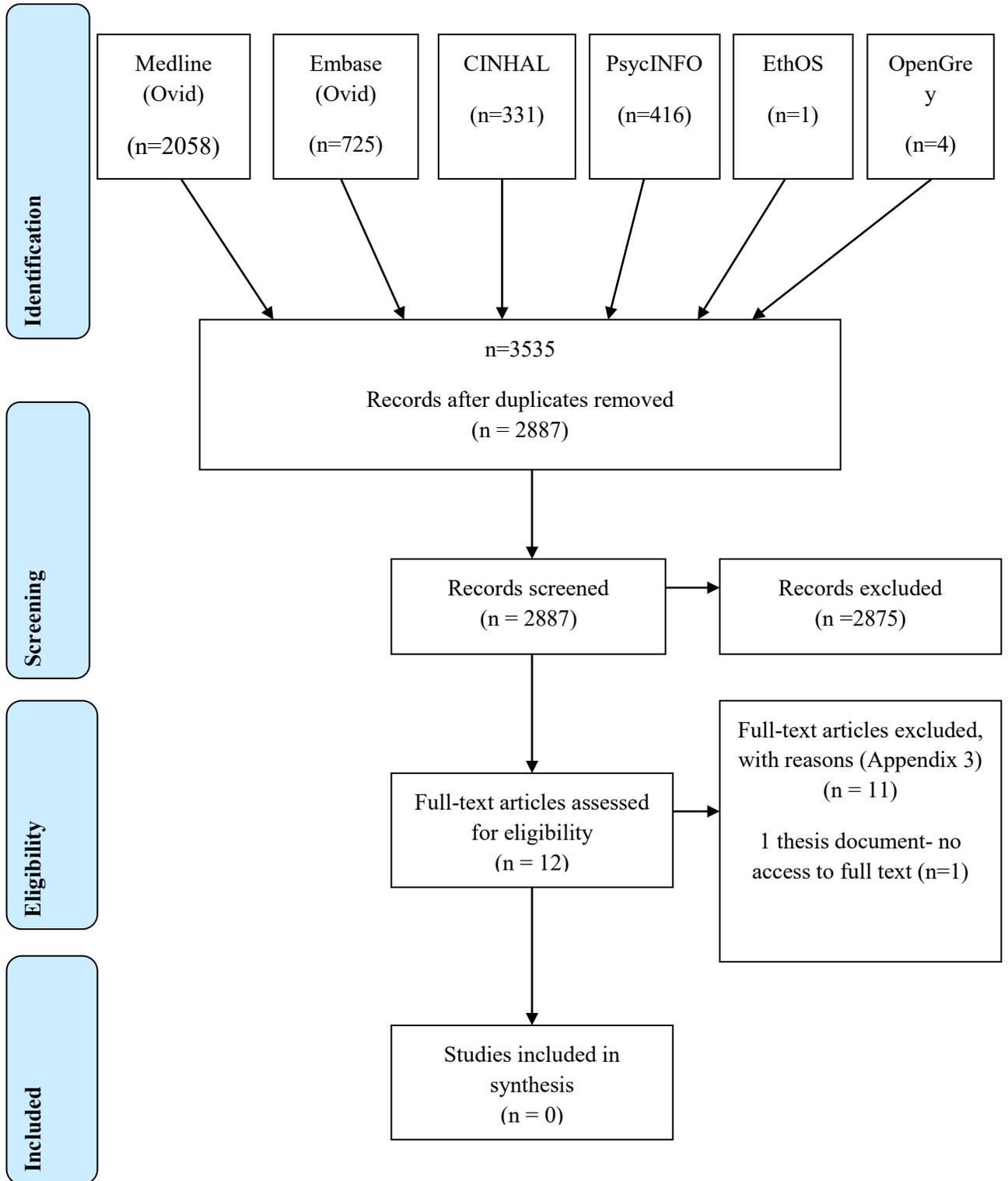
A search of the literature was performed using electronic bibliographic databases and manual searching of citations of relevant studies. The following electronic bibliographic databases: CINAHL, Embase (Ovid), Medline (Ovid), and PsycINFO were searched. The grey literature was searched via EThOS and OpenGrey databases. The reference lists of potentially eligible studies were searched. MeSH Terms and subheadings and free text search terms were used in the literature search. The search strategy for the electronic databases (CINHAL, Embase, Medline and PsycINFO can be found in the Appendix 2. Different combinations of free text search terms were used to identify relevant studies on the EThOS and OpenGrey databases. The electronic searches were last updated on the 31<sup>st</sup> of March 2017, and supplementary searches (screening citation lists of potentially eligible studies) were completed in April 2017.

The citations retrieved from the electronic searches were inserted into the Endnote X7.4 reference management software, and duplicate records were removed. Two reviewers (AP and MBD) independently scanned all the titles and abstracts of the retrieved studies using the Rayyan systematic review web app (Elmagarmid A, 2014). Abstracts

considered as potentially eligible, as well as those that did not supply enough information, were reserved for the assessment of the full-text article. The inclusion criteria were then applied against the full-text version of papers independently by the same two reviewers. Any differences concerning eligibility after the full text was evaluated were resolved through consensus, and when differences persisted, a third reviewer (DRM) was consulted before a final decision was reached. A record of reasons for excluding studies was kept during the review process.

Two appraisal tools were utilised for the risk of bias assessment, depending on the study type included.

- For RCTs: Cochrane Collaboration's Risk of Bias (RoB) tool.
- For non-randomised studies with a separate a control group: the Effective Practice and Organisation of Care (EPOC) RoB Tool.



**Fig. 1: PRISMA Flowchart: Identification and selection process of studies**

## **Results**

The search of electronic databases yielded 3535 references. After removing duplicates and assessing titles and abstracts, twelve publications were considered potentially eligible. Full texts were retrieved and analysed for eligibility. No further studies were identified after screening the citation lists of these papers. Figure 1 (PRISMA flowchart) summarises the process of literature identification and selection. Of those twelve papers, the eleven were rejected for the reasons listed in Table 1.

The remaining citation was a thesis abstract in French (Caron, 2004). The abstract information did not provide sufficient information for the authors to make a judgment regarding its eligibility. One section of the thesis apparently considered the impact of stress on the practice of dentists but there was no information regarding how stress or its impact, were assessed. The contact details of the authors were not available, and further attempts to retrieve them from other sources failed. The institutional library of the University to which the Thesis was submitted to and the French National Library were contacted via e-mail by AP and a University Library information administrator, but the full document could not be retrieved. Therefore, our systematic search of the literature retrieved no relevant publications for analysis, indicating a gap in the dental literature on this topic.

## **Concluding Remarks**

The aim of this review was to answer the question: “‘how does stress impact on dentists’ clinical performance?’. The review did not manage to meet its aim due to the paucity of empirical evidence in the literature. Contrary to an earlier rapid review (Fox, 2010), the present review adopted a more robust and transparent systematic review methodology according to the PRISMA guidelines. A more sensitive and broad search was employed,

including searching the psychological and grey literature. Two reviewers independently screened the retrieved articles and applied the predefined inclusion criteria. A third reviewer was available to solve any disagreements. However, no prospective empirical studies on the impact of stress on dentists' clinical performance were identified. These types of experimental studies are common in psychology and have recently started appearing in healthcare research, in areas such as medicine and surgery (Arora *et al.*, 2010; Hunziker *et al.*, 2011; Leblanc *et al.*, 2012; Piquette *et al.*, 2014; Tsiga *et al.*, 2013).

Given the paucity of empirical evidence within dentistry, studies are necessary to shed light on this important topic which on the basis of the wider health literature may be linked to patient safety and quality of care. Mirroring the approaches adopted in the wider health literature, dental studies could expose dentists to different stressors under which they perform a series of simulated tasks. Stress may be provoked by different stressors such as time pressure or simulated risk of litigation and assessed by validated self-report measures (psychological questionnaires) or physical measures such as heart rate, skin conductance or cortisol levels. Areas of performance to be evaluated may include decision making (treatment planning and diagnostics including the prevalence of errors), psychomotor skills (e.g. quality of cavity preparations, iatrogenic damage to adjacent teeth) and clinical performance, cognitive ability (e.g. memory), interaction with patients (e.g. communication skills) or adherence to guidelines and best practice recommendations. The EPICOT framework was adapted to provide systematic and structured implications for future research (Brown *et al.*, 2006). The EPICOT framework is a well-recognised framework used by established systematic review

organisations such as the Cochrane Collaboration (Schünemann HJ, 2011). Our recommendations for future research are summarised in the following table (Table 2).

**Table 2: Recommendations for future research**

	<b>Core Elements</b>	<b>Status of research for this systematic review</b>
<b>E</b>	<b>Evidence</b>	This systematic review identified <u>no eligible studies</u> .
<b>P</b>	<b>Population</b>	Dental practitioners.
<b>E</b>	<b>Exposure</b>	Stress induced by different stressors (e.g. time pressure, risk of litigation etc.)
		Stress to be evaluated by: <ul style="list-style-type: none"> <li>• Self-reported measures (e.g. psychological validated questionnaires)</li> <li>• Physical measures (e.g. heart rate, skin conductance, cortisol levels, etc.)</li> </ul>
<b>C</b>	<b>Comparison</b>	No stress
		Different levels of stress
<b>O</b>	<b>Outcome</b>	Impact of stress on: <ul style="list-style-type: none"> <li>✓ Decision making (treatment planning and diagnostics including the incidence of errors)</li> <li>✓ Psychomotor skills and clinical performance (quality of cavity or crown preparations, damage to adjacent teeth)</li> <li>✓ Cognitive ability e.g. memory</li> <li>✓ Interaction with patients e.g. communication skills</li> </ul> Adherence to guidelines and best practice recommendations.
		The measures should be able to quantify the impact (e.g. percentage of errors or Likert scale to rate performance).
<b>T</b>	<b>Time Stamp</b>	April 2017
<b>S</b>	<b>Study Type</b>	Exposure to stress in daily clinical environment (observational studies)
		Exposure to stress (induced) in a simulated environment (experimental studies)

**Chapter 3: A Systematic Map of the Decision  
Making Literature and the Factors Influencing  
Dentists' Decision Making**





## **Background:**

### **Why is this review necessary?**

Given the paucity of research activity around the impact of stress, fear and negative emotions on dentists' clinical performance and decision making, a broader systematic search of the literature was conducted to identify the factors that may affect dentists' decisions. We hypothesised that stress or different stressors may have been reported or evaluated in empirical studies without them being the primary outcome of the studies. In order to identify such studies a systematic mapping review was conducted.

In addition, in order to plan a research project on the impact of stress on decision making in dentistry, a good understanding of other contributing or confounding factors that may influence the decision making process is essential. Identifying what type of experimental designs have been used and piloted evaluating decision making in dentistry will inform the design of our subsequent primary experimental study.

### **What is a mapping review and what is its purpose?**

A mapping review, or evidence map, sets out to map the literature. It provides a descriptive overview of a research area, highlighting areas in which empirical research has been conducted and aids in the identification of knowledge gaps (Grant & Booth, 2009; Miake-Lye *et al.*, 2016). This type of review does not aim to provide an overview of study findings or synthesize evidence, rather it involves a search of the literature to determine what sorts of studies addressing the systematic review question have been carried out, where they are published, what sorts of outcomes they have assessed, in which populations and using which methods. Nonetheless, a systematic map can also provide the basis for an informed decision to undertake an in-depth review and synthesis on all the studies or just a subset (Grant & Booth, 2009; Miake-Lye *et al.*, 2016).

A scoping review is a form of knowledge synthesis that addresses a research question aimed at mapping key concepts, types of evidence, and gaps in research related to a defined area or field by systematically searching, selecting, and synthesizing existing knowledge (Colquhoun *et al.*, 2014). The mention of “map” in the above definition may lead to potential confusion between a scoping review and a mapping review. In contrast to mapping reviews which characterise the quantity of the literature (Grant & Booth, 2009), scoping reviews are concerned with contextualising knowledge in terms of identifying the current state of understanding, identifying what it is known and what it is not and subsequently set this within policy and practice contexts (Anderson *et al.*, 2008, Levac *et al.*, 2010). A scoping review seeks to establish the parameters for a planned review and to establish the likely quantity and quality of the evidence to be reviewed. It has both a conceptual and a pragmatic function as a preliminary to more intensive follow-up review activity. In contrast a mapping review within a broad topic area seeks to establish where opportunities for review lie and where subsequent review efforts, if any, might best be targeted. It can therefore be considered more exploratory and more speculative than a scoping review which is often about operationalising detailed plans for a proposed review. (Levac *et al.*, 2010).

**Aim:**

The aim of this evidence map was to answer the following question: In the dental decision-making literature, which areas have been researched, and which have not, and what type and number of primary studies have been conducted?

**Objectives:**

- To understand the current distribution of the type and characteristics of research focusing on dental decisions.

- To identify decision making models which have been described in the dental literature and have been used in experimental studies.
- To map the factors that have been described and/or evaluated as influential in dental decision-making studies in order to identify gaps in the current research base.

## **Methods**

A review protocol was developed a priori and was registered with the International Prospective Register of Systematic Reviews (PROSPERO) under the registration number CRD42016047706 (Appendix 4).

### **Literature search**

A search of the literature was performed using electronic bibliographic databases and manual searching of citations of relevant studies. The following electronic bibliographic databases: CINAHL, Embase (Ovid), Medline (Ovid), and PsycINFO were searched. The grey literature was searched via EThOS and OpenGrey databases. The reference lists of potentially eligible studies were searched. Both MeSH Terms and subheadings and free text search terms were used in the literature search. Different combinations of free text search terms were used to identify relevant studies on the EThOS and OpenGrey databases. The initial searches were conducted in July of 2016 and the body of the systematic map was drafted in early 2017. The electronic searches were last updated on the 19th of May 2017 as well as the supplementary searches (screening citation lists of potentially eligible studies) and the map was updated and finalised subsequently.

The search strategy included the following key search terms and relevant MeSH/keywords and Boolean operators:

```
(dentist* OR SU.EXACT("Dental Surgery") OR SU.EXACT("Dentists") OR
SU.EXACT("Dentistry")) AND (SU.EXACT("Clinical Judgment (Not Diagnosis)") OR
SU.EXACT("Decision Making") OR ("decision making") OR decision* OR
SU.EXACT("Treatment Planning") OR SU.EXACT("Models") OR
SU.EXACT("Clinical Models") OR SU.EXACT("Information Processing Model") OR
SU.EXACT("Heuristic Modeling") OR SU.EXACT("Mental Models"))
```

The above search strategy was performed on PsycINFO and it was adapted for the other databases. The search terms and strategy for the other electronic databases are provided in the appendix 5.

## **Study selection**

### **Screening of title and abstract stage**

The citations retrieved from the electronic searches were imported into the Endnote X7.4 reference management software, and duplicate records were removed. Two reviewers (AP and MBD) read all the titles and abstracts from the literature search independently to assess their relevance, compared their judgments and obtained full-text copies of the studies deemed relevant. Any research papers focusing on dental decision making were included. These included, amongst others, papers describing or testing a decision-making model, studies assessing dentists' decisions in a simulated or clinical environment and qualitative studies examining decision-making. Regarding to the types of decision making, papers or studies looking at dentists decisions related to diagnostics, treatment planning and treatment selection were included. However, papers looking at referral decisions were excluded, as they involve the complex interplay of the referring and receiving practitioner, patients and the healthcare system. The Rayyan systematic review web application was used for this stage (Elmagarmid A, 2014).

### **Screening of full-text**

Subsequently, two reviewers AP and MN scanned independently the abstracts and full-text of the eligible studies. A two stage classification took place. In the first stage the studies were categorised in four broad categories based on common themes in study design and purpose of the research. These categories were developed following an iterative process.

**A) Theoretical papers:** These studies attempt to explain how the decision making process in dentistry works. They suggest a model, theory or framework to explain the process.

**B) Experimental studies:** These studies prospectively attempt to test how dentists make decisions in an experimental setting for given different scenarios or simulated clinical cases.

**C) Studies on dentists' perceptions and preferences:** These studies collect data on dentists' perceptions and preferences with regard to their decision making process. These are either surveys or interviews in which the dentists are asked about what factors affect their decision making and what importance they attach to these factors.

**D) Observational studies:-**These studies include observations or collection of data in a real clinical setting or retrospective collection of clinical data from real patient cases.

Once this broad categorization took place, AP read the full text of the studies in each category again and identified common themes which allowed a thematic categorization of the studies in subcategories. A consensus for the subcategorization between the two reviewers (AP and MN) was also reached after discussion.

#### **Extraction of data and synthesis**

A data extraction form was used to extract specific data from the included studies:

- a) year of publication,
- b) clinical domain tested (e.g cariology, periodontology, endodontics etc.),

- c) factors described or evaluated and
- d) statistical significance of each factor if given in the text by the authors.

For the tabulation and classification of the decision making factors identified in primary studies, the models of decision making described by Bader and Shugars (1992), and Kay and Nattall (1995) were used and adapted. The data are presented in the form of diagrams and tables accompanied with a descriptive synthesis where appropriate (Cough ., 2012).

### **Differences between the protocol and the methods in this review**

In the original protocol (PROSPERO: CRD42016047706), only prospective experimental studies, along with surveys that used a vignette to quantify the dental decisions and the factors that have influenced them were to be included, quality assessed and their results to be synthesised in a systematic review. However, the search results returned studies with very diverse aims and study design that did not address similar focused questions. Therefore, it was deemed more meaningful to map the evidence base on decision making to identify the different types of research already conducted before commencing any in depth systematic reviews around selected focused questions. As we were not attempting to make clinical recommendations and the studies did not cluster around a certain theme, quality appraisal of the studies was not conducted nor their results pooled statistically together.

## **Results**

The literature search identified 9,382 articles, 1,808 of which were duplicates. The remaining 7,574 items were screened, of which 7,337 were excluded as they did not address the questions of interest. Figure 2 summarises the results of the literature search

in a flow-diagram similar to the one suggested by the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) flow diagram.

Two hundred and thirty seven (237) articles satisfied the inclusion criteria and were categorised in 4 broad categories and subcategories based on common themes identified by the reviewers as described above (Figure. 2). Some of the studies appear in more than one category in the given taxonomy. The included papers per category and relevant citations are presented in the Appendix 6.

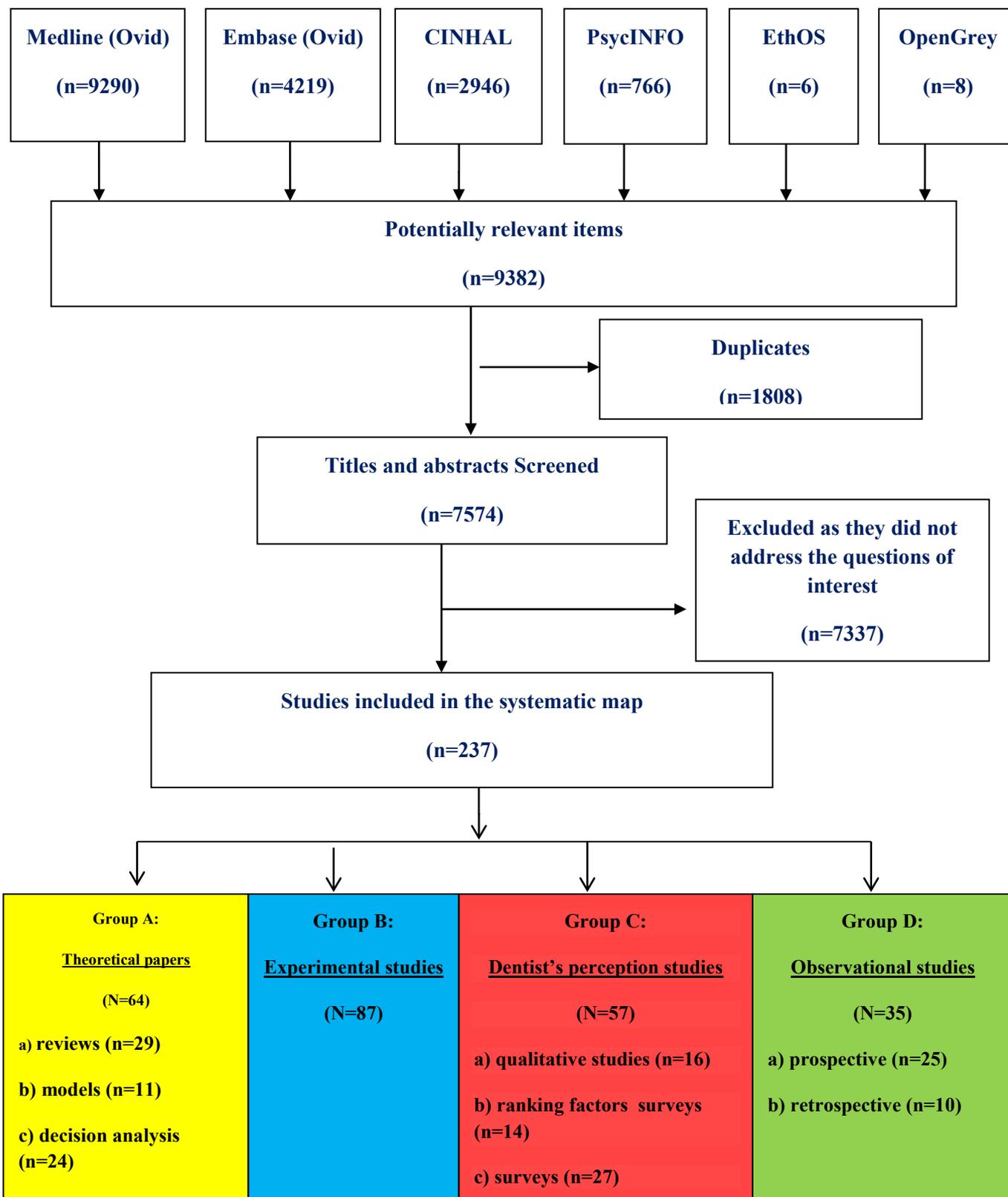


Figure 2. Flowchart of study selection

### **Characteristics of the research**

Sixty four of the included citations were categorised as **Group A (theoretical papers)**, 29 of which were reviews, 11 described a dental decision making model, and 24 described decision analysis models aiming to aid in the clinical decision making process. Eighty-seven **experimental studies (Group B)** were identified. In all of these, the dentists were given one or more scenarios, sometimes with a series of radiographs or photographs, and their decisions were recorded. The vast majority (78 studies) of those were questionnaires along with case scenarios which were sent to dentists. They were aiming to assess the consistency and variation in decision making amongst dentists. The influence of different factors on the variation in decision making was explored via regression analysis in those studies. Only eight studies used other experimental designs (between and within subjects study designs and randomised controlled trials) and they controlled for decision making factors and subsequently assessed their impact in dental decision making.

Fifty-seven of the identified studies fall into the category of studies assessing the **dentist's perceptions and preferences (Group C)**. Sixteen of those were qualitative interview studies, of which 9 prompted the decision making of the dentists by presenting them with one or more scenarios and 7 did not use a scenario. One mixed methods questionnaire study with open ended questions on which thematic analysis was performed was identified. Any influential decision making factors described in these studies stemmed directly from the participant dentists and not the researcher. In fourteen questionnaire-based surveys the dentists were asked to rank the importance of pre-specified factors when forming their decisions. These studies did not use a specific clinical scenario to prompt the dentists' decisions but they were primarily about the dentist's preference between two treatments (e.g. composite vs amalgam, or filling vs

crown). Twenty seven surveys quantifying the variation in dentists' preferences on different treatment modalities and material were identified.

Finally, 35 studies were **observational studies (Group D)** and recorded the dentists decision in a clinical environment either prospectively (25 studies) using data collection sheets provided by the researchers or retrospectively (10 studies) from patient case notes. These studies aimed to identify the chief reasons that led a dentist to choose a particular treatment over another and some explored the impact of different influencing factors via regression analysis.

The studies were summarised based on the decade of publication. Observing figure 3 it becomes apparent that the research activity on dental decision making became more prevalent in the 1990s onwards. Although the rate of experimental studies being published remained the same through the three last decades, the qualitative research activity increased in the last 10 years (11 out of the 16 qualitative studies having been published since 2008). A detailed categorisation of the included studies per year can be found in the Appendix 7.

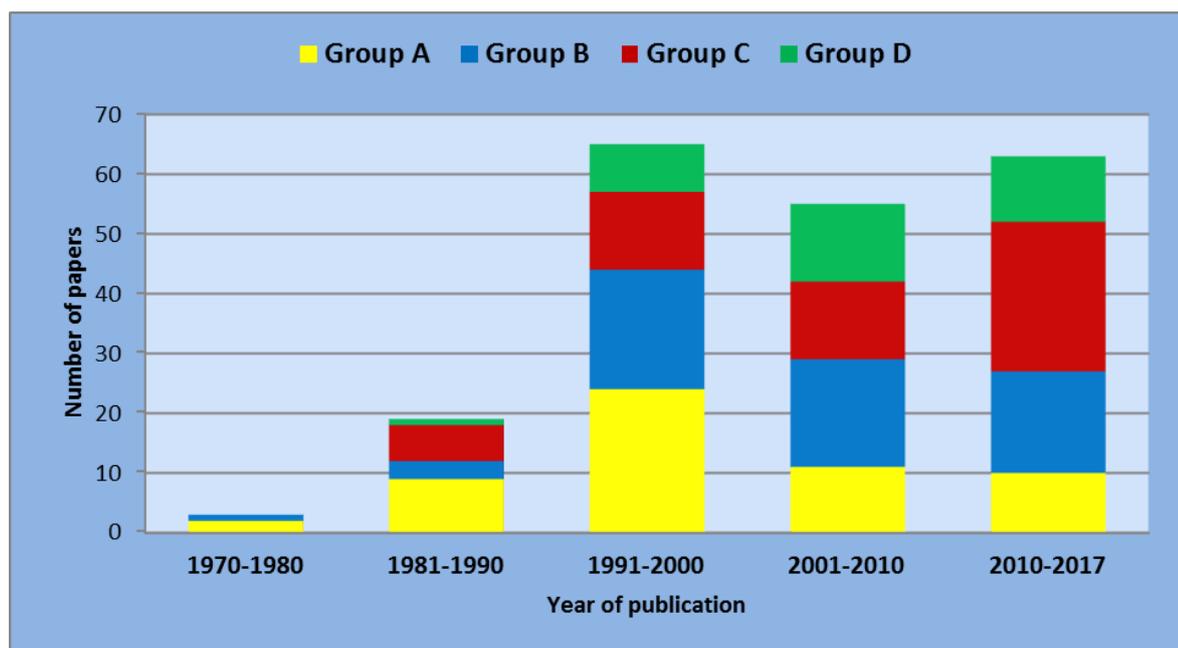
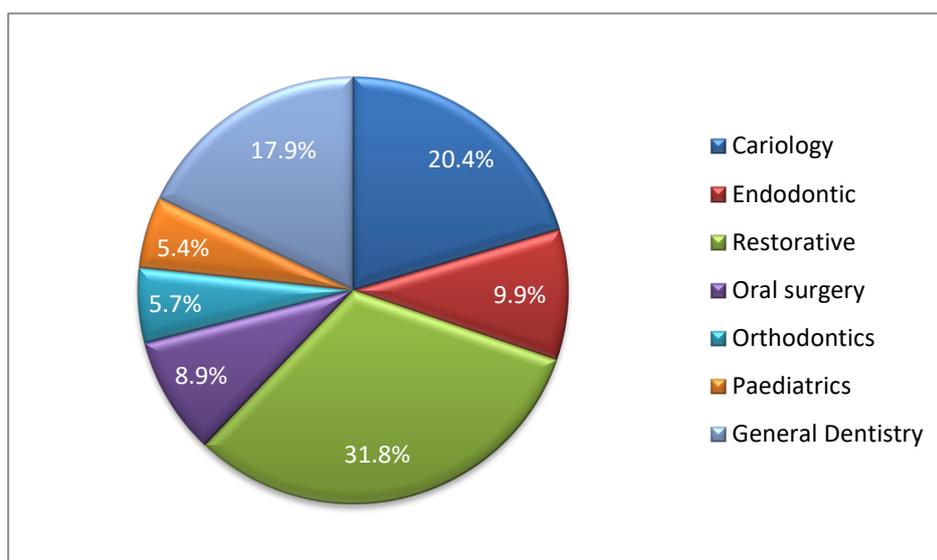


Figure. 3: Classification of studies as per year of publication.

The distribution of studies by clinical domain of interest can be observed in figure 4. Many studies focused their interest in caries diagnosis and the management of carious lesions (20.4%). Equally, a large number of studies have looked at restorative decisions including management of periodontal disease, replacement of missing teeth and placement of implants (31.8%). From the oral surgery studies (8.9%), most investigated the prophylactic removal of mandibular third molars. A smaller percentage of studies examined the variation in orthodontic decisions and decisions about the management of paediatric patients. The “general dentistry” category included mostly theoretical papers that were commenting on decision making in dentistry in general and they could not be taxinomised in any of the above categories. However, some of the empirical studies examined decisions in prescribing of radiographs (7 studies), antibiotic prescribing (1 study), and special care dentistry (1 study). The categorization of the included studies is presented in more detail in the Appendix 7.



**Figure. 4: Categorisation of studies per clinical domain.**

### **Decision making models in dentistry**

Eight conceptual models were identified describing dentists' decision making. Five of those were generic, describing the decision making process in general as regards to provision of dental care and three were specific to the type of treatment decision (e.g caries diagnosis, decision for removal of third molars and re-root canal treatment). Of the identified models, two were driven from the existing dental literature (Bader & Shugars, 1992; Kay & Nuttall, 1995), two were built on empirical observations of clinical decision making (Ettinger, Beck & Martin, 1990; Schuman & Turner, 1997) two were data driven based on experimental studies (Kvist, 2001; Mileman & van der Weele, 1996) and the last two models were adapted versions of decision making models used in psychology (Chipchase, Chapman & Bretherton, 2017; Knutsson, 1996) . A description of the models and a summary of the findings of experimental studies which tested those models, is provided in the following sections.

According to the **decision making model described by Kay and Nuttall**, for a decision to be made, dentist, patient and environmental related factors are taken into consideration (Kay & Nuttall, 1995). **Bader & Shugars conceptual model of dentist's treatment decisions** subcategorise the dentist and patient factors even further (Bader & Shugars, 1992). The patient factors are divided into tooth, mouth and patient level whilst the dentist factors are divided into dentist and practice characteristics and dentist's biases (Bader & Shugars, 1992). These models were adapted and used later in this chapter to aid the taxonomy of the identified decision making factors.

**The Ozar ethical decision making model** supports that each dental clinical decision consists of the following components: life and health, appropriate and pain free oral function, patient autonomy, preferred practice values, aesthetic values, cost and other external factors (Schuman & Turner, 1997). The Ozar model was found to fit well the

decision making behaviour of the dentist-patient encounters observed in a study in an educational clinical setting (University of Tennessee) (Schuman & Turner, 1997).

**The Rational Dental Care model**, described by Ettinger et al. has been used to describe the dentists' decision making process for the provision of dental care (Ettinger, Beck & Martin, 1990). The preferred treatment plan will be based both on the dentist's resources (diagnostic and technical skills and equipment available) and patient resources (life expectancy, general health, expectations and funding ability) (Ettinger, Beck & Martin, 1990). The author has proposed that this model is used in geriatric care treatment planning decisions in particular (Ettinger, Beck & Martin, 1990) (Ettinger, 2015). The model has been tested by using individual naturalistic observation of expert clinicians. Interestingly, although the dentists in this study evaluated a wide range of patient characteristics, they did not follow the proposed process described by the model but they relied heavily on past experience with similar situations instead (Ettinger, Beck & Martin, 1990).

The **Bader & Shugars model** has been applied in caries diagnosis and treatment and it describes how dentists use a "script match" based on previous experiences to aid their treatment decisions (Bader & Shugars, 1997). This script match is now known as pattern recognition. The dentists use their cumulative experience with similar clinical presentations of health and disease before making their caries diagnosis (Bader & Shugars, 1997). This model introduces the notion of uncertainty in decision making. When the dentist cannot confidently match the patient's presentation to a previous "script" they scrutinize the available evidence further before they make a treatment decision (Bader & Shugars, 1997). In the same lines, the **Mileman and Van der Weele caries diagnosis model** describe how dentists' characteristics (background and biases) interact with the dentists' diagnostic accuracy and patient related factors (patient

behaviour and caries prognostic factors) to influence the dentist's decision to intervene (Mileman & van der Weele, 1996).

**The praxis concept** has been used to describe the decision making process of dentists when prescribing re-root canal treatment taking into consideration the periapical health of the tooth in question. According to this model dentists perceive periapical lesions of varying sizes as different stages on a continuous health scale (Kvist, 2001; Kvist, Heden & Reit, 2004). Interindividual variations can then be regarded as the result of the choice of different cut-off points on the continuum for prescribing retreatment. The Praxis concept also suggests that the final re-treatment decision is influenced by factors not related to periapical disease per se. Such factors include assessment of treatment risks, economic costs, and clinical skills of the individual dentist (Kvist, Heden & Reit, 2004). The praxis concept has been tested by experimental studies using simulated cases. These studies have shown that although large variation in treatment decisions amongst dentists exist, the majority of the decision strategies are in line with the Praxis concept.

**The Brunswik Lens model of decision making** has been adapted by Knutsson et al. to describe the process of making a judgment on removal of mandibular third molars (Knutsson, 1996; Knutsson *et al.*, 1997; Knutsson, Lysell & Rohlin, 2000). The Brunswik lens model is an analytical tool used in judgment analysis. Judgment analysis is a descriptive approach that focuses on the cognitive process involved in making a judgment or a decision (Knutsson, 1996; Knutsson *et al.*, 1997; Knutsson, Lysell & Rohlin, 2000). The Lens model uses the analogy of rays of light passing through a convex lens to describe the relationship between the cues (pieces of information) and the true state – the optimal judgment or decision- and the relationship between the cues and the judged state (Knutsson, 1996; Knutsson *et al.*, 1997; Knutsson, Lysell & Rohlin, 2000). According to this model dentists base their judgment on three different cues: patient's age, angular position, and degree of impaction of the wisdom tooth. The

selection of these cues is literature driven (Knutsson *et al.*, 1997). A series of experimental studies was designed to test this model. Dentists in these studies were presented with different cases within which, each cue's different value was equally distributed in the presented cases (Knutsson, 1996). These studies concluded that a variation in decisions exists and dentists use the described cues to a high extent in their judgment of the development of different third molar related diseases and utilise these cues to decide on the prophylactic removal of mandibular third molars.

Finally, a decision making model of the impact of emotional arousal and stress on dentists' decision making was found. Chipchase *et al.* (2017) adapted the **Janis and Mann's conflict theory model of decision making** to dental decision making. According to this model the type of decision making fluctuates to a continuum from unconflicted to avoidance and hyper-vigilance influenced by the level of arousal/stress and the perceived risk of suffering loss as a result of the decision (Chipchase, Chapman & Bretherton, 2017). The original model was adapted by the authors to dentistry following semi-structured interviews with general dental practitioners in England (Chipchase, Chapman & Bretherton, 2017).

### **Characteristic of the experimental studies**

The vast majority of the studies were questionnaire-based studies using case scenarios. These questionnaires were sent to dentists who were asked to record their decisions with regard to diagnosis or treatment of the case based scenarios. Although regarding the decision making scenario, these studies did not have a control group, a number of them used stratification based on dentists' educational background, years of experience and gender to distribute the questionnaires and create comparator groups. The other experimental studies included nine controlled studies - the scenarios remained the same except the one factor under investigation between the groups. The scenarios were manipulated based on that one factor and its impact was evaluated statistically. From

these nine studies, six used a within subjects experimental design and three a between subjects design. The results of these studies are described in the next section.

The case scenarios used, were presented in various ways amongst the studies.

- Thirty studies used a written case description and radiographic images,
- 11 only used written case descriptions,
- 6 used a written case description with a photographic image,
- 5 used a written case description along with relevant radiographs and photographic images and
- 4 used radiographs alone with no case description.

In addition, 10 studies used simulated radiographs. These were bitewing radiographs taken of extracted teeth after being mounted to simulate a real mouth. In two studies the simulated teeth were mounted in phantom heads and the dentists performed clinical examinations of the simulated teeth as well as assessment of the simulated radiographs. These studies also assessed the diagnostic accuracy of the dentists by using as a gold standard results from microscopic evaluation of the extracted teeth (7 studies), expert consensus (3 studies) or both (2 studies).

In a number of the identified experimental studies the dentists were provided with a simulated presentation of progressively larger caries lesions (outer third of enamel, outer third of dentine, inner third of dentine etc.) to assess their treatment threshold (at which depth they would definitely intervene). For the presentation of the size of the lesions 7 studies used a schematic representation, 4 photographic images, 2 a descriptive text, and another 2 simulated radiographic images. Schematic representation of the size of the lesion has been used in studies related to apical pathology and endodontic decisions (4 studies). Finally, in one of the included studies dentists of different educational background examined real patients in an experimental setting.

## Influencing factors in dental decision making

In this section, an overview of the factors that have been described or evaluated in the experimental studies, two of the subcategories of the dentist perception studies (qualitative studies and ranking factor ones) and the prospective real-life studies are presented. A detailed taxonomy of the factors and the studies citations is given in the form of a table in Appendix 7.

According to the decision making models used to inform this taxonomy (Bader & Shugars, 1992; Kay & Nuttall, 1995), the influencing factors can be dentist related (dentists characteristics, education and dentists' biases), patient related (patients' characteristics, their values and health factors in patient, mouth and tooth level) or environmental factors (stemming from the system or an the environment that a dentist is working in). Table 3 summarises the factors identified in the literature. Looking at the research activity in the field of dental decision making as a whole, it can be observed (Figure 5) that the vast majority of studied have evaluated the impact of dentist characteristics and patient related factors and only a minority have evaluated the impact of the environmental factors in dentists' decision making. It is clear that the environmental/system related factors are reported frequently by dentists in qualitative studies (68.75% of the included qualitative studies) but have been evaluated in only 12.80% of the included experimental studies.

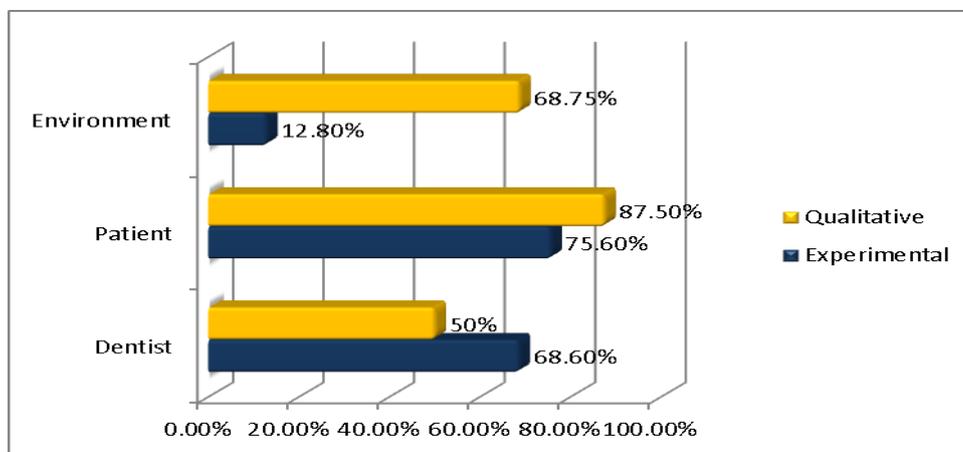


Figure. 5: Percentage of included studies reporting, describing or evaluating dentist, patient or environment related factors in dentists' decision making.

**Table 3: Factors that have been hypothesised as potentially influential in dentists' decision making.**

<b>Dentist related factors</b>		
<b>Characteristics</b>	<b>Education</b>	<b>Biases (Perceptions/experience)</b>
<ul style="list-style-type: none"> <li>• Age</li> <li>• Gender</li> <li>• Location of practice</li> <li>• Type of practice (private/public)</li> <li>• Years of experience</li> </ul>	<ul style="list-style-type: none"> <li>• Continuing education/CPD</li> <li>• Country of graduation</li> <li>• Specialty vs generalist</li> <li>• University of graduation</li> </ul>	<ul style="list-style-type: none"> <li>• Belief in superiority of treatment</li> <li>• Diagnostic ability/accuracy</li> <li>• Difficulty to make a decision/ uncertainty</li> <li>• Familiarity or experience with specific treatment</li> <li>• Importance dentists attach to false negative or positive decisions</li> <li>• Personal experience</li> <li>• Risk perception for future pathology /complications</li> <li>• Treatment thresholds</li> <li>• Weight on different diagnostic information</li> </ul>
<b>Patient related factors</b>		
<b>Characteristics</b>	<b>Wishes / values</b>	
<ul style="list-style-type: none"> <li>• Age</li> <li>• Gender</li> <li>• Physical appearance</li> <li>• Race</li> <li>• Socioeconomic status</li> </ul>	<ul style="list-style-type: none"> <li>• Aesthetic demands</li> <li>• Confidence, self esteem</li> <li>• Dental anxiety/fear</li> <li>• Level of comprehension of dental treatment</li> <li>• Patient's wishes</li> <li>• Risk perception</li> </ul>	

		<ul style="list-style-type: none"> <li>• Symptoms</li> </ul>
<b>General health</b>	<b>Mouth Level Health</b>	<b>Tooth level Health</b>
<ul style="list-style-type: none"> <li>• Medical history (drugs, disease)</li> <li>• Smoking</li> </ul>	<ul style="list-style-type: none"> <li>• Bone resorption</li> <li>• Caries risk</li> <li>• General condition of dentition</li> <li>• Inflammation – bleeding on probing</li> <li>• Occlusion, crowding and inclination of teeth</li> <li>• Oral hygiene</li> <li>• Plaque scores</li> <li>• Pocket depths</li> </ul>	<ul style="list-style-type: none"> <li>• Age of root filling</li> <li>• Angular position of wisdom tooth</li> <li>• Anterior or posterior tooth</li> <li>• Condition of existing restoration</li> <li>• Degree of impaction</li> <li>• Lesion size</li> <li>• Mobility</li> <li>• multi vs single rooted</li> <li>• Periapical radiolucency</li> <li>• Presence of perforation, broken file or silver point</li> <li>• Presence of post</li> <li>• Quality of root filling</li> <li>• Root characteristics morphology/length</li> <li>• Root filling present already</li> </ul>
<b>Systems/ Environment related factors</b>		
<b>Practice Complexities and Time</b>	<b>Society and Pressures</b>	
<ul style="list-style-type: none"> <li>• Cost of treatment</li> <li>• Reimbursement</li> <li>• Technical complexity of treatment</li> <li>• Time pressure</li> <li>• Time required for treatment and number of visits</li> <li>• Timing (out of hours)</li> <li>• Type of diagnostic tools available</li> </ul>	<ul style="list-style-type: none"> <li>• Dentist-patient communication</li> <li>• Emotions (stress, anxiety, fear, anger)</li> <li>• Ethical practice</li> <li>• Guidelines and evidence base</li> <li>• Medicolegal issues and defensive practice</li> <li>• Peer practice and influence</li> <li>• Trusting relationship with the patient</li> </ul>	

Table 4 summarises the results of the mapping review. A colour representation has been used to group the factors in three separate categories: a) factors that have been reported

as influential by dentists and evaluated empirically (green), b) factors that have been evaluated empirically but have not been reported in qualitative studies (blue) and c) factors that have been reported as influential in qualitative studies but they have not been evaluated in experimental studies (red). The number of studies that incorporated a particular factor in their scenarios is noted ( $\diamond$ ). Also the number of studies that reported that each particular factor may (\*) or may not ( $\dagger$ ) have a statistically significant influence in dentists' decision making or explain the variation in dentists' decisions are reported. However, due to the nature and purpose of this review, data regarding the size and direction of the effect have not been extracted from the included studies. Lastly, the number of qualitative studies in which each particular factor has been reported as influential by the dentists (§) is also given. A detailed table including citations of the studies per categories is presented in the Appendix 7.

**Table 4: Categorization of factors**

FACTORS	<b>DENTIST FACTORS</b> <ul style="list-style-type: none"> <li>• Dentist's Characteristics</li> <li>• Dentist's educational background</li> <li>• Biases (perceptions and experience)</li> </ul>	<b>PATIENT FACTORS</b> <ul style="list-style-type: none"> <li>• Patient's Characteristics</li> <li>• Patient's values and wishes</li> <li>• Patient's health (general, mouth and tooth level)</li> </ul>	<b>ENVIRONMENTAL FACTORS</b> <ul style="list-style-type: none"> <li>• Practice Complexities and Time</li> <li>• Society and Pressures</li> </ul>
Evaluated statistically in empirical studies and reported as influential in qualitative studies	Engagement with CPD activities (N= 6*,1†,1§) Previous experience with condition or treatment (N= 1*,6§) Belief in superiority or benefit of treatment (N= 2†,4§) Uncertainty/ difficulty to make a decision (N= 1*,1§)	◇ Size of lesion or pathology (N= 20*,2§) ◇ Age (N= 8*,1§) ◇ Periodontal health (N= 6*,1†,1§) ◇ Patient's motivation and attitude (N= 1*,6§) ◇ Position of tooth/teeth (N= 3*,2§) ◇ Aesthetic demands (N= 1†,3§) ◇ Smoking (N= 2*,1†,1§) ◇ Oral hygiene (plaque control) (N= 3*,1§) ◇ Occlusion (N=3*,3§) ◇ Pulp state (N= 1*,3§) ◇ Symptoms (N= 3*, 1§) ◇ General health (diseases and medication) (N= 1†,2§) ◇ Caries Risk (N= 1*,2§) ◇ Quality of root filling (N= 1*, 1§) Level of comprehension of dental treatment (N=1*,1§) Socioeconomic status (N=1*,2§)	◇ Cost of treatment (N= 2†,9§) Technical complexity of treatment (N= 1*,7§) Guidelines and evidence base (N= 1*,5§) ◇ Reimbursement (N=1†,3§)
Evaluated Statistically in empirical studies but not reported in qualitative studies	Years of Experience/ Years since graduation (N= 11*,13†) Gender (N= 5*,16†) Specialty training or generalist (N= 14*,6†) Age (N= 3*,10†) Type of practice (Private or state funded) (N= 7*,7†) University or Country of graduation (N= 5*,5†) Confidence about presence of pathology (N= 7*) Location or country of practice (N= 2*,5†) Diagnostic ability / accuracy (N= 2*,3†) Risk perception for future pathology/complications (N= 4*) Reported Treatment Threshold (N=3†) Attached importance to false negative or positive decisions (N= 1*)	◇ Degree of impaction of wisdom tooth (N= 6*) ◇ Gender (N= 1*) ◇ Race (N= 1*) ◇ Multi vs single rooted (N= 1*) ◇ Presence of post (N= 1*)	Timing (out of hours) (N= 1*) Type of diagnostic tools available (N= 1*)

NOT evaluated statistically in empirical studies but reported as influential in qualitative studies		<ul style="list-style-type: none"> <li>◇ Patient's wishes, expectations and demands(N=9<sup>§</sup>)</li> <li>Patient's compliance (N=2<sup>§</sup>)</li> <li>◇ Dental anxiety or fear (N=1<sup>§</sup>)</li> <li>Confidence and self-esteem (N=1<sup>§</sup>)</li> <li>◇ Mobility of the tooth/teeth (N=1<sup>§</sup>)</li> </ul>	<ul style="list-style-type: none"> <li>Time required for treatment (N=3<sup>§</sup>)</li> <li>Medicolegal issues and Defensive practice (N=4<sup>§</sup>)</li> <li>Ethical practice (N=2<sup>§</sup>)</li> <li>Trusting relationships with the patient (N=3<sup>§</sup>)</li> <li>Dentist patient communication (N=2<sup>§</sup>)</li> <li>Peer practice and influence (N=1<sup>§</sup>)</li> <li>Emotions (stress, anxiety, fear, anger) (N=2<sup>§</sup>)</li> <li>Time pressure (N=2<sup>§</sup>)</li> </ul>
<ul style="list-style-type: none"> <li>◇ Incorporated into the scenarios used.</li> <li>* Number of comparative empirical studies which quantified the impact of the factor and reported significance</li> <li>† Number of comparative empirical studies which quantified the impact of the factor and did not report significance</li> <li>§ Number of qualitative studies in which the dentist reported the factor as influential</li> </ul>			

As it can be observed in the table above, dentists' characteristics have been evaluated in a number of experimental studies. Overall, it seems that the majority of the identified studies indicated that the dentist's age, gender and the location of their practice do not influence their decisions, whilst the results of the studies are inconclusive about the impact of years of professional experience, the university or country of graduation and the type of practice (private vs publicly funded). However, engagement with continuous professional development and further professional training (specialist vs generalists) seems to influence the dentists' decisions.

As the patient characteristics are concerned, patient's age seems to be a frequently cited influencing factor in dentists' treatment decisions. Health factors at patient, mouth and tooth level have been used extensively to build the scenarios used in the included studies, both experimental and qualitative. However, patients' behaviour, wishes and values have scarcely been used in the scenarios utilised in experimental research although they have frequently been reported as influential in qualitative studies.

Similarly, environmental factors identified as influential in qualitative studies have either not been evaluated in empirical research at all or only by a very small number of experimental studies. The cost of the treatment and dentist's reimbursement has been evaluated in empirical research. The role of guidelines and the evidence base as well as the role of medicolegal issues, litigation, ethical practice, influence of the peer dentists' practice, dentists' emotional state, stress and time constraints are yet to be explored in experimental studies.

In the 'ranking factors surveys' the dentists were asked to rank the importance of given factors when they make a decision for a treatment over another. The dentists' preferences over a pair of treatment modalities were recorded in these studies. The number of studies that have used the following factors in their questionnaires is provided in a parenthesis.

As regards to the dentists' factors, these studies looked at:

- the dentists' perceptions and biases for the risk of future pathology and complications (11),
- dentists' experience and perceived skills to complete the treatment (10) and
- the prognosis of the treatment outcome (8).

Patient related factors were also used in the ranking questionnaires including:

- Patient's age (10)
- Patient's general health (9)
- patient's comfort (8),
- aesthetic outcome (8).
- patient's preferences (5),
- patient's ability to tolerate treatment (3),
- patient's compliance (2)
- patient's motivation (2) and
- life expectancy (1)

Among the mouth and teeth related patient factors, the following were used in the study questionnaires:

- oral hygiene (11)
- caries risk and rate (10),
- periodontal status (9),
- pulp status (7)
- position of teeth (5),
- lesion's size (4),
- occlusion (1),
- mouth-opening (1),
- temporomandibular complaints (1), and

- restorability of tooth (1)

Lastly, environmental factors that have been incorporated in the ranking questionnaires including:

- the cost for the treatment (10),
- the complexity and technical difficulty of the treatment (7),
- number of appointments (6),
- time for treatment (6),
- medicolegal issues (2) and
- patients' relatives' wishes (1).

Due to the nature of this review, no attempt was made to pool the numerical data and synthesize the results of the above studies. However, observing table 4, it becomes again apparent that for factors such as time constraints and medicolegal issues, that dentists may have ranked them as significant, but there is still a paucity of experimental research to assess their impact in dentists' decision making performance.

From the prospective observational studies, 8 only recorded the clinical reason for the dentists' intervention, 3 reported on the agreement between and amongst dentists and the rest (14) investigated the impact of different dentist, patient and tooth-specific factors in the choice between or amongst different treatments. In the latter studies the dentists recorded the decisions made for each patient using questionnaires or data collection sheets. Dentist related factors were evaluated in 5 studies (dentist's age (2), dentist's gender (3), years of experience (1), type of practice (3), previous experience (1) and belief in superiority of treatment (1)). All of the 14 studies evaluated the role of different patient characteristics, wishes and health in dentist's decisions (patient's age (10), gender (9), race (2), education level (3), compliance with regular attendance (7), general health (4), smoking (3), caries experience (4), tooth-brushing frequency (6), periodontal condition (1), mobility of the tooth/teeth (2), occlusion (1), position and

type of teeth (9), size of lesion (3)). Only 3 studies evaluated the impact of the cost of treatment (1) and the type of patient insurance coverage (2) on dentists' decisions.

The identified controlled studies, examined the impact of dentist-related factors (bias and experience), patient-related factors (patient's race and age) and environmental factors (type of diagnostic tools, appearance of restoration, literature and payment fee status).

Gondahl et al. gave different information to dentists regarding the quantity of pathology in the radiographic images they were about to observe. When given the advance information that 75% of surfaces to be examined were carious all observers registered a greater total number of lesions when given the information that 25% of the surfaces were carious. (Gondahl, 1979). The same was observed with increased film density, where the mean numbers of registered lesions was also increased (Gondahl, 1979). The appearance of a restoration seems to have a significant impact on dentists' decisions to replace the restoration. After the same amalgam restorations were finished and polished, the decisions of replacement of the restorations dropped significantly (Cardoso, Baratieri & Ritter, 1999). On the other hand the type of study models (3-D digital or traditional plaster models) was not found to influence orthodontic treatment planning decisions (Whetten *et al.*, 2006).

Knutsson et al. conducted a 10 year follow-up study involving the same population of dentists exposing them to the same scenario based questionnaires on prophylactic removal of 3<sup>rd</sup> molars and observed no change towards a more non-interventionist attitude. (Knutsson, Lysell & Rohlin, 2001) Conversely, when dentists were exposed to relevant literature on prophylactic removal of third molars, their decisions for prophylactic removal dropped significantly (by 37%) in comparison to the control group, in which no significant change in attitude was observed (van der Sanden *et al.*, 2002).

Patient's race was found to play a significant role in dentists' decisions. When dentists were presented with the same scenario with the only difference being the colour of the patient's skin (black vs white) over two occasions (two months apart), an extraction rather than retention of the tooth with restorative treatment was more frequently proposed for the black patient (Dantas Cabral, de França Caldas & Moreira Cabral, 2005). Similarly, when three versions of a vignette with identical materials and information except for the patient's age (either 44, 65, or 84 years) was given to dentists to formulate a treatment plan, the dentists planned limited therapy for the 84 year old suggesting that a patient's age influences general dentists' treatment planning decisions, perhaps limiting the treatment options offered to older adults (Dolan *et al.*, 1992). Also the knowledge of a patient's age has been found to significantly influence the diagnostic decisions about the nature of periodontal disease (chronic versus aggressive) which may in turn impact treatment decision making (Oshman *et al.*, 2016). Finally, in a UK randomised-controlled vignette study describing a hypothetical patient either 'NHS-funded', 'Privately-funded' or undisclosed fee-status, the patient's funding status was found to have no influence on dentists' clinical decision making when considering root canal treatment versus extraction (Walker, Gilbert & Asimakopoulou, 2015).

### **Stress and decision making**

One decision making model (Janis and Mann's conflicting theory model on decision making) adapted for dental clinical practice describing the mechanisms and effects of emotional arousal on decision making style was identified (Chipchase, Chapman & Bretherton, 2017). This model was informed by the conduct of qualitative interviews with dentists in England who reported examples of stressors in their daily clinical practice and how they responded to them (Chipchase, Chapman & Bretherton, 2017). According to this model, the type of decision making fluctuates to a continuum from unconflicted to avoidance and hyper-vigilance influenced by the level of arousal/stress

and the perceived risk of suffering loss as a result of the decision (Chipchase, Chapman & Bretherton, 2017). This model was identified whilst the mapping review was completed and the last update search was performed. At that stage, the experimental study had already been designed and gained ethical approval, Therefore it was not utilised in the development of the experimental study presented later on in the thesis.

The same authors developed and validated a scale to quantify the impact of self-reported anxieties on clinical working in clinically relevant situations (DACSS: Dentists' Anxiety in Clinical Situations Scale) (Chipchase, Chapman & Bretherton, 2017). However, as stress and anxiety are conceptually different it can be argued that this scale may not be as useful or as valid to measure intraoperative stress of the dentists or capture their response to a particular stress stimuli.

The following list is comprised of factors that were found to be or perceived as influential in dentists' decision making and reported as stressors in the dental literature. However, their impact on clinical decision making in specific clinical scenarios has not been yet empirically assessed, as found in the present mapping review. Thus, this list can be used to inform a research agenda on the impact of stress on dentist's decision making in future prospective studies.

- dentist's difficulty to make a decision and uncertainty (Aryanpour, Van Nieuwenhuysen & D'Hoore, 2000; Chipchase, Chapman & Bretherton, 2017),
- patient's dental fear (Chipchase, Chapman & Bretherton, 2017; Korduner *et al.*, 2016; Weaver *et al.*, 1996),
- patient's expectations and demands (Chapman, Chipchase & Bretherton, 2015a; Chipchase, Chapman & Bretherton, 2017; Kay & Blinkhorn, 1996; Korduner *et al.*, 2016; Oliveira & Guerreiro, 2015; Omar & Akeel, 2010; Pearce *et al.*, 2011; Rawski *et al.*, 2003; Sathorn, Parashos & Messer, 2009),

- patient-dentist communication and relationship (Chapman, Chipchase & Bretherton, 2015a; Chipchase, Chapman & Bretherton, 2017; Kay & Blinkhorn, 1996),
- difficulty and complexity of treatment (Alexander *et al.*, 2014; Chapman, Chipchase & Bretherton, 2015a; Chipchase, Chapman & Bretherton, 2017; Ito *et al.*, 1987; Kay & Blinkhorn, 1996; Omar & Akeel, 2010; Pearce *et al.*, 2011; Rawski *et al.*, 2003),
- time pressure and workload (Chapman, Chipchase & Bretherton, 2015a; Chipchase, Chapman & Bretherton, 2017),
- guidelines, regulation and legislation (Alexander *et al.*, 2014; Chipchase, Chapman & Bretherton, 2017; Korduner *et al.*, 2016; O'Donnell *et al.*, 2013; Oliveira & Guerreiro, 2015), and
- medico-legal issues and fear of litigation (Chapman, Chipchase & Bretherton, 2015a; Chipchase, Chapman & Bretherton, 2017; Oliveira & Guerreiro, 2015; Pearce *et al.*, 2011).

## **Concluding Remarks**

This review was set out to describe the decision making research already conducted, The aim, therefore, has been successfully met demonstrating the diversity of the research field of dental decision-making as regards to the purpose of research and research design. This mapping review identified types of research that dominate the research base; these are the case-based surveys. Surprisingly, only a limited number of controlled experimental studies have been conducted to examine the impact of different influencing factors in decision-making. Similarly, it is only in the past 10 years that qualitative methods have been utilised to explore dental decision making. The goal of qualitative research is the development of concepts which help us to understand social

phenomena in natural (rather than experimental) settings, giving due emphasis to the meanings, experiences, and views of all the participants (Pope & Mays, 1995). Therefore, qualitative research, as shown by this review, can bring into light factors that are important for the clinicians but have not been investigated by researchers in experimental studies. Having identified the gap in the past research activity future studies can investigate the impact of these factors in dentists' decision-making.

Therefore, in this project drawing upon the results of the systematic and mapping review a decision was made to explore the impact of time pressure on dentists' decision-making. Reflecting on Michie's (2002) model of sources of occupational stress, time pressure is a source of stress unique to the job (category 1 of the model). Time pressure has been documented as a stressor in numerous studies in the dental literature (Ayers *et al.*, 2008; Chapman, Chipchase & Bretherton, 2015b; Johns & Jepsen, 2015) and it can be easily manipulated in an experimental setting (ALQahtani *et al.*, 2016; Arora *et al.*, 2010; Moorthy *et al.*, 2003; Poolton *et al.*, 2011; Tsiga *et al.*, 2013). A second decision was made as to which area of dentists' performance this project will focus. The mapping of the existing decision-making studies was used to inform this decision and the methods used. Diagnostic decision making using radiographs appeared to dominate the research base on decision-making. Most of the diagnostic decision making studies have used bitewing radiographs to examine the variability in diagnostic ability and treatment decisions amongst dentists. Also for the analysis of dichotomous diagnostic decisions, the diagnostic tests of sensitivity and specificity have been used widely in the aforementioned studies. Thus, the experimental study outlined in Chapter 4 explored the impact of time pressure on dentists' diagnostic performance when they examine bitewing radiographs.

**Chapter 4: Impact of Time Pressure on Dentists'  
Diagnostic Performance. A Primary Research  
Study**



## Rationale and Objectives

Research has shown that time pressure is one of the most common reported stressors amongst dentists (Ayers *et al.*, 2008; Chapman, Chipchase & Bretherton, 2015b; Johns & Jepsen, 2015; Moore & Brodsgaard, 2001; Myers & Myers, 2004). In other healthcare settings, time pressure has been found to affect not only psychomotor performance and procedural skills but also diagnostic accuracy (ALQahtani *et al.*, 2016; Arora *et al.*, 2010; Moorthy *et al.*, 2003; Poolton *et al.*, 2011; Tsiga *et al.*, 2013). Drawing on the systematic review, no prior dental studies have been found that experimentally examined this important issue on dentist performance. Thus, the present investigation was designed to fill this gap and focused on how time pressure impacts upon dentists' performance.

Dentists are faced with diagnostic decisions on a daily basis. Bitewing radiographs are the most common special investigations utilised in general practice to assist the dentist to form a diagnosis. Bitewings are taken at regular intervals according to national guidelines for monitoring purposes, particularly in relation to dental caries and periodontal disease (FGDP(UK), 2018) or they are prescribed by the dentist where there is suspicion of pathology. A plethora of diagnostic information is provided by bitewing radiographs including signs of carious activity, bone loss and integrity of restorations (Shelley, 2013). How time pressure might affect dentists' performance when examining dental radiographs is an open question, which this experimental study was designed to address.

Therefore, this experimental study was designed to answer the research question: 'Does time pressure impact on dentist's diagnostic performance?'

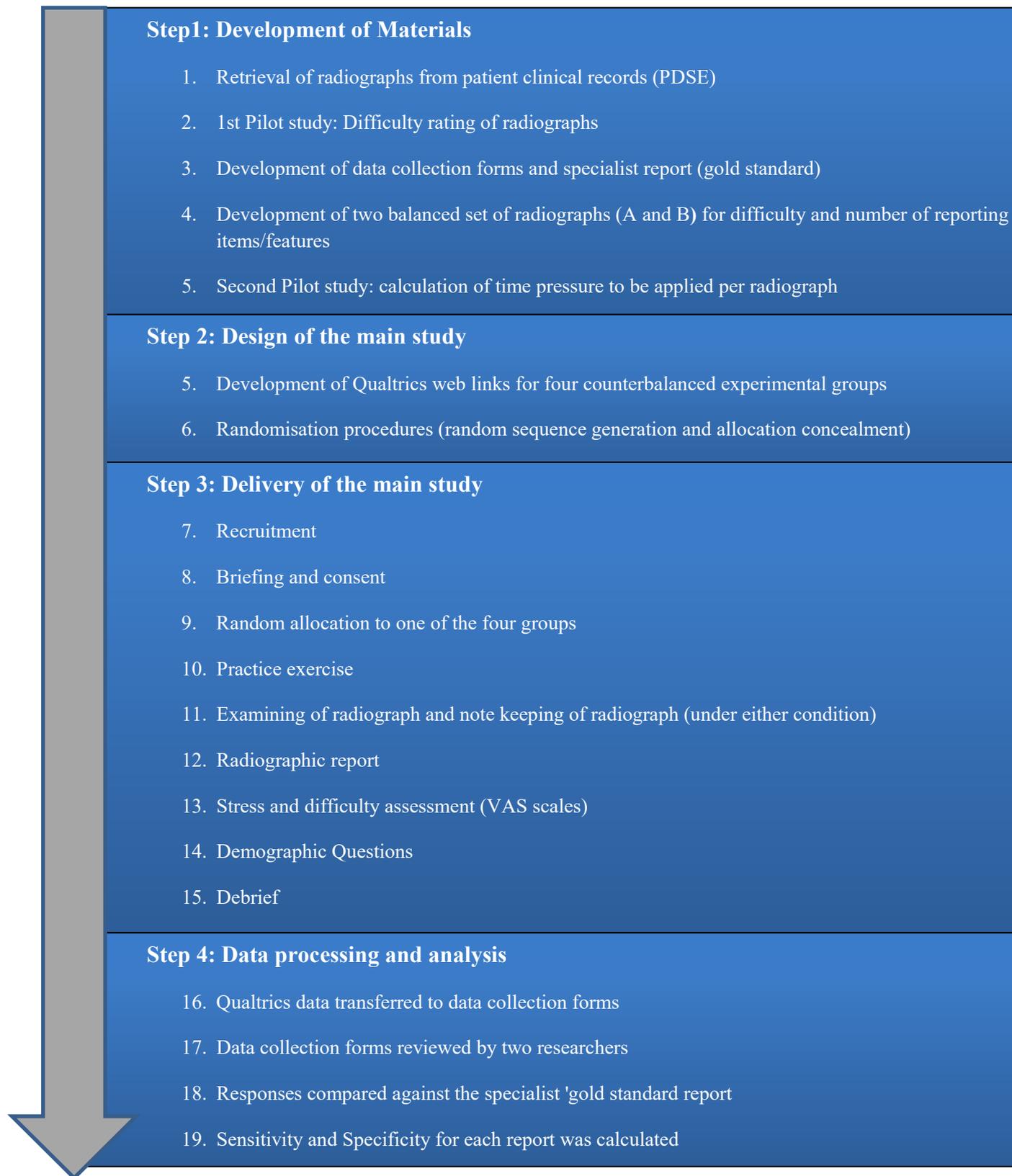
**Aim:** To assess the impact of time pressure on dentists' diagnostic performance when examining bitewing radiographs.

**Objectives:**

- To assess whether the time pressure manipulation acts as a stressor and
- To determine the impact of time pressure on dentists' diagnostic sensitivity and specificity when viewing dental bitewing radiographs.

**Overview of the study**

This was a randomised cross-over study. Primary care dentists examined and provided a radiographic report on two sets of radiographs [A and B (six bitewings in each set)] under two conditions: time-pressure vs. no-time-pressure. Dentists were randomised to one of four groups based on the order in which they examined the two sets of radiographs (A then B, or B then A) and the order in which the examination conditions were applied (time pressure then no time pressure, or no time pressure then time pressure). The radiographic report of an experienced restorative dentistry consultant was considered as the gold standard against which participants diagnostic decisions were compared to calculate sensitivity and specificity. The study received ethical approval (16/17-704) from the University of Plymouth Research Ethics committee, England, UK (Appendix 8). The steps followed for the design and delivery of the study are depicted in Figure 6.



**Figure. 6: Flowchart of steps followed to design and deliver the experimental study**

## **Methods**

### **Retrieval of study radiographs**

The digital radiographs for the study were retrieved from the Peninsula Dental Social Enterprise's clinical patient records system. The patients attending the dental school consent to their records including radiographs to be used anonymously for research purposes (Appendix 9). Authorisation for the researcher (AP) to gain access to patients' records was approved by the Peninsula Dental School Social Enterprise Caldecott Guardian (Mr Robert Witton). A Caldecott Guardian is a senior person responsible for protecting the confidentiality of people's health and care information and making sure it is used properly. All NHS organisations and local authorities which provide social services must have a Caldecott Guardian.

The radiographs were selected on the basis of type (bitewings), quality (grade 1 and 2- excellent and diagnostically acceptable respectively) (FGDP(UK), 2018) and type of pathology (only radiographs with more than one type of pathology were selected, e.g. caries, bony defects etc). As the radiographs were from patients who were treated in a primary care setting, they were judged to be probably similar to radiographs that a general dental practitioner may encounter in their daily clinical practice. The selected radiographs were saved anonymised in a secure encrypted and password protected USB portable device. Twenty four radiographs were selected initially. The size and resolution of the images was identical for all 24 bitewing radiographs.

### **Pilot**

Two pilot studies preceded the main experiment. The pilot studies set out to:

- assess the feasibility of the study,
- develop the materials for the study and

- calculate the time pressure limits to be applied.

### **1<sup>st</sup> Pilot Study- Identification of appropriate radiographs**

Six dentists with a range of experience between 8 and 20 years, were asked to provide a radiographic report for each radiograph and grade the difficulty they faced in reporting on each radiograph (1=easy, 2= difficult). The mode for the difficulty scores for each radiograph was calculated. Eighteen radiographs were deemed easy (mode of 1) and six difficult (mode of 2). After completing the task, the six dentists reported that examining 24 radiographs was a very demanding task and suggested reducing the number to 12. Also the above dentists indicated that due to the pressures and time constraints of general dental practice, it would be highly unlikely dentists would be willing to attend more than once for the study.

### **Development of materials (sets of radiographs and data collection forms)**

A data collection form was developed including the following reporting items (Table 5) based on current national Good Clinical Practice Guidelines (Shelley, 2013):

**Table 5: Reporting Radiographic Items**

1. any radiolucency indicative of caries
2. any defective restorations
3. any overhangs of restorations
4. any bone loss
5. any angular bony defects
6. any furcation involvement lesions
7. any retained roots and
8. any impacted teeth

A specialist in Restorative Dentistry (Tim O' Brien) provided a detailed radiographic report of all pathology identified in each radiograph using the data collection forms

(Appendix 10). The report was reviewed by AP (a general dentist). Any areas of disagreement were resolved with discussion. The number of pathological features of each radiograph and the type of pathology (caries/restoration-related pathology or periodontal related pathology) were calculated for each radiograph. The specialist's report was used as the gold standard.

Two sets of radiographs (A and B) were created taking into consideration their reported difficulty, the number of pathological features, and type of different pathologies of each radiograph. An even distribution of all the above was achieved. Each set was composed of three easy and three difficult radiographs.

The gold standard reports for each radiograph appear in the Appendix 11. Each cell represents a dichotomous decision (yes or no) for the presence or absence of pathology. Some of the decisions (caries, restoration defect and overhang, angular bony defect) refer to a specific tooth surface (e.g mesial or distal), some others such as retained root, impacted or unerupted tooth and furcation involvement refer to a specific tooth and bone loss to the whole dentition appeared in the radiograph. The dentist's diagnostic performance in the experimental study was assessed against the gold standard reports for all the pathological features of the radiographs, and for caries related pathology alone. The prevalence of each of the above for each set of radiographs A and B was calculated based on the gold standard reports as follows:  $\text{Prevalence of disease} = \frac{T_{\text{disease}}}{\text{Total}} \times 100$ . Where  $T_{\text{disease}}$  represents the number of cells/decisions positive for relevant disease and Total represents the total number of relevant cells/decisions. The prevalence of 'global disease' and caries for each radiograph is presented in the gold standard reports/data collection forms (appendix 11). The prevalence of pathological/noteworthy features in set A of radiographs was 7.37% and the prevalence of caries was 14%. Out of the 6 bitewing radiographs in Set A (51 visible teeth), 17 teeth showed signs of caries. The prevalence of pathological/noteworthy features was

6.24% in set B of radiographs the prevalence of caries was 7.48% respectively. Out of the 6 bitewing radiographs in set B (51 visible teeth), 10 teeth showed signs of caries. For both datasets the prevalence of pathological/noteworthy features was 6.81% the prevalence of caries was 10.77%. Out of the 102 visible teeth in the dataset, only 27 teeth were judged as carious.

### **2<sup>nd</sup> Pilot – Time Pressure calculation**

A second pilot study involving the same 6 general dental practitioners was conducted 3 months after the initial pilot study. The purpose of the second pilot study was to define the observation time for each of the above 12 radiographs and pilot the data collection forms. The pilot study was delivered on a computer via the Qualtrics software interface. The participants were presented with each radiograph on the screen, they were asked to examine each radiograph and take notes of any pathology noted. Then they moved to the next page where they provided a radiographic report in a free text box. From examining the radiographic reports, it became apparent that dentists had different reporting styles and they did not necessarily report on all the radiographic features included in the data collection form.

The Qualtrics interface was used to calculate the time that each participant took observing each radiograph and making notes. The radiographs were presented in a random order. The randomisation took place automatically by the Qualtrics interface and ensured that observation times would have not been affected by the participants' fatigue or boredom by the end of the study.

Using the equation suggested by Ordonez and Benson, the time pressure limit for each radiograph was one standard deviation below the mean observation time for each radiograph. (Ordóñez & Benson, 1997). The mean observation times and time pressure limits can be observed in Table 6.

**Table 6: Mean observation times in pilot and time pressure limits**

<b>Xray Code</b>	<b>Mean (<math>\bar{x}</math>)</b>	<b>St Deviation</b>	<b>TP= <math>\bar{x}</math>-1SD</b>	<b>TP for study (secs)</b>
<b>A1</b>	76.99	69.65	7.34	8
<b>A2</b>	71.78	47.61	24.17	24
<b>A3</b>	70.45	51.11	19.34	20
<b>A4</b>	72.60	59.27	13.33	14
<b>A5</b>	87.17	56.00	31.17	31
<b>A6</b>	104.92	66.76	38.16	38
<b>B1</b>	105.74	70.19	35.55	36
<b>B2</b>	74.82	63.00	11.82	12
<b>B3</b>	97.15	76.26	20.89	21
<b>B4</b>	90.55	73.93	16.62	17
<b>B5</b>	75.54	66.93	8.61	9
<b>B6</b>	90.72	72.62	18.1	18

### **Stress assessment**

A computerised 100mm visual analogue scale (VAS) was used to assess participant's perceived stress after the task for each condition (time pressure vs no time pressure). This measure was chosen due to its adequate psychometric characteristics, combined with simple administration (Abend *et al.*, 2014; Lesage and Berjot 2011; Lesage *et al.* 2012; McCormack *et al.*, 1988). VASs have been found to demonstrate acceptable agreement with the Perceived Stress Scale of Cohen, used for assessment of occupational stress, meaning that the two tools assess the same psychological constructs

(Lesage and Berjot 2011). The VAS Scale was judged by the pilot participants as fit for purpose, as a self-rating tool for stress.

In summary the following decisions about the main experimental study were made as a result of the pilot study:

- Data to be collected on one occasion per participant,
- 12 radiographs to be used instead of 24,
- To provide the participants with a list of the reporting items we were seeking from their reporting.

### **Development of the research study**

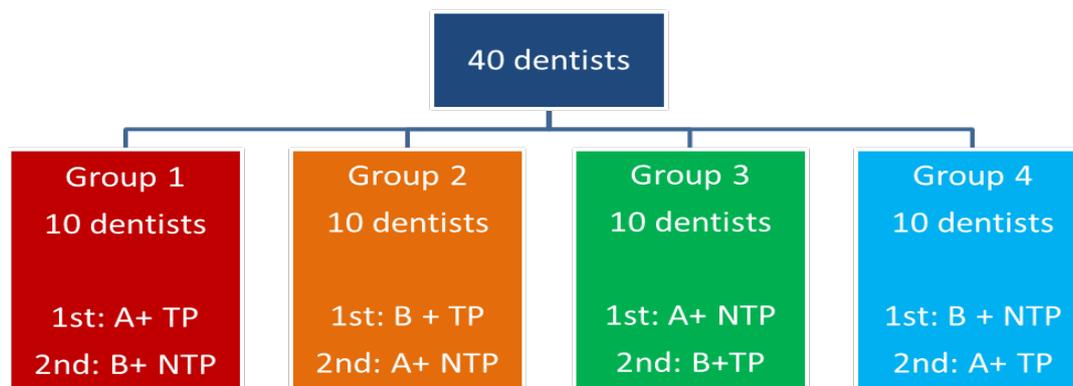
#### **Sample**

Sample size calculations are notoriously difficult to undertake for diagnostic studies with little consistency regarding methods. These calculations have been reported in only 2.5% -5% of biomedical studies (Hajian-Tilaki, 2014). A study on the impact of time pressure in a medical primary care setting (Tsigas *et al.*, 2013) was deemed to be similar to the current study it had provided 80% power to detect a difference of one SD in performance within practitioners between making decisions under time pressure compared to no time pressure at an  $\alpha$  of 0.05 using a sample size of 35. Therefore, for this study 40 primary care dentists were recruited to allow for potential attrition.

#### **Counterbalancing**

Four different counterbalanced experimental test groups were developed. A different Qualtrics Research web link was generated for each group. Care was taken to counterbalance for the two experimental conditions (time-pressure vs no-time pressure) and the sets of radiographs the participants had to observe (A and B). Also within each condition, the order of the radiographs (A or B) was randomised. This random order

within each set was achieved automatically by the Qualtrics software. This is shown diagrammatically in the following figure (Figure. 7).



**Figure. 7: Counterbalancing.**

**TP:Time Pressure, NTP No time pressure, A: Set A of radiographs, B: Set B of radiographs**

The counterbalancing was designed to ensure that the complexity and the order of the tasks were balanced and unaffected by participant's learning or by the participant's fatigue by the end of the study. Thus the observed differences should only be due to the experimental manipulation (time pressure) based on a comparison between all the examinations performed under time pressure (group 1: 1st sequence + group 2: 1st sequence + group 3: 2nd sequence + group 4: 2nd sequence) compared to all the examinations performed without time pressure (group 1: 2nd sequence + group 2: 2nd sequence + group 3: 1st sequence + group 4: 1st sequence)

## **Randomisation**

### **Random sequence generation**

This stage was completed by an independent researcher (Prof. David Moles). Block randomisation was used to ensure that equal numbers of participants were allocated in each of the four groups (Altman & Bland, 1999). STATA version 10 was used for the random sequence generation and the size of blocks varied between 4 and 8. The block randomisation scheme used a two-stage process: the computer first randomly selected

whether the block will contain 4, 6 or 8 participants and then randomly chose one of the possible different blocks for the selected size. The sequence and size of blocks remained unknown to the researcher (AP).

### **Allocation concealment**

This stage was completed by another independent researcher (Miss Maria Bernardes Delgado) who placed a sheet with the group number (1- 4) in forty sequentially numbered opaque sealed envelopes.

### **Participants**

#### **Inclusion and exclusion criteria**

Primary care dentists were eligible to participate in the study. Retired practitioners, dentists not practicing clinical dentistry (i.e solely academics) and dental specialists were excluded.

#### **Recruitment**

Dentists in the Southwest of England were invited to participate. A webpage was created containing essential information about the study. Different methods for recruitment of participants were used.

- An invitation e-mail was distributed to dentists in the southwest via different professional networks [Peninsula Dental Social Enterprise, local British Dental Association (BDA) sections, Local Dental Committees (LDC ), Denplan Sections, Faculty of General Dental Practice (FGDP), British Association for the Study of Community Dentistry (BASCD)] containing the website link.
- Invitation leaflets were sent to individual practices in Devon and Cornwall. A list of individual practices was generated using Google search.
- The clinical supervisors of Peninsula Dental School were invited via an email sent by the Clinical administrator.

The recruitment leaflet and participant information sheet can be found in Appendix 12.

## **Enrolment**

### **Setting**

The recruitment rate of participants initially was rather low, and the enrolment stage took a lot longer than anticipated. Responding to requests and feedback received from potential prospective study participants, who were unwilling to travel to Plymouth but would be happy to participate at their practices, ethical approval was sought for the principal investigator (AP) to visit individual practices too. Therefore, the study took place in either:

- a quiet non-clinical room with no distractions on the premises of Plymouth University or
- individual dental practices in non-operating hours when the dentist's room was quiet and without any distractions.

### **Briefing and consent**

The participants were given the participation information leaflet and any questions were answered before the consent to participate form was signed (Appendix 13).

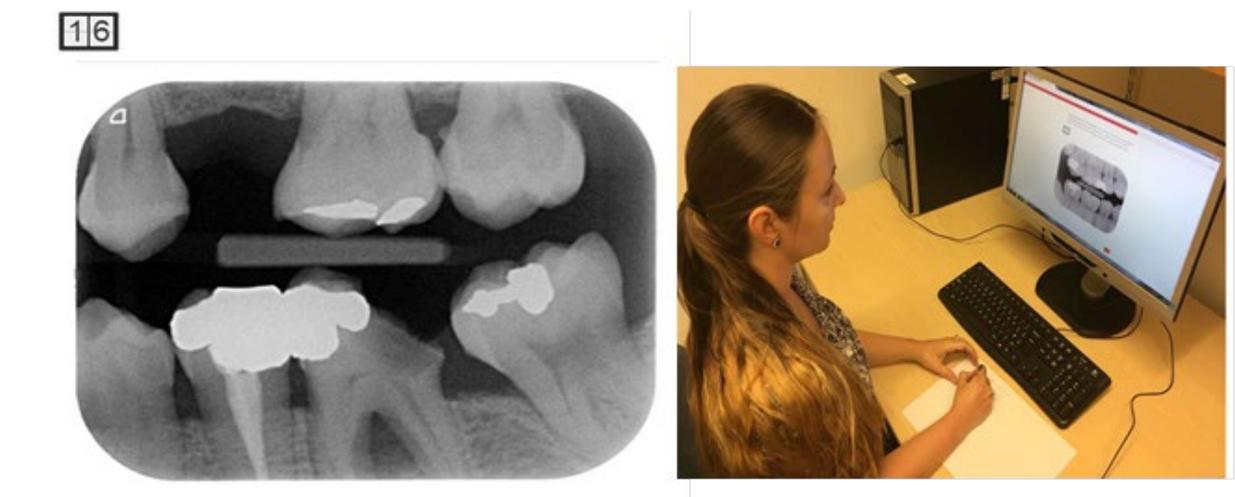
The participants were informed about the procedure. They were instructed to examine each radiograph and to take notes on a blank piece of paper. After viewing each radiograph with either unlimited time or under restricted time, they were asked to provide a report on any pathology they identified with tooth and site specific details. The types of pathology we were seeking in the reports were provided to the participants to avoid different styles of record keeping. Although time was restricted for half of the examinations, there was no time restriction applied to the participants typing of the reports for each radiograph.

## Procedure

Each participant was randomly allocated to one of the four groups. The group they were allocated was revealed after opening a sealed envelope and the corresponding Qualtrics web link was opened on the computer.

Prior to commencing the study, the participants undertook a practice exercise which mimicked the experimental condition.

When the participants were examining the radiographs in the time pressure condition, a countdown clock was present on the screen (Figure. 8). When the predefined time had elapsed, the page with the radiograph disappeared and a page with a free-text box to provide their report was presented. In each of the free-text box pages the list of types of pathology (Table 5) was presented to the participants. While each participant was in the non-time pressured condition, the process was identical except that there was no countdown clock and no time restriction for them to complete their examination of each radiograph.



**Figure 8: Delivery of the study**

After each experimental condition, the participants were asked to complete an electronic visual analogue scale (VAS) indicating the level of stress and difficulty they experienced during the task. (Figure 9). The participants were given a 5-minute break between the two experimental conditions.

How stressful did you find this task? Please use the scale of 0 to 100 below where 0 is not stressful at all and 100 is the worst imaginable level of stress.

not at all stressful 0 10 20 30 40 50 60 70 80 90 100 extremely stressful



How difficult did you find this task? Please use the scale of 0 to 100 below where 0 is no difficulty at all and 100 is the greatest level of difficulty imaginable.

not difficult at all 0 10 20 30 40 50 60 70 80 90 100 extremely difficult

Click to write Choice 1



**Figure 9: Electronic VAS scales used in the study. The red marker can be moved across the scale (0-100) to indicate the participants' stress level and level of difficulty they experienced under each condition.**

At the end of the study, participants were asked to answer questions about their demographics characteristics, including gender, years of experience, work-setting (e.g. private, NHS, mixed, community), working pattern (full-time vs part-time) and educational background (postgraduate qualifications). An example of a Qualtrics report can be found in Appendix 14).

Upon the completion of the study the participants were debriefed on how the outputs of the study would be used and the principal investigator AP also investigated whether the participants felt distressed after the study. (Appendix 15).

### **Data extraction and collection**

Data were extracted from each radiographic report and transferred to the data collection forms by the principal researcher (AP). The completed data collection forms were double-checked by another researcher (MBD) against the participants' reports to ensure that no transcription errors had occurred.

Each participant's responses were compared to the gold-standard report produced by the Specialist (TO'B). For each report the true-positive (TP), true-negative (TN), false-

positive (FP) and false negative (FN) decisions were calculated. Subsequently, for each radiographic report the participant's diagnostic sensitivity and specificity were calculated, according to the following diagnostic equations:

- Sensitivity =  $TP / (TP + FN)$
- Specificity =  $FP / (FP + TN)$

Sensitivity is the ability of the operator to correctly identify sites with pathological features (true positive rate), whereas specificity is the ability of the operator to correctly identify those with no related pathology (true negative rate) (Altman & Bland, 1994a). The calculations were performed by entering the values electronically on a freely available electronic diagnostic test evaluation calculator (MEDCALC) ([https://www.medcalc.org/calc/diagnostic\\_test.php](https://www.medcalc.org/calc/diagnostic_test.php)).

### **Statistical analysis**

All analyses were performed using SPSS version 24 (IBM SPSS Statistics). Continuous variables were presented as means  $\pm$  SD and categorical characteristics as frequencies (and percentages). The difference between VAS values (self-reported stress and difficulty) between the two conditions were evaluated using paired *t*-tests. Independent samples Mann-Whitney U test was used to assess the difference between the diagnostic sensitivity and specificity between the two conditions for all the types of pathology and for caries recognition alone. The analysis was performed by condition globally across all the study radiographs and also by individual radiograph.

## **Results**

### **Participant characteristics**

Twenty-one male and nineteen female dentists with an average of 17 years of experience ( $16.92 \pm 12.58$  (SD) years) took part in the study. The dentists' practicing experience ranged from 1 to 35 years. The participant characteristics are depicted below (Table 7).

**Table 7: Participant characteristics**

Participant Characteristics		Frequency (n)	Percentage (%)
Gender	Male	21	52.5
	Female	19	47.0
Type of Practice	Private	10	25.0
	NHS	10	25.0
	Mixed	13	32.5
	Community	7	17.5
Employment	Full-time	23	57.5
	Part-time	17	42.5
Postgraduate Qualifications	Yes	22	55.0
	No	18	45.0

### **Stress and difficulty upon time pressure**

First, to examine whether our time pressure manipulation worked, we compared participants' stress and difficulty levels in the two conditions. Our data showed a statistically significant difference ( $P < 0.001$ ) in the VAS scores for perceived stress under the time-pressure (Mean =55.78, SD=25.74) compared to the no time-pressure (Mean =10.73, SD=12.06) condition. Similarly, participants found the experimental task statistically significantly more difficult ( $P < 0.001$ ) under the time pressure condition (Mean =65.43, SD=25.11), compared to the no time pressure condition (Mean =14.83, SD=12.63).

### **Impact of time pressure on diagnostic sensitivity in global radiographic reporting between conditions (i.e. all pathologies and features)**

Next, to evaluate the impact of time pressure on performance, we compared diagnostic results under the two conditions. A Mann Whitney U test indicated that median diagnostic sensitivity was statistically significantly worse ( $P < 0.001$ ) under time pressure

(Median=0.50) compared to under no time pressure (Median=0.80), for all radiographs combined. Further, Cohen's effect size value ( $r = 0.41$ ) suggested a moderate effect of time pressure on the dentists' diagnostic ability.

### **Impact of time pressure on diagnostic specificity in global radiographic reporting between conditions (i.e. all pathologies and features)**

To examine whether time pressure had an effect on participants specificity, a Mann Whitney U test indicated a statistically significant ( $P=0.036$ ) albeit negligible effect ( $r = 0.07$ ) of time pressure on dentists' diagnostic specificity. The median value for specificity for both conditions was 1.

### **Impact of time pressure on radiographic caries recognition.**

We were also interested in whether time pressure negatively impacted participants' ability to recognise caries in particular. A Mann Whitney U test indicated that participants' ability to correctly diagnose lesions indicative of caries radiographically (sensitivity) was statistically significantly worse ( $P<0.001$ ) under time pressure (Median=0.6) compared to no time pressure (Median=1). Cohen's effect size value ( $r = 0.29$ ) suggested a moderate effect of time pressure on dentists' diagnostic ability. In contrast, the dentists' ability to correctly identify caries free sites radiographically, did not appear to be affected by time pressure (Median for both conditions 1) ( $P=0.443$ ).

### **Impact of time pressure on dentists' diagnostic ability for each radiograph.**

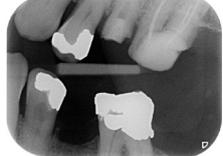
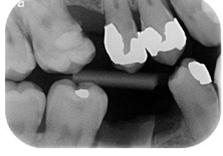
**Global Radiographic Reporting:** The impact of time pressure on diagnostic performance was compared for each of the 12 different radiographs separately to check whether the results were consistent across all radiographs. The participants' median diagnostic sensitivity was statistically significantly worse for 10 out of 12 of the radiographs under the time pressure condition, but their median diagnostic specificity was not statistically significantly different between the experimental conditions for any

of the radiographs. The median sensitivity values varied from 0.21 to 1 for the time-pressure condition, and from 0.5 to 1 for the non-time-pressure condition. The median specificity was in both conditions high ranging from 0.98 to 1. In one of the radiographs (B4) the median specificity was marginally better under the time pressure condition (1 vs 0.98) and this difference was statistically significant ( $p=0.02$ ), but the median sensitivity was not affected by time pressure ( $p=0.277$ ). Finally, in one of the radiographs (A6) the diagnostic performance of the dentists did not differ statistically significantly for either sensitivity ( $p=0.174$ ) or specificity ( $p=0.478$ ).

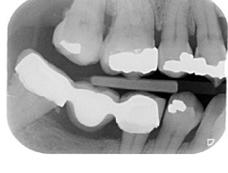
**Caries Recognition:** In contrast, in only two (A4 and B1) of the radiographs the median diagnostic sensitivity of the dentists deteriorated under time pressure statistically significantly (by 50% and 10% respectively). In the reports of six radiographs no statistically significant difference between dentists median diagnostic sensitivity was observed. The sensitivity could not be calculated for the reports of four radiographs as there was no caries-related pathology present. For all the radiographic reports the median specificity was high (Median ranging from 0.91 to 1) and no statistically significant differences were detected between the conditions.

Tables 8 and 9 present the median values for the diagnostic sensitivity and specificity for each radiographic report between the two experimental conditions, as regards to both the global reporting (Table 8) and caries recognition alone (Table 9).

**Table 8: Median Sensitivity and Specificity values for Set A radiographs under the two experimental conditions (time-pressure vs no time-pressure)**

Radiograph (Set A)			Sensitivity			Specificity		
			Time pressure (Median)	No Time Pressure (Median)	P value	Time pressure (Median)	No Time Pressure (Median)	P value
A1		Global Reporting	0.6	1	<0.0001	1	1	0.076
		Caries Recognition	0.66	1	0.006	1	1	0.231
A2		Global Reporting	0.41	0.75	<0.0001	1	1	0.156
		Caries Recognition	1	1	0.429	1	1	1
A3		Global Reporting	0.83	1	0.003	1	0.98	0.602
		Caries Recognition	1	1	0.102	0.96	1	0.414
A4		Global Reporting	0.5	0.83	<0.001	0.99	1	0.904
		Caries Recognition	0.37	0.87	<0.0001	0.98	1	0.841
A5		Global Reporting	0.55	0.75	0.012	1	1	0.495
		Caries Recognition	*	*	*	0.94	0.94	0.799
A6		Global Reporting	0.38	0.53	0.174	0.98	0.98	0.478
		Caries Recognition	0.44	0.55	0.565	0.94	0.94	0.779
		Independent Samples Mann-Whitney U test						
		*The sensitivity could not be calculated for this radiograph as there was not caries-related pathology present						

**Table 9: Median Sensitivity and Specificity values for Set B radiographs under the two experimental conditions (time-pressure vs no time-pressure)**

Radiograph (Set B)			Sensitivity			Specificity		
			Time pressure (Median)	No Time Pressure (Median)	P value	Time pressure (Median)	No Time Pressure (Median)	P value
B1		Global Reporting	0.6	0.7	<0.0001	0.98	0.98	1.0
		Caries Recognition	0.57	0.71	<0.0001	0.95	0.95	0.841
B2		Global Reporting	0.33	0.66	0.005	1	1	0.620
		Caries Recognition	*	*	*	1	1	0.799
B3		Global Reporting	0.5	0.75	0.026	0.98	0.98	0.086
		Caries Recognition	0.66	0.66	0.121	0.97	0.95	0.127
B4		Global Reporting	1	1	0.277	1	0.98	0.02
		Caries Recognition	*	*	*	1	1	0.799
B5		Global Reporting	0.66	0.83	<0.0001	1	1	0.583
		Caries Recognition	*	*	*	1	1	0.799
B6		Global Reporting	0.21	0.5	<0.0001	1	1	0.968
		Caries Recognition	1	1	0.60	1	1	0.461
		Independent Samples Mann-Whitney U test						
		*The sensitivity could not be calculated for this radiograph as there was not caries-related pathology present						

## Discussion

To the best of our knowledge, this is the first study to empirically examine the impact of time pressure among dentists (Plessas *et al.*, 2018). The present investigation was specifically designed to examine the impact of time pressure, as a stressor, on dentists' diagnostic performance when reporting on dental bitewing radiographs.

The study met its aim and objectives by demonstrating that dentists' radiographic diagnostic performance is influenced negatively by time pressure, such that participant dentists who were placed under time pressure were significantly less likely to identify signs of disease. Specifically, when faced with time pressure, participants' sensitivity reduced. Our results align with earlier findings showing the negative impact of time pressure on diagnostic accuracy within doctors (ALQahtani *et al.*, 2016; Tsiga *et al.*, 2013). The time pressure manipulation, acted as a stressor, as evaluated by the significantly higher VAS scores. Therefore, when it comes to conceptualising stress in this study, time pressure was used and viewed as a stress stimulus, and the participant's stress response and appraisal was evaluated via the VAS.

Diagnostic information extracted from bitewing radiographs directly affects dentists' treatment decisions (Mileman, Mulder & van der Weele, 1992; Mileman & van der Weele, 1996). Our participants' ability to detect any pathology correctly (sensitivity), was reduced by 30% on average when they were under time constraints. Bitewing radiographs are the most prescribed radiographs in general dental practice for caries recognition (Mileman & van der Weele, 1996). In the present study, the impact of time pressure on caries recognition was both statistically and clinically significant with, on average a 40% decrease in the dentists' ability to detect signs of caries when they were under time pressure. In contrast, time pressure did not affect the dentists' ability to correctly identify sites free of pathology (specificity).

### **Implications for clinical practice**

Time constraints frequently occur in dental practice and dentists identify time pressures and running late as important stressors, which may potentially influence their decisions (Chapman, Chipchase & Bretherton, 2015a; Chipchase, Chapman & Bretherton, 2017). Within the current climate of 'meeting targets' in general dental practice (BDA, 2018), dentists are faced with shorter appointment times (Chipchase, Chapman & Bretherton, 2017). As the results of this study indicated, the latter may negatively impact the dentists' performance with them failing to diagnose and report important pathological features on bitewing radiographs.

Under the current Ionizing Radiation (Medical Exposure) Regulations IR(ME)R, a radiographic report should detail the resulting diagnostic findings or therapeutic implications (Shelley, 2013). Radiographs provide valuable information about current or historical disease activity (e.g. caries and periodontal destruction). Missing radiographic information may lead to under-diagnosis and subsequent under-treatment which may directly impact on patient safety and experience and can have further medicolegal implications. Dental complaints and negligence claims have been on the rise (Pearce *et al.*, 2015), with 9% of the dental claims relating to diagnostic errors (Hapcook, 2006), whilst, incorrect interpretation of diagnostic tests account for the 37% of medical claims (Gandhi *et al.*, 2006).

Dentists need to be mindful of the potential impact that time pressure may have on their performance as missing diagnostic information can result in avoidable harm to patients and possible medicolegal implications to their practice. Strategies to minimise the risk of diagnostic errors in practice are warranted. These could include allowing or requesting longer appointment times when dentists are planning to take and report on radiographs and/or re-assessing and reviewing their radiographs and radiographic reports when they are not under time constraints. However, changes in dental guidelines and policy might be warranted to facilitate longer appointment times. Further evidence

on the role of time pressure on dentists' efficiency, patient experience and patient safety is required in order to influence the policy makers' decisions (Hanney *et al.*, 2003).

### **Measures of diagnostic performance and prevalence of disease**

The prevalence of caries in our dataset was 10.77%. This may be considered relatively low compared to the prevalence of caries experience in the UK. The 2009 Adult Dental Health Survey (ADHS) showed that 31% of the dentate adults examined, would present with at least one carious lesion visibly into dentine and the mean number of decayed teeth per person was 2.7 (White *et al.*, 2009). However, it is difficult to directly compare the prevalence of disease (such as caries) captured in our study sample to national data such as the ADHS. The ADHS did not use radiographic data for formulating diagnosis for caries experience, and our study only used partial-mouth measurements for caries experience as depicted in a single bitewing radiograph.

Sensitivity and specificity are characteristics of a “diagnostic test” and the population does not affect the results. Therefore, the sensitivity and specificity values are unaffected by the prevalence of the disease (Altman & Bland, 1994b). Other measures of performance in diagnostic studies include the positive and negative likelihood ratios and positive and negative predictive values.

The likelihood ratio is the probability that a given test result would be expected in a patient with the target disease compared to the probability that that same result would be expected in a patient without the target disease. The likelihood ratio is calculated as  $LR = \text{Sensitivity} / (1 - \text{Specificity})$ , and hence similar to sensitivity and specificity is immune to disease prevalence (Altman & Bland, 1994b). A likelihood ratio greater than 1 indicates that the test result is associated with the presence of the disease, whereas a likelihood ratio less than 1 indicates that the test result is associated with the absence of disease. The further likelihood ratios are from 1 the stronger the evidence for the presence or absence of disease. Likelihood ratios above 10 and below 0.1 are

considered to provide strong evidence to rule in or rule out diagnoses respectively (Deeks & Altman, 2004). When tests report results as being either positive or negative the two likelihood ratios are called the positive likelihood ratio and the negative likelihood ratio (Deeks & Altman, 2004).

Positive predictive value (PPV) is the proportion of patients/teeth/sites with positive test results who are correctly diagnosed, while negative predictive value (NPV) is the proportion of patients/teeth/sites with negative test results who are correctly diagnosed. Positive and negative predictive values are influenced by the prevalence of disease in the population that is being tested (Altman & Bland, 1994b). Therefore, if we test in a high prevalence setting, it is more likely that individuals/teeth or sites who test positive truly have the disease than if the test was performed in a population with low prevalence of disease (Altman & Bland, 1994b). PPV and NPV can be calculated using a 2x2 contingency table by the following equations:  $PPV = TP / (TP + FP)$  and  $NPV = TN / (FN + TN)$ . Alternatively, when the disease prevalence is known, the positive and negative predictive values can be calculated using the following formulas based on Bayes' theorem:

$$PPV = \frac{\text{Sensitivity} \times \text{prevalence}}{\text{Sensitivity} \times \text{prevalence} + (1 - \text{specificity}) \times (1 - \text{prevalence})}$$

$$NPV = \frac{\text{Specificity} \times (1 - \text{prevalence})}{(1 - \text{sensitivity}) \times \text{prevalence} + \text{specificity} \times (1 - \text{prevalence})}$$

The above equations were used to calculate the predictive values for global caries recognition for our 'population' and for the UK population. The prevalence of caries in our population was 10.77% and for the UK population the prevalence of 31% as

reflected by the latest ADHS. The results of these calculations are summarised in table 10.

**Table 10: Predictive values and prevalence of disease**

	Our Population (caries Prevalence 10.77%, / 0.11)		UK population (caries prevalence 31% / 0.31)	
	PPV	NPV	PPV	NPV
TP*	1	0.69	1	0.22
NTP**	1	1	1	1
*Sensitivity (TP)= 0.6, Specificity (TP)=1 / **Sensitivity (NTP)=1, Specificity (NTP)=1				

As expected and shown in the above table, higher disease prevalence results in decreased negative predictive values for the time pressure condition. Whilst when the prevalence increases, the positive predictive value also increases. However, in our example the specificity was equal to 1, a rare finding for diagnostic tests, and therefore the positive predictive values were also 1 regardless the prevalence of the disease.

Positive and negative predictive values are valuable in clinical practice when interpreting the results of a diagnostic test for a patient's condition. The patient and clinician are interested in the question: what is the chance that a patient with a positive test, truly has the disease? However, in our study, we were interested in the performance of the actual diagnostic 'test', which in our case is the clinician/participant's performance. As sensitivity and specificity are characteristics of the 'test' and quantify the diagnostic ability of the test, these were the only diagnostic data analysed in the present study (Altman and Bland 1994a).

### **Strengths and limitations**

This study used materials that are often used in clinical practice. The radiographs used in this study came from a primary dental care organisation (PDSE) and are therefore likely to be similar to ones that general dentists may encounter in clinical practice. The dentists' characteristics were more or less split equally with regards to their gender, practising setting, working pattern and educational background. The fact that in our sample, dentists were working in a variety of primary care settings (private, NHS, mixed practices and community services) and had a broad range of experience (1-35 years) increases the generalisability of the findings of this study.

The time pressure limits applied in this study were calculated from a pilot study based on previously validated methods (Ordóñez & Benson, 1997). The statistically significant difference in VAS scores between the two conditions confirmed that the time pressure in the present study acted as a stressor factor amongst the participants. In addition, counterbalancing and randomisation procedures utilised in this study helped to ensure that the observed difference in diagnostic performance should be solely the result of the experimental manipulation (time pressure).

However, the simulated nature of the experimental task does not represent fully what happens in a real clinical environment. Namely, in the present study, the dentists could not return to the radiograph, whilst in practice they can go back to the radiograph at any time point to confirm or correct their diagnosis. In addition, in clinic the dentists face different sources of time pressure or additional other pressures (e.g difficult consultations) and may also be subjected to distractions (from the patient, dental nurse or other staff).

A further limitation of the study is that the dentists assessed different radiographs under each condition, albeit matched for subjective difficulty. Asking the same group of dentists to assess the same radiographs over two separate occasions would have allowed

a direct comparison of diagnostic sensitivity and specificity under the two conditions within the same dentist. For example, a period of four weeks has been used in other dental decision making studies assessing intra-observer variability (Dincer *et al.*, 2013; Kostopoulou *et al.*, 1998; Lee, MacFarlane & O'Brien, 1999).

### **Future research**

The recommendations for future research will be discussed in the following chapter (Chapter 5).

### **Conclusions**

This study is the first attempt, to the author knowledge, to test the complexity of the role of time pressure in dentists' performance. The present study showed that, in a simulated environment, dentists' ability to detect pathological features, including caries related pathology, on bitewing radiographs is negatively affected by time pressure. However, their ability to correctly identify teeth and sites free of signs of disease, however, was not affected.



## **Chapter 5: Discussion and Concluding Remarks**



It has been suggested that research should start with a systematic review (Robinson, Saldanha & McKoy, 2011). Reviewing and mapping the literature systematically is necessary to identify gaps in the literature, develop an answerable question and design of a study most likely to answer that question (Robinson, Saldanha & McKoy, 2011). This ResM project followed an evidence informed approach to answer the question: “what is the impact of time pressure, as a stressor, on dentist’s diagnostic decision making?”

The project built upon a research question which stemmed from a research prioritisation process. The question that was originally submitted to the prioritisation process referred to fear and decision making and an earlier review identified no relevant studies addressing this question (Fox, 2010). Therefore, primary research aiming to answer this question was judged as a priority. Fear is defined as the unpleasant emotional state consisting of psychological and psychophysiological responses to a real or perceived threat or danger. Fear produces an associated stress response (Miller-Keane, 2003) and so for the purpose of the current research the question was refined to consider the impact of stress and different stressors more generally rather than fear specifically.

The literature suggests that dentists face different pressures in practice and experience high levels of stress, which in some cases may lead to mental health disorders or even burnout (Singh *et al.*, 2016). Although a breadth of research on dentists’ wellbeing and stress related-factors has been published internationally, very little is known about the impact of different stressors on dentists’ performance. In other healthcare settings, it has been shown that increased levels of stress impact on healthcare professionals’ technical and non-technical performance (including diagnostic, psychomotor and communication skills) (Arora *et al.*, 2010). Therefore, a decision was made to systematically review the dental literature on the impact of stress on all aspects of dentists’ performance, and not only decision making.

The systematic review of the dental literature (Chapter 2) yielded no relevant studies looking specifically at the impact of any stressors on dental decision-making. In the literature search for this review, terms referring to fear, anxiety and emotions were also included. Their inclusion aimed to capture any studies addressing the priority question about fear and decision making as well. However, on reflection, these terms are conceptually different to stress as they refer to different emotional states, and the underlying mechanisms; therefore, they possibly should have been avoided.

A subsequent decision was made to map the literature of decision making to identify which factors may affect dentists' decision-making and to ensure that no studies looking at the impact of different stressors were missed. Also, through mapping the existing literature on dental decision making (Chapter 3) the researcher (AP) familiarised himself with the types of research studies on decision making already conducted, which would inform the design of any subsequent primary experimental studies. From the map, different stressors were found to be perceived as influential by dentists on their decision-making. For example, these included patient's expectations and demands, time pressure and workload, medico-legal issues and fear of litigation. However, the mapping review showed that their impact on dentists' decision-making process has not been determined experimentally.

Due to the paucity of research on the topic and the high number of studies reporting that time pressure acts as a stressor amongst dentists, a decision was made to investigate the role of time pressure on dentists' decision-making. Dentists' decision making, as shown from the findings of the mapping review, is a complex interplay of several dentist, patient and environment-related factors. Dentists' treatment decisions are often influenced by radiographic diagnostic information and diagnosis is the first step of every subsequent treatment decision. Bitewing radiographs are routinely used in general practice to compliment clinical diagnostic findings. Therefore, the above led to a

decision to design a study exploring the effect of time pressure on dentists' radiographic diagnostic performance when examining bitewing radiographs.

The study was designed to counterbalance and randomise the order of the experimental condition the participants were exposed to and the order of set of radiographs they examined. This ensured that any observed difference was most likely solely due to the experimental manipulation. The method used to calculate the time pressure limits for each radiograph and participants stress assessment was based on validated and previously used methods from the fields of psychology and medicine (Ordóñez & Benson, 1997; Tsigas *et al.*, 2013). A visual analogue scale (VAS) was used to assess participant's stress upon the experimental manipulation of time pressure. VAS has been shown to be a valid measure for assessing stress in lab-based psychological experimental studies (McCormack *et al.*, 1988).

The study demonstrated a significant deterioration in dentists' sensitivity, both in terms of identifying all the reporting items in the radiographs (30% median reduction in sensitivity) and caries-related radiolucencies in particular (40% median reduction in sensitivity). However, no clinically relevant or significant differences were observed for changes in specificity.

## **Challenges and Limitations**

The dentists' response rate to the study invitation was initially low and the recruitment took a lot longer than was initially expected. Contrary to our original initial plan, participants examined different radiographs under the two conditions on only one occasion. Thus, although we were planning to ask the same group of dentists to examine and report on the same radiographs on two occasions, following feedback received by all the pilot participants, this was not attempted. The low response rate and the time it

took to recruit the desired 40 participants reflected the feedback we received by those taking part in the pilot. It was recognised that it would have been unlikely that dentists would have been willing to attend on two occasions as it was hard enough to get them engaged for one session. During recruitment, among the reasons that our potential participants gave to explain their unwillingness or inability to participate were the need to travel, time issues, busy schedule and fear of what impact their participation and possible poor performance in the experiment would have on their registration with the GDC and contract with their employer. Lack of time, heavy workload, lack of rewards and concerns or negative beliefs about research in general have been previously cited as barriers in healthcare professional's participation in research (Hummers-Pradier *et al.*, 2008; Rahman *et al.*, 2011). To increase participation, adjustments to the study design were deemed necessary. For example, the original plan was all the dentists to carry out the experiment on the same computer, in the same non-clinical room. However, potential participants who contacted the principal investigator reported that they were interested in participating, but were not willing to travel. Therefore, an amendment was made to permit the principal investigator to visit the dentists at their practices out of office hours. Given that the experiment took place in a quiet room with no distractions, the use of different settings may have had only a negligible effect on the internal validity, particularly since each dentist examined equal numbers of radiographs under both experimental states (time pressure and no-time pressure). Ironically, this adaption may have actually increased the external validity of the study since many of the dentists undertook the study in their own practice setting.

The time pressure limits used in this study varied from 8 to 38 sec. These time pressure limits were suggested by the pilot study after applying a previously used and validated equation (Ordóñez & Benson, 1997; Tsiga *et al.*, 2013). Whether this is a reasonable time limit, which reflects the time constraints that dentists may face in clinical practice is

an open question, as currently we lack such data from general dental practice. Admittedly, the time given to the participants to observe the radiographs under the time pressure condition was rather short. It is possible that participants did not have the time to scan the whole image for pathology and this is why pathological features were missed. On the other hand, the participants may have had enough time to assess the radiograph but not enough time to note the pathology observed. therefore they may had to rely upon their memory to complete their radiographic report. The above may have implications for the validity of the study, as it can be argued that the study may have not totally assessed the participants' diagnostic ability but also partially their memory and recall of information. Therefore, the conclusions made from our study should be treated with caution.

In light of the stress and decision making literature, if we see the experimental study via the lens of Janis and Mann's Conflict-theory model of decision making (as adapted for the dental setting) (Chipchase, Chapman & Bretherton, 2017) the following remarks can be made: It can be argued that as the participants would not suffer any loss or unfavourable consequences from performing poorly in the study, their level of arousal, although elevated, was possibly significantly lower than what it would have been if they had to make similar decisions in a real-life clinical setting case for a real patient. In this case, their type of decision-making would have remained unconflicted. On the other hand, some of the participants fed back to the researcher that, although their decisions would have not harmed a patient, their levels of stress were high due to their desire to excel in the task and achieve perfection. Interestingly, although they had been already reassured of the confidential nature of the study, few of the participants were still worried that the researcher would be able to identify their individual results. In that case, poor performance would have been seen as a threat to their kudos and therefore

their level of arousal could have been high, leading to a more vigilant or hypervigilant decision-making behaviour.

In our study, stress was viewed as both stimulus and response, partially via the lens of the transactional models of stress (Lazarus and Folkman, 1987). In our primary study, the experimental manipulation, i.e time pressure, was used as a stress stimulus, whilst the VAS scale reflected the participant's subjective response and appraisal of the stress condition. However, the transactional model of stress views stress as a more dynamic process consisting of different cycles of appraisal and re-appraisal of the stressor or situation. Quantitative methodology in stress research, as employed in this study, has been criticised for obtaining data that captures only a static moment in time, and that it fails to harness the full extent of the complex and fluctuating subjective interpretation of an individual's stress experience (Mazzetti and Blenkinsopp 2012). It can be argued, for example, that the participant's attitudes towards the nature of the experiment and their perception of "threat" could have influenced the results of the study. As all participants were fully aware that their decision would not directly impact on patient's safety, it is plausible that their level of attention and motivation or desire to excel in this 'exercise' was also influenced. Exploring the participant's appraisal processes through qualitative methodology, could have given insight into the transactional nature of stress experienced by the participants during the experimental manipulation and it could also examine its impact on the types of decision-making behaviour the participants displayed.

The present experimental study (Chapter 4) demonstrated that when under time pressure in a simulated environment, dentists' diagnostic sensitivity is negatively affected. In the study only bitewing radiographs without any priming clinical information, were used.

However, in practice clinical decisions should be based on careful evaluation of findings of the patient's history and clinical and radiographic examination. Nonetheless, dentists in practice may face more than one stressor simultaneously (time pressure, demanding patient, difficult treatment). These are conditions which are difficult to replicate in a simulated experimental setting. Therefore, future studies can build upon the present study by using different types of radiographs and accompanying each radiograph or set of radiographs with a clinical scenario (e.g. vignette, clinical photographs). The use of adjunctive clinical information or scenarios in future studies would allow exploration of how different priming information may affect dentists' diagnostic decisions and increase the applicability of the findings to clinical practice.

## **Implications and Future Research**

Further research is required to understand the underlying mechanism(s) that lead to the deterioration of diagnostic sensitivity in order to develop interventions or decision aids to prevent these diagnostic errors from occurring. Diagnostic errors may put patient safety at risk, with patients potentially being harmed if pathology (e.g. carious lesion) is missed. This can potentially lead to unnecessary pain, the need for more complex treatment such as root canal treatment, or even loss of the tooth. Of course, this could potentially have medicolegal implications affecting the dentists' practice and reputation too. The need for more research on patient safety including a conceptual understanding of the issues around patient safety has also been highlighted by a recent systematic review in patient safety interventions in dentistry (Bailey *et al.*, 2015).

Eye-tracking technology, being widely used in psychology and human factors research, can be used for example to assess the dentists' information processing strategies under time pressure versus no-time pressure. (Kok & Jarodzka, 2017). Eye tracking objectively measures the movements of the eyes to see what a person is looking at, for

how long, and in what order which may facilitate a deeper insight into visual aspects of performance under time pressure (Kok & Jarodzka, 2017). As eye movements reflect cognitive processes, it can be hypothesised that dentists under no time pressure may follow a systematic approach when examining radiographs (as they are typically taught to do), but they might become erratic when they are put under time pressure. Therefore, employing eye tracking technology in future studies may give a better insight into the potential underlying mechanisms (cognitive or behavioural) explaining any observed difference in performance between the two conditions.

Understanding these mechanisms may facilitate and inform the development of tools to decrease the risk of diagnostic errors, such as decision support systems. Clinical decision-support systems are computer programs that are designed to provide expert support for health professionals making clinical decisions (Vikram & Karjodkar, 2009). The goal of these systems is to help health professionals analyse patient data and make better decisions regarding diagnosis, prevention, and treatment of health problems (Mendonca, 2004; Vikram & Karjodkar, 2009). In dental radiology, these systems have been used to generate messages if a radiograph is taken too often or if a radiographic examination is due (White, 1996), but also to assist with the identification of infrabony lesions (White, 1989). By using artificial intelligence, such systems might be trained to alert the dentist of any radiolucencies associated with disease, interpret radiographic signs or even automatically interpret dental radiographs to some extent (Mendonca, 2004).

Nonetheless, the impact of time pressure, or other stressors, on other aspects of performance also needs further exploration. For example, its effect on dentists' treatment planning and adherence to guidelines could be experimentally tested using case scenarios and vignettes. Communication skills could be evaluated using simulated consultations, which are used worldwide in healthcare professionals' communications

skills training (Lane & Rollnick, 2007). Different healthcare communication skills assessment tools have been developed in recent years (Frankel *et al.*, 2007; Rehim *et al.*, 2017) which could be adapted to be used in a dental setting. Psychomotor skills, such as preparation of teeth and occurrence of iatrogenic errors (e.g. damaging an adjacent tooth) could be evaluated under time pressure, in a simulated setting, such as through the use of phantom heads. Virtual reality dental simulation systems could also be used to provide a standardized report about psychomotor proficiency and number of errors (Plessas, 2017).

## **Conclusion**

This project identified a gap in the dental literature on the role of stress on dentists' performance and attempted to fill some of this gap. The experimental study demonstrated that when examining dental bitewing radiographs in a simulated environment, dentists missed pathological features. The deterioration in sensitivity (30% for all pathological features and 40% for caries related pathology) was not only statistically, but also clinically significant. However, dentists' ability to correctly identify sound sites and teeth free of pathology (specificity) was not materially affected. These diagnostic errors have the potential to lead to negative patient outcomes and even patient harm. Future research is warranted to assess the impact of time pressure on diagnostic, treatment planning, communication and psychomotor skills of dentists as well to explore the underlying mechanisms, which may explain any observed differences in dentists' performance. These research findings could inform the future development of appropriate educational, patient safety or quality improvement interventions to address any dentists' performance issues.



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# Appendices



**Appendix 1: Protocol for Systematic Review: Impact of stress on Dentists' Clinical Performance (PROSPERO: CRD42016045756)**

### Impact of stress on dentists' performance

Anastasios Plessas, Maria Bernardes Delgado, Mona Nasser, Yaniv Hanoch, David Moles  
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#### Review question

Does stress affect dentists' performance?

#### Searches

We will search the following electronic bibliographic databases: MEDLINE via Ovid, EMBASE via Ovid, CINHAL via EBSCO, PsycINFO. For the search of the grey literature: OpenGrey and EThOS databases will be searched.

No language limits are set. The searches will be re-run just before the final analyses and further studies retrieved for inclusion.

The search strategy will include the following key search terms and relevant MeSH/keywords and Boolean operators:

" (SU.EXACT("Dental Surgery") OR SU.EXACT("Dentists") OR SU.EXACT("Dentistry") OR dentist\*) AND (SU.EXACT("Stress") OR SU.EXACT("Occupational Stress") OR SU.EXACT("Psychological Stress") OR stress\* OR SU.EXACT("Fear") OR fear OR SU.EXACT("Anxiety") OR anxiety OR SU.EXACT("Emotions") OR emotion\*) AND (SU.EXACT("Decision Making") OR ("decision making") OR SU.EXACT("Clinical Judgment (Not Diagnosis)") OR SU.EXACT("Medical Diagnosis") OR SU.EXACT("Diagnosis") OR decision\* OR SU.EXACT("Treatment Planning") OR ("treatment plan") OR ("treatment planning") OR SU.EXACT("Performance") OR SU.EXACT("Job Performance") OR SU.EXACT("Motor Performance") OR SU.EXACT("Motor Skills") OR psychomotor OR SU.EXACT("Competence") OR SU.EXACT("Professional Competence") OR ("clinical performance") OR SU.EXACT("Communication Skills") OR communication) "

The above is the search strategy for PsycINFO. It has been adopted for other databases.

#### Types of study to be included

Prospective experimental studies with or without control group

#### Condition or domain being studied

Occupational Stress

#### Participants/population

Dentists

#### Intervention(s), exposure(s)

The exposure of interest in this review will be dentist's occupational stress, fear, and anxiety.

#### Comparator(s)/control

The comparator group will be participants (dentists) who have not developed or demonstrated any signs of stress.

#### Context

The studies included will be involving dentists. Any studies involving other health care professionals (eg. doctors, surgeons, nurses etc), or dental students and dental hygienists will be excluded.

#### Primary outcome(s)

Differences between stressed and non-stressed dentists in

- Diagnosis
- Treatment plan
- Psychomotor skills (eg. cavity preparation size)
- Communication skills

### Secondary outcome(s)

Differences between stressed and no-stressed dentist in any other aspect of decision making or performance.

### Data extraction (selection and coding)

The reference management software (Endnote X7.4) will be used to manage the records retrieved from the above database searches. Two reviewers will independently (AP and MBD) scan all the titles and abstracts of the retrieved studies. Irrelevant titles will be excluded and full-text papers will be obtained where titles are deemed to be relevant or where eligibility is unclear. During the above two stages any disagreement will be resolved with the discussion and the involvement of a third reviewer (DM) when necessary. The relevant full text papers will be reviewed by AP and MBD; any disagreement will be resolved as stated above. A record of reasons for excluding studies will be kept during the review process. The inclusion and exclusion decisions will be reported by completing a PRISMA flow chart. The study characteristics and outcome data will be extracted in duplicate using a piloted data extraction form (adapted from the Cochrane data collection form for intervention studies). The two main reviewers AP and MBD will extract the data and DM will be consulted where there is any disagreement. Data regarding demographic details of participants, study type and design details and outcomes reported will be included as items in a reporting of studies table.

### Risk of bias (quality) assessment

As different study types may be included in this review taking into consideration the diversity of it's context more of one tools may need to be utilised depending on the study type included.

- For RCTs: Cochrane Collaboration's Risk of Bias (RoB) tool
- For non-randomised studies with a separate a control group: the Effective Practice and Organisation of Care (EPOC) RoB Tool

### Strategy for data synthesis

The results of the included studies will be summarised in tables and diagrams and a narrative synthesis of the results will be provided. If enough quantitative data are retrieved a quantitative analysis will be performed to summarise the results.

### Analysis of subgroups or subsets

None planned.

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<https://www.plymouth.ac.uk/your-university/about-us/university-structure/faculties/medicine-dentistry>

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**Appendix 2: Search Strategy for Systematic Review  
(Impact of Stress on Dentists' Clinical Performance).**

Database	Search Terms		
	P	E	O
<b>CINHAL</b>	<ol style="list-style-type: none"> <li>1. Dentists</li> <li>2. dentist</li> <li>3. (MH "Dentists")</li> <li>4. (MH "Dentistry, Operative")</li> <li>5. dentistry</li> <li>6. (MH "Dentistry")</li> <li>7. "dental"</li> </ol>	<ol style="list-style-type: none"> <li>8. (MH "Stress")</li> <li>9. (MH "Stress, Occupational")</li> <li>10. (MH "Stress, Psychological")</li> <li>11. "stress"</li> <li>12. (MH "Fear")</li> <li>13. "fear"</li> <li>14. (MH "Anxiety")</li> <li>15. "anxiety"</li> <li>16. (MH "Emotions")</li> <li>17. emotion*</li> </ol>	<ol style="list-style-type: none"> <li>18. decisions</li> <li>19. decision</li> <li>20. "decision making"</li> <li>22. (MH "Decision Making, Clinical")</li> <li>23. (MH "Decision Making")</li> <li>24. (MH "Judgment")</li> <li>25. judgement</li> <li>26. (MH "Clinical Competence")</li> <li>27. (MH "Motor Skills")</li> <li>28. "clinical performance"</li> <li>29. performance</li> <li>30. (MH "Psychomotor Performance")</li> <li>31. (MH "Job Performance")</li> <li>32. "psychomotor"</li> <li>33. "treatment planning"</li> <li>34. "treatment plan"</li> <li>35. "diagnostic error"</li> <li>36. (MH "Diagnostic Reasoning")</li> <li>37. (MH "Diagnostic Errors")</li> <li>38. (MH "Treatment Errors")</li> <li>39. (MH "Communication")</li> <li>40. (MH "Communication Skills")</li> </ol>
<b>Embase (Ovid)</b>	<ol style="list-style-type: none"> <li>1.dental.mp.</li> <li>2. dentistry/</li> <li>3. dentistry.mp.</li> <li>4. dentist/</li> <li>5. dentist*.mp.</li> </ol>	<ol style="list-style-type: none"> <li>7. stress/</li> <li>8. acute stress/</li> <li>9. emotional stress/</li> <li>10. job stress/</li> <li>11. stress.mp.</li> <li>12. fear/</li> <li>13. fear.mp.</li> <li>14. anxiety/</li> <li>15. anxiety.mp.</li> <li>16. emotion/</li> <li>17. emotion*.mp.</li> </ol>	<ol style="list-style-type: none"> <li>19. decision making/</li> <li>20. "decision making".mp.</li> <li>21. clinical decision making/</li> <li>24. decision*.mp</li> <li>25. treatment planning/</li> <li>26. "treatment plan".mp.</li> <li>27. "treatment planning.mp.</li> <li>28. performance/</li> <li>29. job performance/</li> <li>30. mental performance/</li> <li>31. motor performance/</li> <li>32. psychomotor performance/</li> <li>33. clinical competence/</li> <li>34. clinical practice/</li> <li>35. "clinical performance".mp.</li> <li>36. interpersonal communication/</li> <li>37. psychomotor.mp.</li> <li>38. communication skill/</li> <li>39. "communication skills".mp.</li> <li>40. diagnostic error/</li> </ol>
<b>Medline (Ovid)</b>	<ol style="list-style-type: none"> <li>1. Dental Staff/</li> <li>2. dental.mp.</li> <li>3. Dentistry/</li> <li>4. dentistry.mp.</li> <li>5. Dentists/</li> <li>6. dentist*.mp.</li> </ol>	<ol style="list-style-type: none"> <li>7. stress.mp.</li> <li>8. Fear/</li> <li>9. fear.mp.</li> <li>10. Anxiety/</li> <li>11. anxiety.mp.</li> <li>12. Emotions/</li> <li>13. emotion*.mp.</li> </ol>	<ol style="list-style-type: none"> <li>14. Decision Making/</li> <li>15. "decision making".mp.</li> <li>16. "decision making model".mp.</li> <li>17. Clinical Decision-Making/</li> <li>20. decision*.mp.</li> <li>21. treatment plan.mp.</li> <li>22. treatment planning.mp.</li> <li>23. Work Performance/</li> <li>24. Psychomotor Performance/</li> <li>25. Clinical Competence/</li> <li>26. Motor Skills/</li> <li>27. performance.mp.</li> <li>28. " clinical performance".mp.</li> <li>29. psychomotor.mp.</li> <li>30. Diagnostic Errors/</li> <li>31. Communication/</li> <li>32. "communication skills".mp.</li> </ol>
<b>PsychInfo</b>	<ol style="list-style-type: none"> <li>1. SU.EXACT("Dental Surgery")</li> <li>2. SU.EXACT("Dentists")</li> <li>3.SU.EXACT("Dentistry")</li> <li>4. (dentist*)</li> </ol>	<ol style="list-style-type: none"> <li>5. SU.EXACT("Stress")</li> <li>6. SU.EXACT("Occupational Stress")</li> <li>7. SU.EXACT("Psychological Stress")</li> <li>8. stress*</li> <li>9. SU.EXACT("Fear")</li> <li>10. fear OR</li> <li>11. SU.EXACT("Anxiety")</li> <li>12. anxiety</li> <li>13. SU.EXACT("Emotions")</li> <li>14. emotion*</li> </ol>	<ol style="list-style-type: none"> <li>15. SU.EXACT("Decision Making")</li> <li>16. "decision making"</li> <li>17. decision*</li> <li>18. SU.EXACT("Clinical Judgment (Not Diagnosis)")</li> <li>19. SU.EXACT("Diagnosis")</li> <li>20. SU.EXACT("Treatment Planning")</li> <li>21. "treatment plan"</li> <li>22. "treatment planning"</li> <li>23. SU.EXACT("Performance")</li> <li>24. SU.EXACT("Job Performance")</li> <li>25. SU.EXACT("Motor Performance")</li> <li>26. SU.EXACT("Motor Skills")</li> <li>psychomotor</li> <li>27. SU.EXACT("Competence")</li> <li>28. SU.EXACT("Professional Competence")</li> <li>29. "clinical performance"</li> <li>30.SU.EXACT("Communication Skills")</li> <li>31. communication</li> </ol>

## **Appendix 3: Excluded Studies and Reasons for Exclusion**

<b>Excluded studies and reasons for exclusion</b>		
	<b>Citation</b>	<b>Reason</b>
1.	Abdelkarim, A., and Jerrold, L. (2015): Litigation and legislation. Risk management strategies in orthodontics. Part 1: Clinical considerations. <i>American Journal of Orthodontics &amp; Dentofacial Orthopedics</i> 148,345-349.	Opinion Piece How to avoid litigation
2.	Anonymous. (1986): Emphasis. Controlling anxiety in the dental office. <i>Journal of the American Dental Association</i> (1939) 113,728-733, 735.	Opinion piece on patient's anxiety
3.	Azodo, C.C., Ezeja, E.B., and Ehikhamenor, E.E. (2011): Occupational violence against dental professionals in southern Nigeria. <i>African Health Sciences</i> 11,486-492.	Survey -Not experimental. Influence of violence towards dental professionals.
4.	Chapman, H.R., Chipchase, S.Y., and Bretherton, R. (2015a): Understanding emotionally relevant situations in primary dental practice. 2. Reported effects of emotionally charged situations. <i>British Dental Journal</i> 219,E8-E8.	Not experimental. Perceived impact of stress. Not actual measurement of stress.
5.	Chapman, H.R., Chipchase, S.Y., and Bretherton, R. (2015b): Understanding emotionally relevant situations in primary dental practice. 3. Emerging narratives. <i>British Dental Journal</i> 219,491-496.	Not experimental. Focusing on role of CBT (cognitive behavioural therapy) on stress.
6.	Fox, C. (2010): Evidence summary: Does dentists' fear have an adverse effect on clinical decision-making? <i>British Dental Journal</i> 209,181-182.	Review
7.	Chipchase, S.Y., Chapman, H.R., and Bretherton, R. (2017): A study to explore if dentists' anxiety affects their clinical decision-making. <i>British Dental Journal</i> 222,277- 290.	Questionnaire. Self-perceived stress and self-perceived impact in decision making
8.	Johnson, I., Chestnutt, I., and Smith, A. (2010): Dental decisions--an emotional experience? <i>Dental Update</i> 37,700-705.	Opinion Piece.
9.	Mellor, A.C., and Milgrom, P. (1995): Dentists' attitudes toward frustrating patient visits: Relationship to satisfaction and malpractice complaints. <i>Community Dentistry and Oral Epidemiology</i> 23,15-19.	Survey, does not assess stress. Stress is not a variable.
10.	Moore, R., and Brødsgaard, I. (2001): Dentists' perceived stress and its relation to perceptions about anxious patients. <i>Community Dentistry &amp; Oral Epidemiology</i> 29,73- 80.	Not experimental. Not reporting impact of stress on performance.
11.	Ronneberg, A., Strom, K., Skaare, A.B., Willumsen, T., and Espelid, I. (2015): Dentists' self-perceived stress and difficulties when performing restorative treatment in children. <i>European Archives of Paediatric Dentistry: Official Journal of the European Academy of Paediatric Dentistry</i> 16,341-347.	Survey Looking at stressors rather than impact.
<b>Unable to assess</b>		
12.	Caron, A. 2004. Stress factors of dentist (general and specific concepts), Université Paul Sabatier.	Not available online or via ILL Request.

**Appendix 4: Protocol for Systematic Review: Decision Making in Dentistry (PROSPERO: CRD42016047706)**

## Dental decision making

*Anastasios Plessas, Maria Bernardes Delgado, Mona Nasser, Yaniv Hanoch, David Moles*

### Citation

Anastasios Plessas, Maria Bernardes Delgado, Mona Nasser, Yaniv Hanoch, David Moles. Dental decision making. PROSPERO 2016 CRD42016047706 Available from: [http://www.crd.york.ac.uk/PROSPERO/display\\_record.php?ID=CRD42016047706](http://www.crd.york.ac.uk/PROSPERO/display_record.php?ID=CRD42016047706)

### Review question

What decision making models have been described in the dental literature?  
Which of these models have been experimentally tested in a dental setting?  
What are the factors which influence dental decision making?

### Searches

We will search the following electronic bibliographic databases: MEDLINE via Ovid, Embase via Ovid, CINHAL via EBSCO, PsycINFO.

For the grey literature, OpenGrey and EThOS databases will be searched.

No language limits will be set, and the searches will be re-run just before the final analyses and further studies retrieved for inclusion.

The search strategy will include the following key search terms and relevant MeSH/keywords and Boolean operators:

(dentist\* OR SU.EXACT("Dental Surgery") OR SU.EXACT("Dentists") OR SU.EXACT("Dentistry")) AND (SU.EXACT("Clinical Judgment (Not Diagnosis)") OR SU.EXACT("Decision Making") OR ("decision making") OR decision\* OR SU.EXACT("Treatment Planning") OR SU.EXACT("Models") OR SU.EXACT("Clinical Models") OR SU.EXACT("Information Processing Model") OR SU.EXACT("Heuristic Modeling") OR SU.EXACT("Mental Models"))

The above search strategy is intended for PsycINFO. It has been adapted for the other databases.

### Types of study to be included

Prospective experimental studies along with surveys which use a vignette to quantify the dental decisions and the factors that have influenced them.

### Condition or domain being studied

Dentist's decision making.

### Participants/population

Dentists.

### Intervention(s), exposure(s)

The exposure will be scenarios (in the form of vignettes including a description of a clinical case and/or a clinical photograph or radiograph(s)) used to test a decision making model or to quantify the impact of the factors that influence the decision(s) made by the participating dentists.

### Comparator(s)/control

The comparator will be a different decision making model/scenario (for studies with a control group) or no comparator at all (for studies with no control group).

### Context

The studies will include those involving dentists. Any studies involving other health care professionals (e.g. doctors, surgeons, nurses etc.), or dental students and dental hygienists will be excluded. Studies that have not used a clinical scenario/vignette will also be excluded.

### Primary outcome(s)

Impact of any factors that may influence any aspect of the decision making process.

### Secondary outcome(s)

None pre-specified.

### Data extraction (selection and coding)

The reference management software (EndNote X7.4) will be used to manage the records retrieved from the above database searches. Two reviewers (AP and MBD) will independently scan all the titles and abstracts of the retrieved studies. Irrelevant titles will be excluded and full text papers will be obtained where titles are deemed to be relevant or where eligibility is unclear. During the above two stages, any disagreements will be resolved by discussion and with the involvement of a third reviewer (MN) when necessary.

The relevant full text papers will be reviewed by AP and MBD/MN, and any disagreements will be resolved as stated above. A record of reasons for excluding studies will be kept during the review process. The inclusion and exclusion decisions will be reported by completion of a PRISMA flow chart. The study characteristics and outcome data will be extracted in duplicate using a piloted data extraction form (adapted from the Cochrane data collection form for intervention studies). The two main reviewers (AP and MBD) will extract the data and MN will be consulted where there is any disagreement. Data regarding the demographic details of the participants, study types and design details and outcomes reported will be included as items in a reporting of studies table.

### Risk of bias (quality) assessment

As different study types may be included in this review (taking into consideration the diversity of the context), more than one tool may be required to assess risk of bias depending on the type of study involved:

- For RCTs: Cochrane Collaboration's Risk of Bias (RoB) tool will be used.
- For non-randomised studies with a separate a control group, the Effective Practice and Organisation of Care (EPOC) RoB Tool will be applied.

### Strategy for data synthesis

The results of the included studies will be summarised in tables and diagrams and a narrative synthesis of the results will be provided.

If appropriate data are available, a quantitative synthesis will be performed to quantify the impact of the factors that may affect dental decision making.

### Analysis of subgroups or subsets

None planned.

### Contact details for further information

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### Organisational affiliation of the review

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<https://www.plymouth.ac.uk/your-university/about-us/university-structure/faculties/medicine-dentistry>

### Review team members and their organisational affiliations

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## **Appendix 5: Search Strategy for Systematic Mapping Review: Decision Making in Dentistry**

<b>Databases</b>			
<b>CINHAL</b>	1. Dentists 2. dentist 3. (MH "Dentists") 4. dentistry 5. (MH "Dentistry") 6. "dental"	AND	8. decisions 9. decision 10. "decision making" 11. (MH "Decision Making, Clinical") 12. (MH "Decision Making") 13. (MH "Judgment") 14. judgement 15. "treatment planning" 16. "treatment plan" 17. (MH "Diagnostic Reasoning") 18. (MH "Models, Theoretical") 19. (MH "Mental Processes")
<b>Embase (Ovid)</b>	18. dental.mp. 19. dentistry/ 20. dentistry.mp. 21. dentist/ 22. dentist*.mp.	AND	22. decision making/ 23. "decision making".mp. 24. clinical decision making/ 25. decision*.mp 26. judgment mp. 27. treatment planning/ 28. "treatment plan".mp. 29. "treatment planning.mp. 30. theoretical model/ 31. information processing/
<b>Medline (Ovid)</b>	1. Dental Staff/ 2. dental.mp. 3. Dentistry/ 4. dentistry.mp. 5. Dentists/ 6. dentist*.mp.	AND	7. Decision Making/ 8. "decision making".mp. 9. "decision making model".mp. 10. Clinical Decision-Making/ 11. decision*.mp. 12. judgment 13. Judgment/ 14. treatment plan.mp. 15. treatment planning.mp. 16. Models, Theoretical/

## **Appendix 6: Mapping Categories and Citations**

## Mapping Review Appendix

### I) Theoretical Papers

#### A. Reviews

1. Avila, G., Galindo-Moreno, P., Soehren, S., Misch, C. E., Morelli, T. & Wang, H. L. (2009) 'A novel decision-making process for tooth retention or extraction'. *Journal of Periodontology*, 80 (3). pp 476-491 416p.
2. Azouni, K. G. & Tarakji, B. (2014) 'The trimeric model: A new model of periodontal treatment planning'. *Journal of Clinical and Diagnostic Research*, 8 (7). pp 17-20.
3. Bader, H. I. (2002) 'Treatment planning for implants versus root canal therapy: a contemporary dilemma'. *Implant Dentistry*, 11 (3). pp 217-223.
4. Bader, J. D. & Shugars, D. A. (1995) 'Variation in dentists' clinical decisions'. *Journal of Public Health Dentistry*, 55 (3). pp 181-188.
5. Bader, J. D. & Shugars, D. A. (1997) 'What do we know about how dentists make caries-related treatment decisions?'. *Community Dentistry and Oral Epidemiology*, 25 (1). pp 97-103.
6. Bauer, J., Spackman, S., Chiapelli, F. & Prolo, P. (2005) 'Model of evidence-based dental decision making'. *Journal of Evidence-Based Dental Practice*, 5 (4). pp 189-197 189p.
7. Carr, B. T., Dersh, D. A., Harrison, W. R. & Kinsel, R. P. (2001) 'When contemplating treatment involving endosseous implants, what clinical and laboratory factors most significantly affect your choice of an implant system?'. *The International journal of oral & maxillofacial implants*, 16 (1). pp 123-127.
8. Chiappelli, F. & Cajulis, O. S. (2009) 'The logic model for evidence-based clinical decision making in dental practice'. *Journal of Evidence-Based Dental Practice*, 9 (4). pp 206-210 205p.
9. Chuljian, D. T. (1998) 'Insurers and treatment decisions'. *Journal of the American Dental Association (1939)*, 129 (10). pp 1370.
10. Crabb, L., Simpson, R., Hall, D., Beck, J. & Willard, D. (1981) 'Effective decision-making method for dentists: the nominal group technique'. *General Dentistry*, 29 (2). pp 129-132.
11. Douglass, C. W. & McNeil, B. J. (1983) 'Clinical decision analysis methods applied to diagnostic tests in dentistry'. *Journal of Dental Education*, 47 (11). pp 708-714.
12. Garg, A. & Guez, G. (2011) 'Clinical decision making: natural tooth salvage or implant?'. *Dental Implantology Update*, 22 (9). pp 57-60.
13. Gowda, D. & Lamster, I. B. (2011) 'The diagnostic process'. *Dental Clinics of North America*, 55 (1). pp 1-14 14p.
14. Grondahl, H. G. (1979) 'Decision strategies in radiographic caries diagnosis'. *Swedish Dental Journal*, 3 (5). pp 173-180.
15. Heners, M. (2003) 'Regional, generational, educational, personal, and other factors that influence a provider's choice of treatment'. *International Journal of Prosthodontics*, 16 pp 17-18.

16. Hollender, L. (1992) 'Decision making in radiographic imaging'. *Journal of Dental Education*, 56 (12). pp 834-843.
17. Howe, G. L. (1975) 'Decision making in dentistry'. *British Dental Journal*, 138 (3). pp 105-108.
18. Ichikawa, T., Nagao, K. & Goto, T. (2012) 'Alternative decision-making considerations in prosthodontics'. *The International journal of prosthodontics*, 25 (3). pp 260-261.
19. Kay, E. & Nuttall, N. (1995a) 'Clinical decision making--an art or a science? Part I: An introduction'. *British Dental Journal*, 178 (2). pp 76-78.
20. Kay, E. & Nuttall, N. (1995c) 'Clinical decision making--an art or a science? Part III: To treat or not to treat?'. *British Dental Journal*, 178 (4). pp 153-155.
21. Kay, E. & Nuttall, N. (1995d) 'Clinical decision making--an art or a science? Part V: Patient preferences and their influence on decision making'. *British Dental Journal*, 178 (6). pp 229-233.
22. Kehm-Yelton, P. (1989) 'An approach to decision making'. *The Dental Assistant*, 58 (3). pp 6-7.
23. Lindsey Jr, E. M. (1997) 'Treatment decision making'. *Journal of the American Dental Association*, 128 (7). pp 818-820.
24. Messer, H. H. (1999) 'Clinical judgement and decision making in endodontics'. *Australian Endodontic Journal*, 25 (3). pp 124-132.
25. Nuttall, N. & Fyffe, H. (1995) 'Decision processes in the management of dental disease. Part 2: Rationalizing dental treatment decisions in clinical practice'. *Dental Update*, 22 (3). pp 113-116.
26. Rohlin, M. & Mileman, P. A. (2000) 'Decision analysis in dentistry--the last 30 years'. *Journal of Dentistry*, 28 (7). pp 453-468.
27. Verdonschot, E.H., Liem S.L, and Van Palenstein Helderma W.H., Decision making in cariology. *Nederlands Tijdschrift voor Tandheelkunde*, 2003. **110**(12): p. 482-487.
28. White, B. A. & Maupome, G. (2001) 'Clinical decision-making for dental caries management'. *Journal of Dental Education*, 65 (10). pp 1121-1125.
29. Yule, B. F. (1984) 'Need and decision making in dentistry--an economic perspective'. *International Dental Journal*, 34 (3). pp 219-223.

## **B. Models**

1. Bader, J. D. & Shugars, D. A. (1992) 'Understanding dentists' restorative treatment decisions'. *Journal of Public Health Dentistry*, 52 (2). pp 102-110.
2. Bader, J. D. & Shugars, D. A. (1997) 'What do we know about how dentists make caries-related treatment decisions?'. *Community Dentistry and Oral Epidemiology*, 25 (1). pp 97-103.
3. Chipchase, S.Y., Chapman, H.R., and Bretherton, R. (2017): A study to explore if dentists' anxiety affects their clinical decision-making. *British Dental Journal*, **222**,277-290.

4. Ettinger, R. L., Beck, J. D. & Martin, W. E. (1990) 'Clinical decision making in evaluating patients: a process study'. *Special Care in Dentistry*, 10 (3). pp 78-83.
5. Kay, E. & Nuttall, N. (1995) 'Clinical decision making--an art or a science? Part II: Making sense of treatment decisions'. *British Dental Journal*, 178 (3). pp 113-116.
6. Knutsson, K., Brehmer, B., Lysell, L. & Rohlin, M. (1997) 'Mandibular third molars as mediated by three cues. Dentists' treatment decisions on asymptomatic molars compared with molars associated with pathologic conditions'. *Acta Odontologica Scandinavica*, 55 (6). pp 372-377.
7. Knutsson, K., Lysell, L. & Rohlin, M. (2000) 'Dentists' judgment strategies on prophylactic removal of mandibular third molars'. *Journal of Dental Research*, 79 (12). pp 1989-1995.
8. Kvist, T., Heden, G. & Reit, C. (2004) 'Endodontic retreatment strategies used by general dental practitioners'. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics*, 97 (4). pp 502-507.
9. Kvist, T. & Reit, C. (2002) 'The perceived benefit of endodontic retreatment'. *International Endodontic Journal*, 35 (4). pp 359-365.
10. Mileman, P. A. & van der Weele, L. T. (1996) 'The role of caries recognition: treatment decisions from bitewing radiographs'. *Dento Maxillo Facial Radiology*, 25 (5). pp 228-233.
11. Schuman, N. J. & Turner, J. E. (1997) 'Ethical decisions in dental treatment planning using the Ozar model: a descriptive study of fifty-two consecutive patients'. *The Journal of Clinical Pediatric Dentistry*, 21 (3). pp 193-199.

**C. Decision analysis papers and decision trees.** These papers described a decision analysis method (eg. decision tree) which aims to aid the dentist to choose the optimal treatment.

1. Aliev, R.A., Aliyev, B.F., Gardashova, L.A., and Huseynov, O.H. (2012): Selection of an optimal treatment method for acute periodontitis disease. *Journal of Medical Systems* 36,639-646.
2. Anusavice, K.J., (1992) Decision analysis in restorative dentistry. *Journal of Dental Education*,. 56 (12): p. 812-822.
3. Anusavice, K. J. (1994) 'Optimum treatment based on decision tree-analysis, Part 2'. *Dentistry Today*, 13 (4). pp 90-93.
4. Balevi, B. (2008) 'The management of incipient or suspicious occlusal caries: a decision-tree analysis'. *Community Dentistry and Oral Epidemiology*, 36 (5). pp 392-400 399p.
5. Balevi, B. (2010) 'Should warfarin be discontinued before a dental extraction? A decision-tree analysis'. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontology*, 110 (6). pp 691-697 697p.
6. Flemmig, T. F. & Beikler, T. (2009) 'Decision making in implant dentistry: an evidence-based and decision-analysis approach'. *Periodontology 2000*, 50 (1). pp 154-172 119p.
7. Froum, S., Lemler, J., Horowitz, R. & Davidson, B. (2001) 'The use of enamel matrix derivative in the treatment of periodontal osseous defects: a clinical decision tree based

- on biologic principles of regeneration'. *The International Journal of Periodontics and Restorative Dentistry*, 21 (5). pp 437-449.
8. Holtzman, S. & Kornman, K. S. (1992) 'Decision analysis for periodontal therapy'. *Journal of Dental Education*, 56 (12). pp 844-862.
  9. Jia-Hui, F. & Hom-Lay, W. (2011) 'Horizontal Bone Augmentation: The Decision Tree'. *International Journal of Periodontics and Restorative Dentistry*, 31 (4). pp 428-436 429p.
  10. Kay, E. J., Brickley, M. and Knill-Jones, R. (1995) 'Restoration of approximal carious lesions--application of decision analysis'. *Community Dentistry and Oral Epidemiology*, 23 (5). pp 271-275.
  11. Kay, E., V. Tamosiunas, and R. Craven (2013) 'A preliminary study applying decision analysis to the treatment of caries in primary teeth.' *Stomatologija*, 15(3): pp. 84-91.
  12. Lee, J.Y., Sigurdsson A., and Vann Jr W.F., (2001) Management of avulsed permanent incisors: a decision analysis based on changing concepts. *Pediatric Dentistry*, 23(4): p. 357-360.
  13. Ovaydi-Mandel, A., Petrov, S. D. & Drew, H. J. (2013) 'Novel decision tree algorithms for the treatment planning of compromised teeth'. *Quintessence International*, 44 (1). pp 75-84 10p.
  14. Martens, L. C. (2013) 'A decision tree for the management of exposed cervical dentin (ECD) and dentin hypersensitivity (DHS)'. *Clinical Oral Investigations*, 17 pp 77-83.
  15. Martens, L., Surmont P., and D'Hauwers R. (1990), A decision tree for the treatment of caries in posterior teeth. *Quintessence International*, 21 (3): pp. 239-246.
  16. McIntyre, J.D., Lee, J.Y., Trope, M., and Vann Jr, W.F. (2009): Permanent tooth replantation following avulsion: Using a decision tree to achieve the best outcome. *Pediatric Dentistry* 31,137-144.
  17. Mileman, P. A. & Van Den Hout, W. B. (2003) 'Preferences for oral health states: Effect on prescribing periapical radiographs'. *Dentomaxillofacial Radiology*, 32 (6). pp 401-407.
  18. Mileman, P. A., Vissers, T. & Purdell-Lewis, D. J. (1986) 'The application of decision making analysis to the diagnosis of approximal caries'. *Community Dental Health*, 3 (1). pp 65-81.
  19. Mohl, N. D. & Ohrbach, R. (1992) 'Clinical decision making for temporomandibular disorders'. *Journal of Dental Education*, 56 (12). pp 823-833.
  20. Okayasu, K. & Wang, H. L. (2011) 'Decision tree for the management of periimplant diseases'. *Implant Dentistry*, 20 (4). pp 256-261.
  21. Popelut, A., Rousval, B., Fromentin, O., Feghali, M., Mora, F. & Bouchard, P. (2010) 'Tooth extraction decision model in periodontitis patients'. *Clinical Oral Implants Research*, 21 (1). pp 80-89.
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## II) Experimental Studies

### D. Empirical comparative studies with a scenario (vignette/ radiograph/ photographs)

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### **III) Studies on dentists' perceptions and preferences**

- E. **Generic Identification of factors.** Qualitative studies where a specific clinical case (vignette, radiograph or clinical photographs) has not been given to the dentist to assess their decision making.
  1. Alexander, G., Hopcraft, M., Tyas, M. & Wong, R. (2014) 'Dentists' restorative decision-making and implications for an 'amalgamless' profession. Part 2: a qualitative study'. *Australian Dental Journal*, 59 (4). pp 420-431 412p.
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**F. Qualitative studies in which the decision making was prompted by a specific scenario (vignette, radiograph or clinical photographs).**

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**G. Ranking of importance of given factors**

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10. Palotie, U. & Vehkalahti, M. M. (2012) 'Reasons for replacement of restorations: dentists' perceptions'. *Acta Odontologica Scandinavica*, 70 (6). pp 485-490.
11. Pearce, M., Gedling, C., Whittle, G., Robinson, J. & Whitehead, H. (2011) 'Factors that dentists use to decide whether or not to render a patient edentulous. Part 2. An investigation using a postal questionnaire sent to dentists in East Lancashire'. *Primary Dental Care*, 18 (1). pp 19-25 17p.
12. Rushton, V. E., Horner, K. & Worthington, H. V. (1996) 'Factors influencing the frequency of bitewing radiography in general dental practice'. *Community Dentistry and Oral Epidemiology*, 24 (4). pp 272-276.
13. Soderfeldt, B., Palmqvist, S., Eriksson, T., Kronstrom, M. & Carlsson, G. E. (1996) 'A questionnaire instrument to assess clinical decision-making in prosthodontics among general practitioners'. *Acta Odontologica Scandinavica*, 54 (5). pp 314-319.
14. Verdonschot, E.H., Plasschaert, A.J., and De Vries Robbe, P.F. (1998): Re-restoration decisions. *Nederlands Tijdschrift Voor Tandheelkund*, 105,84-86.

**H. Surveys.** Survey studies which investigate the dentists' practices, preference of diagnostic methods, treatment modalities and materials etc. These studies have not used a clinical case, scenario or vignette.

1. Ahmed, S.N., Donovan, T.E., and Ghuman, T. (2017): Survey of dentists to determine contemporary use of endodontic posts. *Journal of Prosthetic Dentistry*, 117,642-645.

2. Bibona, K., Shroff, B., Best, A. M. & Lindauer, S. J. (2014) 'Factors affecting orthodontists' management of the retention phase'. *The Angle orthodontist*, 84 (2). pp 225-230.
3. Bindal, P., Lin, C. W., Bindal, U., Safi, S. Z., Zainuddin, Z. & Lionel, A. (2015) 'Dental Treatment and Special Needs Patients (SNPs): Dentist's Point of View in Selected Cities of Malaysia'. *Biomedical Research*, 26 (1). pp 152-156.
4. Cardoso, R. C., Gerngross, P. J., Dominici, J. T. & Kiat-amnuay, S. (2013) 'Survey of currently selected dental implants and restorations by prosthodontists'. *The International Journal of Oral and Maxillofacial Implants*, 28 (4). pp 1017-1025.
5. Domejean-Orliaguet, S., Tubert-Jeannin, S., Riordan, P. J., Espelid, I. & Tveit, A. B. (2004) 'French dentists' restorative treatment decisions'. *Oral Health and Preventive Dentistry*, 2 (2). pp 125-131.
6. Gnich, W., Bonetti, D., Sherriff, A., Sharma, S., Conway, D. I. & Macpherson, L. M. D. (2015) 'Use of the theoretical domains framework to further understanding of what influences application of fluoride varnish to children's teeth: a national survey of general dental practitioners in Scotland'. *Community Dentistry and Oral Epidemiology*, 43 (3). pp 272-281.
7. Grembowski, D., Milgrom, P. & Fiset, L. (1991) 'Dental decisionmaking and variation in dentist service rates'. *Social Science and Medicine*, 32 (3). pp 287-294.
8. Haj-Ali, R., Walker, M. P. & Williams, K. (2005) 'Survey of general dentists regarding posterior restorations, selection criteria, and associated clinical problems'. *General Dentistry*, 53 (5). pp 369-376.
9. Kanzow, P., Hoffmann, R., Tschammler, C., Kruppa, J., Rodig, T., and Wiegand, A. (2017): Attitudes, practice, and experience of german dentists regarding repair restorations. *Clinical Oral Investigations*, 21,1087-1093.
10. Koka, S., Eckert, S. E., Choi, Y. G. & Montori, V. M. (2007) 'Clinical decision-making practices among a subset of North American prosthodontists'. *International Journal of Prosthodontics*, 20 (6). pp 606-608 603p.
11. Kon, M., Zitzmann, N. U., Weiger, R. & Krastl, G. (2013) 'Postendodontic restoration: a survey among dentists in Switzerland'. *Rivista Mensile Svizzera Di Odontologia E Stomatologia*, 123 (12). pp 1076-1088.
12. Korduner, E.K., Soderfeldt, B., Kronstrom, M., and Nilner, K. (2006): Attitudes toward the shortened dental arch concept among swedish general dental practitioners. *Int J Prosthodont* 19,171-176. Kronström, M., Palmqvist, S., Söderfeldt, B. & Carlsson, G. E. (2000) 'Dentist-related factors influencing the amount of prosthodontic treatment provided'. *Community Dentistry and Oral Epidemiology*, 28 (3). pp 185-194 110p.
13. Mileman, P., van der Weele, L., van de Poel, F. & Purdell-Lewis, D. (1988) 'Dutch dentists' decisions to take bitewing radiographs'. *Community Dentistry and Oral Epidemiology*, 16 (6). pp 368-373.

14. Mileman, P. A. & Espelid, I. (1988) 'Decisions on restorative treatment and recall intervals based on bitewing radiographs. A comparison between national surveys of Dutch and Norwegian practitioners'. *Community Dental Health*, 5 (3). pp 273-284.
15. Nascimento, G. G., Correa, M. B., Opdam, N. & Demarco, F. F. (2013) 'Do clinical experience time and postgraduate training influence the choice of materials for posterior restorations? Results of a survey with Brazilian general dentists'. *Brazilian Dental Journal*, 24 (6). pp 642-646.
16. Pair, R. L., Udin, R. D. & Tanbonliong, T. (2004) 'Materials used to restore class II lesions in primary molars: a survey of California pediatric dentists'. *Pediatric Dentistry*, 26 (6). pp 501-507.
17. Patel, P. M., Lynch, C. D., Sloan, A. J. & Gilmour, A. S. M. (2010) 'Treatment planning for replacing missing teeth in UK general dental practice: current trends'. *Journal of Oral Rehabilitation*, 37 (7). pp 509-517 509p.
18. Riley, I. J. L., Gordan, V. V., Rindal, D. B., Fellows, J. L., Ajmo, C. T., Amundson, C., Anderson, G. A. & Gilbert, G. H. (2010a) 'Preferences for caries prevention agents in adult patients: Findings from the dental practice-based research network'. *Community Dentistry and Oral Epidemiology*, 38 (4). pp 360-370.
19. Riley, J. L., III, Qvist, V., Fellows, J. L., Rindal, D. B., Richman, J. S., Gilbert, G. H. & Gordan, V. V. (2010b) 'Dentists' use of caries risk assessment in children: findings from the Dental Practice-Based Research Network'. *General Dentistry*, 58 (3). pp 230-234 235p.
20. Romberg, E., Cohen, L. A. & LaBelle, A. D. (1988) 'A national survey of sealant use by pediatric dentists'. *ASDC Journal of Dentistry for Children*, 55 (4). pp 257-264.
21. Sarkis-Onofre, R., Pereira-Cenci, T., Opdam, N. J. & Demarco, F. F. (2015) 'Preference for using posts to restore endodontically treated teeth: findings from a survey with dentists'. *Brazilian Oral Research*, 29 pp 1-6.
22. Schwendicke, F., Stangvaltaite, L., Holmgren, C., Maltz, M., Finet, M., Elhennawy, K., Eriksen, I., Kuzmiszyn, T.C., Kerosuo, E., and Domejean, S. (2017): Dentists' attitudes and behaviour regarding deep carious lesion management: A multi-national survey. *Clinical Oral Investigations*, 21,191-198.
23. Shelley, A. M., Wardle, L., Goodwin, M., Brunton, P. & Horner, K. (2013) 'A questionnaire study to investigate custom and practice of imaging methods for the anterior region of the mandible prior to dental implant placement'. *Dento Maxillo Facial Radiology*, 42 (3). pp 20120179-20120111.
24. Shepherd, A. R. & Hill, F. J. (2000) 'An investigation of patient management methods used for orthodontic extractions by general dental practitioners in north west England'. *British Dental Journal*, 188 (11). pp 614-616.

25. Sundberg, H., Mejare, I., Espelid, I. & Tveit, A. B. (2000) 'Swedish dentists' decisions on preparation techniques and restorative materials'. *Acta Odontologica Scandinavica*, 58 (3). pp 135-141.
26. Swan, E. S. & Lewis, D. W. (1993) 'Ontario dentists: 2. Bitewing utilization and restorative treatment decisions'. *Journal of the Canadian Dental Association*, 59 (1). pp 68-75.
27. Zimmerman, J. A., Feigal, R. J., Till, M. J. & Hodges, J. S. (2009) 'Parental attitudes on restorative materials as factors influencing current use in pediatric dentistry'. *Pediatric Dentistry*, 31 (1). pp 63-70.

#### IV) Observational studies

- I. **Prospective studies.** These studies were observational studies in a practice or hospital setting where the decisions made were recorded prospectively. The studies looked at the chief reason why the treatment was provided or recommended.
  1. Agerholm, D. M. & Sidi, A. D. (1988) 'Reasons given for extraction of permanent teeth by general dental practitioners in England and Wales'. *British Dental Journal*, 164 (11). pp 345-348.
  2. Al-Shammari, K. F., Al-Ansari, J. M., Al-Khabbaz, A. K., Nociti Jr, F. H. & Wang, H. L. (2005) 'Factors associated with implant recommendation for single-tooth replacement'. *Implant Dentistry*, 14 (2). pp 201-208.
  3. Al-Shammari, K. F., Al-Khabbaz, A. K., Akar, M. H., Al-Ansari, J. M. & Wang, H. L. (2006) 'Implant recommendation as a replacement option after tooth loss for periodontal reasons'. *Implant Dentistry*, 15 (1). pp 104-110.
  4. Al Negrish, A. R. (2001) 'Reasons for placement and replacement of amalgam restorations in Jordan'. *International Dental Journal*, 51 (2). pp 109-115.
  5. Allen, R. T., Witherow, H., Collyer, J., Roper-Hall, R., Nazir, M. A. & Mathew, G. (2009) 'The mesioangular third molar - To extract or not to extract? Analysis of 776 consecutive third molars'. *British Dental Journal*, 206 (11). pp E23.
  6. Bader, J. D. & Shugars, D. A. (1993) 'Agreement among dentists' recommendations for restorative treatment'. *Journal of Dental Research*, 72 (5). pp 891-896.
  7. Bader, J. D., Shugars, D. A. & Rozier, R. G. (1993) 'Relationship between epidemiologic coronal caries assessments and practitioners' treatment recommendations in adults'. *Community Dentistry and Oral Epidemiology*, 21 (2). pp 96-101.

8. Bader, J. D. & Shugars, D. A. (1998) 'Descriptive models of restorative treatment decisions'. *Journal of Public Health Dentistry*, 58 (3). pp 210-219.
9. Brennan, D. S. & Spencer, J. (2002) 'Factors influencing choice of dental treatment by private general practitioners'. *International Journal of Behavioral Medicine*, 9 (2). pp 94-110 117p.
10. Carson, P. & Freeman, R. (2001) 'Dental caries, age and anxiety: factors influencing sedation choice for children attending for emergency dental care'. *Community Dentistry and Oral Epidemiology*, 29 (1). pp 30-36 37p.
11. Correa, M. B., Peres, M. A., Peres, K. G., Horta, B. L., Barros, A. D. & Demarco, F. F. (2012) 'Amalgam or composite resin? Factors influencing the choice of restorative material'. *Journal of Dentistry*, 40 (9). pp 703-710.
12. Cosyn, J., Raes, S., Meyer, S., Raes, F., Buyl, R., Coomans, D. & Bruyn, H. (2012) 'An analysis of the decision-making process for single implant treatment in general practice'. *Journal of Clinical Periodontology*, 39 (2). pp 166-172 167p.
13. Domejean-Orliaguet, S., Leger, S., Auclair, C., Gerbaud, L. & Tubert-Jeannin, S. (2009) 'Caries management decision: Influence of dentist and patient factors in the provision of dental services'. *Journal of Dentistry*, 37 (11). pp 827-834.
14. Gordan, V. V., Riley Iii, J. L., Geraldeli, S., Rindal, B., Qvist, V., Fellows, J. L., Kellum, P. & Gilbert, G. H. (2012a) 'Repair or replacement of defective restorations by dentists in The Dental Practice-Based Research Network'. *Journal of the American Dental Association (JADA)*, 143 (6). pp 593-601 599p.
15. Gordan, V. V., Riley, J., Geraldeli, S., Williams, O. D., Spoto, J. C. & Gilbert, G. H. (2015) 'The Decision to Repair or Replace a Defective Restoration is Affected by Who Placed the Original Restoration: Findings from the National Dental PBRN'. *Texas Dental Journal*, 132 (7). pp 448-458.
16. Gordan, V. V., Riley, J. L., 3rd, Worley, D. C., Gilbert, G. H. & Group, D. C. (2012b) 'Restorative material and other tooth-specific variables associated with the decision to repair or replace defective restorations: findings from The Dental PBRN'. *Journal of Dentistry*, 40 (5). pp 397-405.
17. Konstantonis, D., Anthopoulou, C. & Makou, M. (2013) 'Extraction decision and identification of treatment predictors in Class I malocclusions'. *Progress in Orthodontics*, 14 pp 47.
18. Loesche, W. J., Taylor, G., Giordano, J., Hutchinson, R., Rau, C. F., Chen, Y. M. & Schork, M. A. (1997) 'A logistic regression model for the decision to perform access surgery'. *Journal of Clinical Periodontology*, 24 (3). pp 171-179.

19. Makhija, S. K., Gordan, V. V., Gilbert, G. H., Litaker, M. S., Rindal, D. B., Pihlstrom, D. J. & Qvist, V. (2011) 'Practitioner, patient and carious lesion characteristics associated with type of restorative material: Findings from The Dental Practice-Based Research Network'. *Journal of the American Dental Association*, 142 (6). pp 622-632 611p.
20. Nascimento, M. M., Gordan, V. V., Qvist, V., Litaker, M. S., Rindal, D. B., Williams, O. D., Fellows, J. L., Ritchie, L. K., Jr., Mjör, I. A., McClelland, J. & Gilbert, G. H. (2010) 'Reasons for placement of restorations on previously unrestored tooth surfaces by dentists in The Dental Practice-Based Research Network'. *Journal of the American Dental Association*, 141 (4). pp 441-448 448p.
21. Pink, F. E., Minden, N. J. & Simmonds, S. (1994) 'Decisions of practitioners regarding placement of amalgam and composite restorations in general practice settings'. *Operative Dentistry*, 19 (4). pp 127-132.
22. Svardstrom, G. & Wennstrom, J. L. (2000) 'Periodontal treatment decisions for molars: an analysis of influencing factors and long-term outcome'. *Journal of Periodontology*, 71 (4). pp 579-585.
23. Trovik, T. A., Klock, K. S. & Haugejorden, O. (2002) 'Predictors of Norwegian dentists' decisions to recommend replacement of teeth at the time of extraction'. *Community Dental Health*, 19 (1). pp 18-23 16p.
24. Vidnes-Kopperud, S., Tveit, A. B., Gaarden, T., Sandvik, L. & Espelid, I. (2009) 'Factors influencing dentists' choice of amalgam and tooth-colored restorative materials for Class II preparations in younger patients'. *Acta Odontologica Scandinavica*, 67 (2). pp 74-79 76p.
25. Warren, J. J., Hand, J. S., Levy, S. M. & Kirchner, H. L. (2000) 'Factors related to decisions to extract or retain at-risk teeth'. *Journal of Public Health Dentistry*, 60 (1). pp 39-42.

**J. Retrospective studies.** The dental clinical decisions and the influencing factors were identified using a retrospective analysis of clinical cases.

1. Abouqal, R., et al., Deciding factors in the treatment of Class II division 1 cases with and without single-jaw extractions (2014). *International Orthodontics*, 12 (2): pp. 239-248.
2. Abramovitz, I., Better, H., Shacham, A., Shlomi, B. & Metzger, Z. (2002) 'Case selection for apical surgery: a retrospective evaluation of associated factors and rational'. *Journal of Endodontics*, 28 (7). pp 527-530.
3. Bataineh, A. B., Albashaireh, Z. S. & Hazza'a, A. M. (2002) 'The surgical removal of mandibular third molars: a study in decision making'. *Quintessence International*, 33 (8). pp 613-617 615p.
4. Becker, W., Becker, B. E. & Hujoel, P. (2000) 'Retrospective case series analysis of the factors determining immediate implant placement'. *Compendium Of Continuing Education In Dentistry*, 21 (10). pp 805-820.

5. Guo, Y., Han, X., Xu, H., Ai, D., Zeng, H. & Bai, D. (2014) 'Morphological characteristics influencing the orthodontic extraction strategies for Angle's class II division 1 malocclusions'. *Progress in Orthodontics*, 15 (1). pp 44.
6. Helminen, S. E., Vehkalahti, M., Lammi, R., Ketomaki, T. M. & Murtomaa, H. (1999) 'Dentists' decisions as to mode of preventive treatment in adolescents and young adults in Finland'. *Community Dental Health*, 16 (4). pp 250-255.
7. Johnson, T. E. (1993) 'Factors contributing to dentists' extraction decisions in older adults'. *Special Care in Dentistry*, 13 (5). pp 195-199.
8. Mardinger, O., Oubaid, S., Manor, Y., Nissan, J. & Chaushu, G. (2008) 'Factors affecting the decision to replace failed implants: a retrospective study'. *Journal of Periodontology*, 79 (12). pp 2262-2266 2265p.
9. Sarmadi, R., Gahnberg, L. & Gabre, P. (2011) 'Clinicians' preventive strategies for children and adolescents identified as at high risk of developing caries'. *International Journal of Paediatric Dentistry*, 21 (3). pp 167-174.
10. Wang, S., Chalkley, M. & Tilley, C. (2012) 'Comparing the treatment provided by UK and non-UK trained health professionals: dentists in Scotland.'. *Journal of Health Services Research and Policy*, 17 (4). pp 227-232 226p.

## **Appendix 7: Mapping Categorisation Tables and Citations**

**GROUP A: Theoretical Papers (a.Reviews (Rev), b.Models (Mod), c.Decision Analysis (DA))**

**GROUP B: Experimental Studies**

**Group C: Studies on dentists' perceptions and preferences (a. Qualitative (unprompted) (Qu), b. Qualitative prompted by a scenario (Qp), c. Ranking factors and their importance (Rnk), d. Surveys(S))**

**GROUP D: Observational Studies (Observational) (a.Prospective (Pros), b.Restrospective(Retro))**

**GROUP A: Theoretical Papers (a.Reviews (Rev), b.Models (Mod), c.Decision Analysis (DA))**

**GROUP B: Experimental Studies**

**Group C: Studies on dentists' perceptions and preferences (a. Qualitative (unprompted) (Qu), b. Qualitative prompted by a scenario (Qp), c. Ranking factors and their importance (Rnk), d. Surveys(S))**

**GROUP D: Observational Studies (observational) (a.Prospective (Pros), b.Restrospective(Retro))**

**Summary per year of publication**

Year	Theoretical			Experimental	Perception				Observational	
	Rev	Mod	DA		Qu	Qp	Rnk	S	Pros	Retro
1971										
1972										
1973										
1974										
1975	(1)									
1976										
1977										
1978										
1979	(2)			(3)						
1980										
1981	(4)									
1982										

<b>1983</b>	(5)									
<b>1984</b>	(6)			(7)						
<b>1985</b>				(8)						
<b>1986</b>			(9)							
<b>1987</b>			(10)	(11)						
<b>1988</b>			(12)	(13)			(14)	(15-17)	(18)	
<b>1989</b>	(19)						(20)			
<b>1990</b>		(21)	(22)	(23, 24)		(25)				
<b>1991</b>				(26)				(27)		
<b>1992</b>	(28)	(29)	(30-33)	(34, 35) (36-38)						
<b>1993</b>				(39)				(40)	(41, 42)	(43)
<b>1994</b>			(44)	(45, 46) (47, 48)					(49)	
<b>1995</b>	(50-54)	(55)	(56)	(57)						
<b>1996</b>		(58)		(59, 60) (61-65)	(66)	(67)	(68, 69)			
<b>1997</b>	(70, 71)	(70, 72, 73)		(72)	(74)				(75)	
<b>1998</b>	(76)			(77)			(78)		(79)	
<b>1999</b>	(80)			(81-84) (85)			(86-88)			(89)
<b>2000</b>	(90)	(91)		(92) (91, 93)			(94)	(95, 96)	(97, 98)	(99)
<b>2001</b>	(100, 101)		(102, 103)	(104-107) (108)					(109, 110)	
<b>2002</b>	(111)	(112)		(112-117) (118)					(119, 120)	(121, 122)
<b>2003</b>	(123, 124)		(125)			(126)				
<b>2004</b>		(127)		(127, 128)				(129, 130)		
<b>2005</b>	(131)			(132) (133)				(134)	(135)	
<b>2006</b>				(136)				(137)	(138)	

<b>2007</b>				(139, 140)				(141)		
<b>2008</b>			(142)	(143, 144)						(145)
<b>2009</b>	(146, 147)		(148, 149)			(150)		(151)	(152-154)	
<b>2010</b>			(155, 156)	(157-159)		(160, 161)		(162-164)	(165)	
<b>2011</b>	(166, 167)		(168, 169)	(170-173)		(174)	(175)		(176)	(177)
<b>2012</b>	(178)		(179)	(180-184) (185)			(186)		(187-190)	(191)
<b>2013</b>			(192-194)	(195) (196)		(197)		(198-201)	(202)	
<b>2014</b>	(203)			(204-210)	(211)		(212)	(213)		(214, 215)
<b>2015</b>				(216, 217)	(218) (219)		(220)	(221-223)	(224)	
<b>2016</b>				(225-227) (228)	(229)	(230)	(231)			
<b>2017</b>		(232)		(233)	(232, 234)			(235-237)		

### Summary per domain

Domain	Theoretical			Experimental	Perceptions				Observational	
	Rev	Mod	DA		Qu	Qp	Rnk	S	Pros	Retro
<b>Caries Diagnosis, prevention and management</b>	(2, 70, 101, 124)	(29, 58, 70)	(9, 12, 22, 56, 142, 194)	(8, 26, 34, 46, 59, 105, 114, 128, 132, 159, 171, 173, 183, 204, 210, 233)  (3, 23, 24, 36, 37, 47, 48, 63, 64, 85, 133, 210)		(197)	(220)	(163, 164, 237)	(42, 153, 176)	(89)
<b>Endodontics</b>	(80)	(112, 127)		(7, 11, 13, 45, 81, 92, 104, 107, 112, 113, 127, 128, 143, 157, 195, 225)  (93, 216)		(126, 150)				(121)

<b>Orthodontics</b>				(60, 83, 184) (62, 136, 185, 196, 229)		(67)		(95, 213)	(202)	(214, 215)
<b>Paediatrics</b>			(103, 149)	(139, 180-182, 226) (217)				(17, 151, 222)	(110)	(177)
<b>Third Molar Surgery, Exodontia &amp; Oral Surgery</b>		(72, 91)	(10, 155)	(35, 82) (39, 57, 61, 65, 72, 77, 91, 106, 108, 118)			(174)		(18, 98, 152)	(43, 122)
<b>Restorative (choice of type of restoration)/ Periodontics/ Prosthodontics/ Implantology)</b>	(100, 111, 146, 166, 178, 203)		(30, 31, 33, 102, 148, 156, 168, 169, 179, 192)	(84, 115-117, 140, 144, 170, 172, 205-209, 227) (38, 228)	(66, 211, 219)	(161, 174, 230)	(69, 86-88, 94, 186, 212, 231)	(78, 96, 129, 130, 134, 137, 141, 162, 198-200, 223, 235, 236)	(41, 49, 75, 79, 97, 109, 120, 135, 138, 154, 165, 187-190, 224)	(99, 145)
<b>General Dentistry</b>	(1, 4-6, 19, 28, 50-54, 71, 76, 90, 123, 131, 167)	(55, 73, 232)	(32, 44, 125, 193)		( <u>74</u> , <u>232</u> , <u>234</u> , <u>238</u> )	( <u>21</u> , <u>160</u> )	( <u>14</u> , <u>20</u> , <u>68</u> )	( <u>15</u> , <u>16</u> , <u>27</u> , <u>40</u> , <u>201</u> , <u>221</u> )	(119)	(191)

FACTORS	Experimental			Qualitative		Prospective Observational	
	In scenario	Reported in results		In scenario	Reported as influential	Reported as	
		Significant	Non-significant			Significant	Non-significant
<b>DENTIST FACTORS</b>							
<b>Dentist's Characteristics</b>							
Age		(105, 117, 170)	(35, 36, 92, 106, 108, 112, 113, 116, 139, 172)				(120, 188)
Gender		(117, 139, 172, 183, 204)	(35, 84, 92, 106, 108, 112-116, 173, 185, 195, 206, 210, 227)			(176)	(120, 188)
Years of Experience/ Years since graduation		(46, 81, 92, 104, 132, 157, 170, 173, 185, 204, 217)	(35, 36, 57, 106, 108, 112, 114, 128, 132, 171, 195, 208, 210)			(176)	
Type of practice (Private or state funded)		(105, 115, 117, 128, 159, 171, 227)	(8, 112, 116, 139, 185, 195, 216)			(120, 176, 187)	
Location or country of practice		(48, 172)	(106, 139, 181, 183, 227)				

<b>Dentist's educational background</b>							
University or Country of graduation		(92) (105, 139, 144, 182)	(59, 112, 173, 185, 204)				
Specialty training or generalist		(81, 93, 104, 106, 128, 143, 157, 170, 172, 180, 195, 209, 225, 233)	(11, 39, 61, 108, 139, 208)				
Engagement with CPD activities		(115-117, 132, 181, 204)	(113)		(211)		
<b>Biases (perceptions and experience)</b>							
Diagnostic ability / accuracy		(36, 239)	(57) (59, 217)				
Attached importance to false negative or positive decisions		(239)					
Risk perception for future pathology		(8) (39, 72, 77)					
Confidence about presence of pathology		(8, 13, 24, 47, 64, 132, 239)					
Treatment Threshold			(37, 59, 63)				
Previous experience with condition or treatment		(139)			(21, 174, 197, 211, 218, 230)	(188)	

Belief in superiority or benefit of treatment			(112) (180)		(126, 150, 174, 211)	(98)	
Uncertainty/ difficulty to make a decision		(92)			(232)		
<b>PATIENT FACTORS</b>							
<b>Patient's Characteristics</b>							
Age	(35, 38, 39, 46, 65, 72, 77, 83, 91, 106, 117, 118, 140, 208, 233)	(35, 38, 46, 106, 117, 140, 208, 228)	(207)	(174)	(67, 174, 230)	(97, 110, 120, 135, 138, 153, 154, 176)	(98, 188)
Gender	(39, 140)		(140)			(138, 176)	(98, 120, 135, 153, 154, 187, 188)
Race	(133)	(133)				(176)	(187)
Socioeconomic status and education level	(84, 209)	(84)			(161, 219)		(120, 187, 188)
<b>Patient's values and wishes</b>							
Patient's wishes, expectations and demands	(158)			(161, 230)	(66, 218, 230, 234) (126, 150, 161, 174, 232)	(79)	

Symptoms (pain)	(39, 45, 81, 92, 113, 116, 128, 143, 144, 180, 182, 207, 209, 225, 233)	(207, 209, 225)		(174, 230)	(161)	(79)	
Aesthetic demands	(60, 117)		(117)		(161, 174, 211)	(79)	
Dental anxiety or fear	(60)			(230)	(232)	(110)	
Confidence and self-esteem	(60)				(74)		
Risk perception	(84)	(84)					
Level of comprehension of dental treatment	(84)	(84)			(74)		
Patient's motivation and attitude to oral health and treatment	(60)	(216)			(74, 161, 174, 211, 219, 230)	(120)	
Patient's compliance/ Regularity of attendance					(74, 211)	(79, 120, 135, 138, 153, 176, 188)	
<b>Patient's health (general, mouth and tooth level)</b>							
General health (diseases and medication)	(82, 116, 117, 208)	(38)	(117)	(174, 197, 230)	(21, 211, 232)	(98, 135, 138)	(188)
Smoking	(117, 140)	(117, 216)	(140)	(197, 230)	(161)		(135, 138, 188)

Caries Risk /experience (Fluoride, diet, , dental history)	(117, 128, 144, 159, 183, 210)	(117, 159, 171, 183, 210)		(197) (230)	(174) (211)	(98, 110, 154, 187)	
Oral hygiene (habits and plaque control)	(116, 117, 140, 210, 233)	(117, 140, 216)		(197, 230)	(161)	(98, 110, 138, 153)	(154, 188)
Periodontal health (BOP, pocket depths, furcation involvement and bone levels)	(81, 82, 116, 117, 140, 170, 172, 208, 228)	(82, 117, 140)		(174, 230)	(161, 174)	(97)	
Occlusion	(60, 83, 184)	(60, 83, 184)		(230)	(21, 67, 161)	(97, 202)	
Position of tooth/teeth (upper vs lower)	(82, 195)		(38, 82)		(174)	(97, 188, 190)	(135)
Type of tooth (anterior/posterior, single or multi-rooted)	(140)	(140)				(120, 138, 154, 176, 187, 188)	(135)
Lesion size	(8, 59, 92, 104, 105, 112, 114, 132, 204, 239) (7, 24, 37, 46-48, 63, 64, 115, 128, 158, 171, 183, 207, 217, 233)	(7, 207)			(126, 211)	(98, 176, 190)	
Degree of impaction and angular position of tooth	(35, 39, 65, 72, 77, 91, 106, 108, 118)						

Mobility of the tooth/teeth	(11, 81, 172)			(174)	(161)	(97, 98)	
Pulp state	(82, 170, 172, 182, 208, 233)	(82, 208)			(21, 161, 211)		
Periapical radiolucency/pathology	(11, 45, 92, 104, 112, 113, 128, 143, 144, 195, 208, 225)	(128, 208, 225)		(126)			
Quality of root filling	(7, 45, 81, 92, 104, 112, 113, 128, 143, 157, 195, 208)	(112)	(7)	(126)	(126)		
Age of root filling	(45, 81, 93)	(93)			(126)		
Presence of post	(7, 92, 104, 112, 113, 144, 157, 208)	(112, 208)	(7)				
Presence of Perforation, broken file or silver point	(45, 92, 104, 128, 157)						
Root characteristics morphology/length	(11, 208)	(208)					
Condition of restoration (polished surface)		(85)					
<b>ENVIRONMENTAL FACTORS</b>							

Reimbursement/ Insurance coverage	(216)		(216)		(197, 230, 232)	(153, 176)	
Cost of treatment	(216)		(38, 216)		(66, 126, 150, 161, 174, 211, 219, 230, 232)	(98)	
Technical complexity of treatment		(11)			(66, 126, 161, 174, 211, 218, 232)		
Time required for treatment					(66, 161, 211)		
Timing (out of hours)	(181)	(181)					
Number of visits							
Type of diagnostic tools available		(3, 185, 196, 229)	(136)				
Medicolegal issues and Defensive practice					(174, 218, 232, 234)		
Guidelines and evidence base		(118)			(197, 211, 230, 232, 234)		
Peer practice and influence					(234)		
Emotions (stress, anxiety, fear, anger)					(218, 232)		
Ethical practice					(66, 211)		
Trusting relationships with the patient					(66, 218, 232)		

Time pressure					(218, 232)		
Dentist patient communication					(218, 232)		

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## **Appendix 8: Ethics Approval and Amendments**

17<sup>th</sup> March 2017

**CONFIDENTIAL**

Anastasios Plessas

Flat 5

22 Constantine Street

Plymouth

PL4 8AF

Dear Anastasios,

**Application for Approval by Faculty Research Ethics Committee**

**Reference Number:** 16/17-704

**Application Title:** Role of time pressure on dentist's diagnostic decision making.

I am pleased to inform you that the Committee has granted approval to you to conduct this research.

Please note that this approval is for three years, after which you will be required to seek extension of existing approval.

Please note that should any MAJOR changes to your research design occur which effect the ethics of procedures involved you must inform the Committee. Please contact Sarah Jones (email [sarah.c.jones@plymouth.ac.uk](mailto:sarah.c.jones@plymouth.ac.uk)).

Yours sincerely

**Judy Edworthy PhD FAcSS**

**Professor of Applied Psychology**

Chair, Faculty Psychology Ethics Committee &

Acting Chair, Research Ethics Committee –

Faculty of Health & Human Sciences and

Peninsula Schools of Medicine & Dentistry

## MINOR AMENDMENT TO RESEARCH STUDY

Date 22<sup>nd</sup> of June 2017

Reference Number: 16/17-704

Application Title: Role of time pressure on dentist's diagnostic decision making

Dear Professor Edworthy,

Following the pilot and comments we received from the pilot participants we decided to replace the STAI questionnaire in our experiment with a VAS 100mm analogue scale. The questions in the STAI questionnaire were judged as inappropriate for the task by the participants.

We are interested in the state anxiety that the experimental condition (time pressure) may elicit. A VAS scale will be given to the participants in the end of the task for the test and control experimental condition.

How anxious did you feel during this task? If 0 is not anxious at all and 100 extremely anxious ?

not at all anxious extremely anxious

0 10 20 30 40 50 60 70 80 90 100

Click to write  
Choice 1

It has been shown that the scores in the STAI- State Anxiety questionnaire highly correlate to the VAS- anxiety scale scores. (Abend *et al.*, 2014; Facco *et al.*, 2013; McCormack *et al.*, 1988)

I attach the participant information sheet altered to accommodate this change for your approval. The changes are highlighted in red.

Yours Sincerely

*Anastasios*

**Anastasios Plessas** DipDS (Ath), Msc (Dent Sci) (Gla), DipPCD RCSI, MFGDP (UK), FHEA  
NIHR Academic Clinical Fellow in General Dental Practice

27<sup>th</sup> June 2017

**CONFIDENTIAL**

Anastasios Plessas

Flat 5

22 Constantine Street

Plymouth

PL4 8AF

Dear Anastasios,

***Amendment to Approved Application***

***Amendment Reference Number:* 16/17-789**

***Original application Reference Number:* 16/17-704**

***Application Title:* Role of time pressure on dentist's diagnostic decision making.**

I am pleased to inform you that the Committee has granted approval to you for your amendment to the application approved on 17<sup>th</sup> March 2017.

Please note that this approval is for three years, after which you will be required to seek extension of existing approval.

Please note that should any MAJOR changes to your research design occur which effect the ethics of procedures involved you must inform the Committee. Please contact Sarah Jones ([hhsethics@plymouth.ac.uk](mailto:hhsethics@plymouth.ac.uk)).

Yours sincerely,

**Professor Paul H Artes, PhD MCOptom**

Professor of Eye and Vision Sciences

Co-Chair, Research Ethics Committee -

Faculty of Health & Human Sciences and

Peninsula Schools of Medicine & Dentistry

Date 22<sup>nd</sup> of September 2017

Reference Number: 16/17-704

Dear Professor Artes,

**Re: Minor amendment to research study titled: “Role of time pressure on dentist’s diagnostic decision making” (16/17-704).**

I am writing to kindly request two minor amendments to my research study.

The above study has commenced. Within the past two months the recruitment has been rather slow and static. We are aiming to recruit 40 dentists but so far we have recruited only four participants. Invitation e-mails have been sent to clinical supervisors of Peninsula Dental School (PDS) and dentists in the Southwest via the PDS and BDA secretaries. Although I have received e-mails from potential participants who would be happy to participate in the study, they would only do so if I could visit their practices.

As a result of the above, I would like to request the two following minor amendments for my research study.

- A) **Method of recruitment.** We believe that sending leaflets to local practices in Devon and Cornwall will increase the chances of successful recruitment.
- B) **Location of study.** As I explained above, dentists find it easier, if I travel to their premises. Therefore, we would like to offer the additional option to the participants to undertake the study in their practice. As each participant act as their own control, the environment for the two experimental conditions (time pressure and no time pressure) will be the same. The visits will be undertaken with due regard to the University’s lone working safety policy.

We believe that the above changes will increase the success of the recruitment and the power for our study.

Please also find attached the amended participant information sheet (changes highlighted in yellow)

Yours sincerely

*Anastasios*

**Anastasios Plessas** DipDS (Ath), Msc (Dent Sci) (Gla), DipPCD RCSI, MFGDP (UK), FHEA  
NIHR Academic Clinical Fellow in General Dental Practice

29<sup>th</sup> September 2017

**CONFIDENTIAL**

Anastasios Plessas

Flat 5

22 Constantine Street

Plymouth

PL4 8AF

Dear Anastasios,

***Amendment to Approved Application***

***Amendment Reference Number:* 16/17-824**

***Previous Amendment Reference Number:* 16/17-789**

***Original application Reference Number:* 16/17-704**

***Application Title:* Role of time pressure on dentist's diagnostic decision making.**

I am pleased to inform you that the Committee has granted approval to you for your amendment to the application approved on 17<sup>th</sup> March 2017.

Please note that should any MAJOR changes to your research design occur which effect the ethics of procedures involved you must inform the Committee. Please contact Sarah Jones ([hhsethics@plymouth.ac.uk](mailto:hhsethics@plymouth.ac.uk)).

Yours sincerely

**Professor Paul H Artes, PhD MCOptom**

Professor of Eye and Vision Sciences

Co-Chair, Research Ethics Committee -

Faculty of Health & Human Sciences and

Peninsula Schools of Medicine & Dentistry

## **Appendix 9: PDSE Patient Consent form**

**PENINSULA DENTAL SOCIAL ENTERPRISE**

**PATIENT AGREEMENT TO TREATMENT**

**Statement of Peninsula Dental Social Enterprise**

- 1) We agree to provide you with the most appropriate dental treatment that can be provided by a Dental / Dental Therapy Hygiene student within a primary care dental setting.
- 2) We will refer you to another care provider if you require treatment that cannot be provided.
- 3) Once your treatment is complete and you are dentally fit, you will be discharged from the care of Peninsula Dental Social Enterprise (PDSE). You will need to find your own dentist to continue your care as we are unable to offer long term dental care.
- 4) PDSE clinics close during holiday periods. If you require emergency dental care during this time, you will need to contact a local NHS dental service (there may be a charge for this). Details of this service can be found in the waiting room, at reception and are available on the PDSE answerphone.

**Signed (Student)..... Date.....**

**Print.....**

**Signed (Clinical Supervisor)..... Date.....**

**Print.....**

**Statement of Patient**

- 1) I understand and agree to initial investigations that are required to help devise a suitable treatment plan. These may include questions about my medical history, social history, radiographs (x-rays) and a full dental examination.
- 2) I understand the treatment plan that has been explained to me and I have received a copy.
- 3) I understand that my treatment plan may change or additional treatment may be required. I will be informed about any changes and I understand that I have the right to change my mind at any time, including after I have signed this form.
- 4) I understand that my treatment will be provided by a Dental / Dental Therapy Hygiene student supervised by a qualified dentist or other qualified dental professional.
- 5) I realise that some treatment sessions may take longer than I would expect from a qualified dentist or other qualified dental professional and I may also need to attend more appointments.
- 6) I agree to attend all appointments on time and will notify the PDSE Dental Education Facility as soon as I can if I am unable to attend.
- 7) I realise that if I fail to attend two appointments, or cancel three, then I will not be able to continue my treatment at Peninsula Dental Social Enterprise.
- 8) I understand that I cannot be guaranteed that a particular student will provide all my treatment.
- 9) I agree that the information from my dental records, including clinical photographs, can be used anonymously for research purposes, teaching and in student case presentations.

**Signed (Patient)..... Date.....**

**Print.....**

Parents/guardians of children under 16 years of age should sign below. A witness or interpreter should sign below if the patient is unable to sign but has indicated his/her consent.

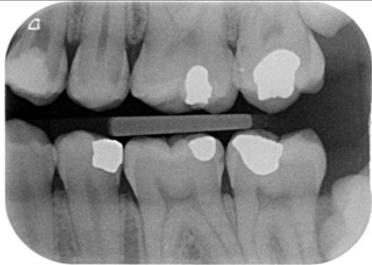
**Signed (parent/guardian/interpreter)..... Date.....**

**Print.....**

**Relationship to patient.....**

## **Appendix 10: Examples of Data Collection Forms**

Study Code: 10 TP

A1													
TP													
Caries				Retained Roots	Impacted /unerupted	Angular bony defects		Furcation involvement	Restoration deficiency		Restoration overhang		BONE LOSS
	M	O	D			M	D		M	D	M	D	NONE
24			2 x										
25			2 x										
26													
27													
28					X x								
34													
35													
36			1 x										
37													
38					X v								
TP: 1								TN: 94				Decisions: 99	
FN: 4								FP: 0					
Sensitivity= 0.2								Specificity= 1					
Caries Sensitivity= 0								Caries Specificity= 1					

Code: 15 NTP

B1													
NTP													
Caries				Retained Roots	Impacted /unerupted	Angular bony defects		Furcation involvement	Restoration deficiency		Restoration overhang		Bone loss
	M	O	D			M	D		M	D	M	D	Mild localised v
23			2v										
24			x										
25			2 v								X v		
26			2 v								x		
27	2 v		2 v										
28													
33													
34													
35									X v				
36			2 v										
37	3 v												
38													
TP: 10								TN: 85				Decisions: 95	
FN: 0								FP: 2					
Sensitivity= 1								Specificity= 0.9770					
Caries Sensitivity= 1								Caries Specificity= 0.9565					

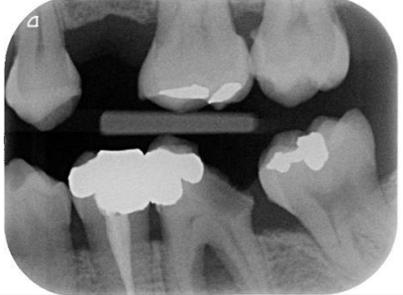
## **Appendix 11: Set A and B of radiographs Gold Standard Reports**

Study Code:

A1 TP / NTP																								
Caries				Retained Roots	Impacted /unerupted	Angular bony defects		Furcation involvement	Restoration deficiency		Restoration overhang		BONE LOSS											
	M	O	D			M	D		M	D	M	D	NONE											
24			x																					
25			x																					
26																								
27																								
28					X																			
34																								
35																								
36			x																					
37																								
38					X																			
TP:								TN:					Decisions:											
FN:								FP:					99											
Sensitivity=								Specificity=																
Global Disease Prevalence= 5.05%								Caries Prevalence= 10.00%																

+++

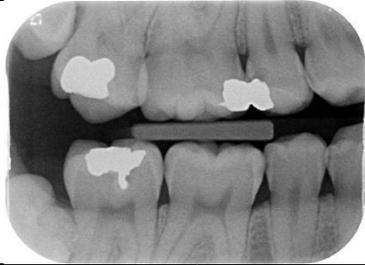
Study Code:

A2													
TP / NTP													
Caries				Retained Roots	Impacted /unerupted	Angular bony defects		Furcation involvement	Restoration deficiency		Restoration overhang		BONE LOSS
	M	O	D			M	D		M	D	M	D	-
24													
25													
26													
27													
28													
34													
35													
36			x					X					
37						X							
38													
TP:				TN:				Decisions:					
FN:				FP:				68					
Sensitivity=				Specificity=									
Global Disease Prevalence= 4.41%				Caries Prevalence= 5.00%									

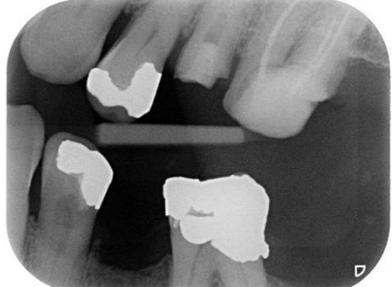
Study Code:

A3													
TP / NTP													
Caries			Retained Roots	Impacted /unerupted	Angular bony defects		Furcation involvement	Restoration deficiency		Restoration overhang		BONE LOSS	
	M	O	D			M	D		M	D	M	D	MODERATE GENERALISED
13			x										
14				X									
15													
16													
17													
18													
44													
45													
46			x										
47			x										
48	x												
TP:							TN:					Decisions: 68	
FN:							FP:						
Sensitivity=							Specificity=						
Global Disease Prevalence= 8.82%							Caries Prevalence= 21.05%						

Study Code:

A4													
TP / NTP													
Caries				Retained Roots	Impacted /unerupted	Angular bony defects		Furcation involvement	Restoration deficiency		Restoration overhang	BONE LOSS	
	M	O	D			M	D		M	D	M	D	NONE
14													
15			x										
16													
17													
18					X								
44													
45			x										
46	x		x										
47													
48					X								
TP:								TN:				Decisions:	
FN:								FP:				97	
Sensitivity=								Specificity=					
Global Disease Prevalence= 6.18%								Caries Prevalence= 13.33%					

Study Code:

A5												
TP / NTP												
Caries		Retained Roots	Impacted /unerupted	Angular bony defects	Furcation involvement	Restoration deficiency	Restoration overhang	BONE LOSS				
	M	O	D		M	D		M	D	M	D	MILD GENERALISED
23												
24												
25				x								
26						X						
27												
28												
33												
34												
35												
36										X		
37												
38												
26: RADIOLUCENCY BENEATH COMPOSITE PROBABLY ARTEFACTUAL												
TP:					TN:					Decisions:		
FN:					FP:					76		
Sensitivity=					Specificity=							
Global Disease Prevalence= 5.26%					Caries Prevalence= 0.00%							

Study Code:

A6													
TP / NTP													
Caries			Retained Roots	Impacted /unerupted	Angular bony defects		Furcation involvement	Restoration deficiency		Restoration overhang		BONE LOSS	
	M	O	D			M	D		M	D	M	D	-
13													
14	x		x								x		
15	x		x								x		
16													
17	x		x			X							
18	x												
44	x												
45													
46				X									
47		x											
48													
TP:							TN:					Decisions:	
FN:							FP:					94	
Sensitivity=							Specificity=						
Global Disease Prevalence= 13.83%							Caries Prevalence= 33.33%						

Code: 12 TP

B1													
TP													
Caries			Retained Roots	Impacted /unerupted	Angular bony defects		Furcation involvement	Restoration deficiency		Restoration overhang		Bone loss	
	M	O	D			M	D		M	D	M	D	Mild localised
23			X										
24													
25			X										
26			X									X	
27	X		X										
28													
33													
34													
35									X				
36			X										
37	X												
38													
TP:							TN:					Decisions:	
FN:							FP:					95	
Sensitivity=							Specificity=						
Global Disease Prevalence= 10.53%							Caries Prevalence= 23.23%						

Code: 12 TP

B2												TP			
Caries												Retained Roots		Impacted /unerupted	
	M	O	D			M	D			M	D	M	D	MODERATE TO ADVANCED GENERALISED	
14															
15															
16															
17															
18															
44															
45															
46								X							
47								X							
48															
TP:								TN:						Decisions: 81	
FN:								FP:							
Sensitivity=								Specificity=							
Global Disease Prevalence= 3.70%								Caries Prevalence= 0%							

Code: 12 TP

B3													
TP													
Caries				Retained Roots	Impacted /unerupted	Angular bony defects		Furcation involvement	Restoration deficiency		Restoration overhang		BONE LOSS
	M	O	D			M	D		M	D	M	D	-
13			x										
14													
15													
16													
17			x										
18						x							
44													
45													
46	x												
47													
48													
TP:								TN:				Decisions:	
FN:								FP:				79	
Sensitivity=								Specificity=					
Global Disease Prevalence= 5.06%								Caries Prevalence= 12.50%					

Code: 12 TP

B4																
TP																
Caries				Retained Roots	Impacted /unerupted	Angular bony defects		Furcation involvement	Restoration deficiency		Restoration overhang		Bone loss			
	M	O	D			M	D		M	D	M	D	none			
24																
25																
26												X				
27												X (b p)				
28							X									
34																
35																
36																
37																
38					X											
TP:								TN:				Decisions: 97				
FN:								FP:								
Sensitivity=								Specificity=								
Global Disease Prevalence= 4.12 %								Caries Prevalence= 0%								

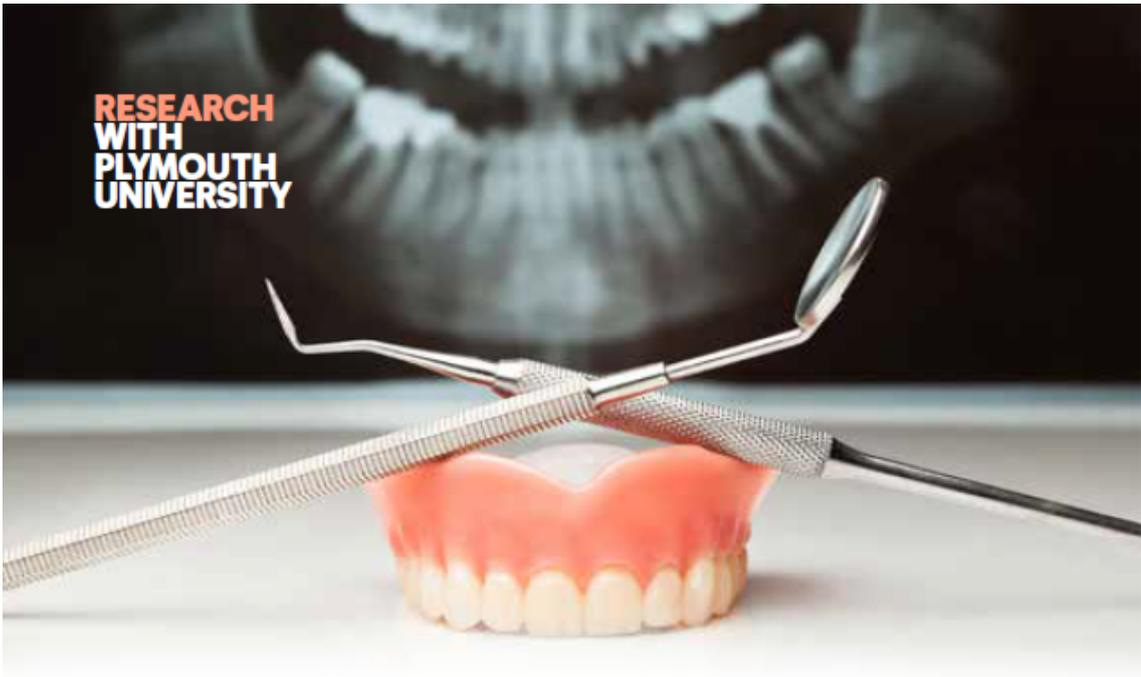
Code: 12 TP

B5													
TP													
Caries			Retained Roots	Impacted /unerupted	Angular bony defects		Furcation involvement	Restoration deficiency		Restoration overhang		BONE LOSS	
	M	O	D			M	D		M	D	M	D	-
24													
25													
26													
27												X	
28													
34													
35						X (EARLY)							
36													
37													
38					X								
TP:							TN:					Decisions: 69	
FN:							FP:						
Sensitivity=							Specificity=						
Global Disease Prevalence= 4.35%							Caries Prevalence= 0%						

Code: 12 TP

B6																	
TP																	
Caries				Retained Roots	Impacted /unerupted	Angular bony defects		Furcation involvement	Restoration deficiency		Restoration overhang		BONE LOSS				
	M	O	D							M	D	M	D	SEVERE			
14			x					M	D								
15																	
16																	
17									X								
18																	
43																	
44																	
45																X	
46																	
47										X	X						
48																	
TP:								TN:				Decisions: 76					
FN:								FP:									
Sensitivity=								Specificity=									
Global Disease Prevalence= 9.21%								Caries Prevalence= 5.55%									

**Appendix 12: Recruitment Leaflet and Participant's Information Sheet**



**RESEARCH  
WITH  
PLYMOUTH  
UNIVERSITY**

## **Invitation to participate in dental research:** Role of time pressure on dentists' diagnostic decision making.

---

**Previous research suggests that dentists experience stress in their working lives, and time pressure is one of the most frequently cited stressors. However, there is no published research in which the performance of dentists under time pressure has been evaluated.**

Researchers at Plymouth University are conducting a study aiming to explore the impact of time pressure on dentists' decision making when viewing dental radiographs. We are looking for primary care dentists to take part in the study.

Participation in the study will give you an opportunity to explore how you perform under time pressure and reflect on your daily practice and performance. The research findings may also hold important implications for dental policy.

Your participation in the study will last approximately 40 minutes. You will be asked to complete a series of questions (diagnostic tasks) using a computer in a quiet room with no distractions either at your practice or Plymouth University, depending on your preference. Your participation will be anonymous. This research study has been granted ethical approval by the Plymouth University Research Ethics Committee.

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Should you wish to find out more about the study or wish to participate please contact the researcher at: [anastasios.plessas@plymouth.ac.uk](mailto:anastasios.plessas@plymouth.ac.uk) or **07832 495628**

**Anastasios Plessas** DipDS(Ath), MSc(Dent Sci)(Gla), DipPCD RCSI, MFGDP(UK), FHEA  
*Academic Clinical Fellow in Primary Dental Care, Plymouth University Peninsula  
Schools of Medicine and Dentistry*

## **Participant information Sheet**

**Study Title: A study on time pressure and dentist's diagnostic making.**

You are invited to participate in a study on diagnostic decision making. Please read the information sheet carefully and discuss it with others if you wish. If you wish to participate please contact me directly ( [anastasios.plessas@plymouth.ac.uk](mailto:anastasios.plessas@plymouth.ac.uk) )

### **What is the purpose of the study?**

In dentistry, we are called to make decisions on the spot. The international literature suggests that dentist experience stress in their working lives, and time constrictions and pressure is one of the most frequently cited stressor factors. There is conflicting evidence in the medical literature on how this time pressure may affect doctor's diagnostic and treatment decisions. This study is aiming to explore the impact of time pressure, if any, on dentist's decision making when viewing dental radiographs. This study is part of my ResM postgraduate degree project (Research Masters).

### **Why have I been chosen?**

We are looking for general dental practitioners with different number of years of clinical experience who are currently engaged in treating dental patients in a primary dental care setting (general dental practice).

### **Do I have to take part?**

Your decision to take part in this study is entirely voluntary. You can withdraw at any time during the study, without this affecting your practice or legal rights.

### **What will happen to me if I take part?**

*Your participation in the study will last less than an hour. You will have to complete a series of questions (diagnostic tasks) using a computer in a quiet room with no distractions. This can be in your practice or in the premises of the Plymouth University depending on which of the two is most convenient for you.*

As part of the study, you will be asked to examine a set of radiographs supplied by the researcher. You will be asked to provide a radiographic report of your main observations as you would do normally in your own practice. The same process will take place in two different sessions under different conditions based on the time you will be given to complete each task (limited time versus no time pressure). After each session, you will be asked to complete a psychological visual analogue scale (VAS) about your feelings at the time. In the end, you will be asked to provide demographic data such as practicing years, postgraduate qualifications and gender.

The sequence of tasks you will be asked to complete is illustrated in the flowchart in the end of the information sheet.

### **What are the other possible disadvantages and risks of taking part?**

During the study you will be asked to make decisions under limited time. Although we do not expect this to cause any distress, should this occur, if you remain distressed, you will be given the opportunity to stop and withdraw from the study. In such a case, you will be signposted to your GP or local Occupational Health Service for support.

### **What are the possible benefits of taking part?**

You will be able to self-evaluate your performance under time pressure. Once the data of the study have been anonymised and analysed, you will have the opportunity to receive a brief summary of the results of the study through the clinics administrator or secretary who invited you to the study.

### **What if there is a problem?**

If you have any concerns of the conduct of this study or you wish to complain please contact :

Dr Mona Nasser (Director of Studies)

Lecturer in Evidence Based Dentistry

John Bull Building, Science Park, Research Way,

*Plymouth*, PL6 8BU.

**[mona.nasser@plymouth.ac.uk](mailto:mona.nasser@plymouth.ac.uk)**

Or alternatively the Research Administrator to the Faculty Research Ethics Committee:

Sarah C Jones

Faculty of Health and Human Sciences

4<sup>th</sup> Floor Rolle Building, Drake Circus

Plymouth PL4 8AA

**[hhsethics@plymouth.ac.uk](mailto:hhsethics@plymouth.ac.uk)**.

### **Will my taking part in the study be kept confidential?**

The tasks you complete and any reports that you write will remain anonymous. Your name will only be used in this consent form to keep a record of those who agreed to take part in the study. A unique study number will be given to you to record on all your answer sheets for the study. Your answers will be kept confidential at all times and treated with respect. Any data and results included in future publications will remain anonymous too.

### **What will happen if I don't want to carry on with the study?**

Your decision to take part in this study is entirely voluntary. You can withdraw at any time during the study up until you have completed the tasks. Please let the principal investigators (AP) know you wish to withdraw. Your data will not be used for analysis and they will be destroyed. Once your data is anonymised with a unique identifier, it will not be possible to withdraw your anonymised data.

### **What will happen to the results of the research study?**

The results of the study will be used in a thesis document (for the principal investigator's Research Masters) and also they will be disseminated within the dental research community via peer-review publications and conference presentations. A brief report of the findings will be made available to the clinical administrator or relevant secretary who invited you to the study. You will not be able to be identified in any of the write up or publications.

### **Who is organising the research?**

The research is funded by the National Institute for Health Research (NIHR) and sponsored by the University of Plymouth.

### **Who has reviewed the study?**

The study has been reviewed by the Plymouth University Faculty Ethics Research Committee.

***Thank you for reading the participant's information for the present study.***

Warmest Regards

Anastasios Plessas DipDS(Ath), MSc(Dent Sci)(Gla), DipPCD RCSI, MFGDP(UK), FHEA

Principal Investigator

NIHR Academic and Clinical Fellow in General Dental Practice

Peninsula Dental School, Plymouth University (PUPSMD)

**anastasios.plessas@plymouth.ac.uk**

## **Appendix 13: Study Consent Form**

## CONSENT FORM

**Study Title: “Time pressure and dentist’s diagnostic decision making.”**

Participant Identification Number:

Name of Researcher: Mr Anastasios Plessas

Director of studies: Dr Mona Nasser

Please initial box

1. I confirm that I have read the information sheet dated. (version 1.0, 22 Sept 2017) for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.
  
2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without my legal rights being affected.
  
3. I understand that the information collected about me will be used to support other research in the future, and may be shared anonymously with other researchers.
  
4. I agree to take part in the above study.

\_\_\_\_\_  
Name of Participant                      Date                      Signature

\_\_\_\_\_  
Name of Person                      Date                      Signature  
taking consent

## **Appendix 14: Example of a Qualtrics Report**



## **Appendix 15: De-brief Sheet**

**De-brief**

**Dentist's diagnostic decision making study.**

Thank you for participating in this study. You have contributed to the understanding of how time pressure affects dentists' diagnostic decision making.

The research you just participated had a number of goals. The main goal was to better understand how time pressure may affect dentists' diagnostic skills. We are also interested to see whether individual differences such as educational background and experience would influence the way that dentists respond under pressure. We are also taking under consideration the effect of any emotions of anxiety as measured by the psychological scale questionnaire used in this study.

I would like to remind you that the results of this study will remain confidential and anonymous. I will analyse the data from all participants together, and not from each individual. Anonymity will be guaranteed in any future publications. If you are concerned, you can withdraw your answers today before you leave the premises. Once you data is anonymised with a unique identifier it will not be possible to withdraw your anonymised data.

You will have the opportunity to receive a brief report of the summary of the results of the study once analysed. You will be notified that the report is available via an email sent by the relevant clinic administrator or secretary who invited you to this study. The results of the study will remain anonymised in the report and in any future publication (Thesis document, peer review publications and conference proceedings).

If you felt overly distressed during the study, we will encourage you to seek support by your GP and local Occupational Health Service.

If you would like more information on the study after this date you can contact the principal investigator of this study: Mr Anastasios Plessas.

***anastasios.plessas@plymouth.ac.uk***

If you have any concerns of the conduct of this study or you wish to complain please contact either

The Director of studies: Dr Mona Nasser  
Lecturer in Evidence Based Dentistry  
John Bull Building, Science Park, Research Way,  
Plymouth, PL6 8BU.  
**mona.nasser@plymouth.ac.uk**

or the Research Administrator to the Faculty Research Ethics Committee:  
Sarah C. Jones  
Faculty of Health and Human Sciences  
4<sup>th</sup> Floor Rolle Building, Drake Circus,  
Plymouth PL4 8AA  
**hhsethics@plymouth.ac.uk.**

## **Appendix 16: Results of Taught Modules undertaken during the ResM**

**University of Plymouth Statement of Results/eTranscript**

Date: 01 September 2018

Date of Birth 20/12/1985

Student Reference Number: 10507140

HESA Reference: 1410731259395

Enrolment Status: L/ Live

Name Anastasios Plessas

Institution responsible for programme delivery: University of Plymouth

Language(s) of Instruction/Assessment: English

**ResM Dental Studies Stage 1 - 2015/2016**

Credit achieved in this academic year: 60

Progression: [A1/ May progress, module results and any credit awarded are as indicated on the transcript.](#)

Module Code	Module Title	Credit	Level	Mark (%)	Att.	Result	Mod. Decn.	Mod Grd
PDD721	Project Design, Development and Knowledge Transfer	30	7	70.00	1	A		
	<i>Coursework</i>			<i>Confirmed</i>		<i>70.00</i>		
	Assignment			Marking Status	Mark %	Att. Result	Weighting	
	<i>Critical Review and Project Proposal</i>			<i>Confirmed</i>	<i>70.00</i>	<i>1</i>	<i>1.00</i>	
SIM715	Human Factors in Healthcare	30	7	74.00	1	A		
	<i>Coursework</i>			<i>Confirmed</i>		<i>74.00</i>		
	Assignment			Marking Status	Mark %	Att. Result	Weighting	
	<i>Portfolio</i>			<i>Confirmed</i>	<i>74.00</i>	<i>1</i>	<i>1.00</i>	



