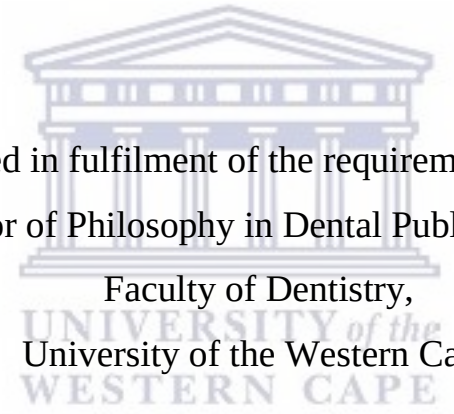
MANAGEMENT OF DEFECTIVE DENTAL AMALGAM RESTORATIONS – A MIXED-METHODS STUDY

By

Razia Z Adam



A thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy in Dental Public Health,

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Supervisor: Professor Sudeshni Naidoo

Co-Supervisor: Professor Greta Geerts

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KEYWORDS

South Africa

Dental amalgam

Treatment patterns

Clinical decision-making

Repair

Refurbishment

Replacement

Defective restorations

ABSTRACT

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RZ Adam, PhD Thesis, Faculty of Dentistry, University of the Western Cape

Aim: Much variation exists in the practice of dentistry with regard to the diagnosis of caries and the recommendations for treatment. Even though criteria for the selection of 'faulty' restorations often appear ill-defined, subjective and/or variable restoration replacement is a major component of dental practice in developed countries (Brennan and Spencer, 2006). While the prevalence of caries is decreasing in developed countries, low- and middle-income countries are experiencing an increase. The investigation of factors influencing the clinical decision-making process has identified and compared the roles of technical (e.g. oral health factors), patient and dentist factors (Brennan and Spencer, 2006; Bader and Shugars, 1995a; 1995b). A recent trend for a more conservative approach to restorative dentistry has led to the alternative management of defective dental restorations. Repair and refurbishment of defective dental restorations have been established as viable options. The purpose of this study was to provide information regarding the practices, knowledge and attitudes of South African dentists with regard to the management of defective dental amalgam restorations.

Methodology: A mixed-methods study with an online survey administered to all members of the South African Dental Association was conducted and followed by in-depth interviews of 15 purposefully selected dentists in the Western Cape. The online data included demographic data, education level, continuing education practices, attitudes and use of dental amalgam as a restorative material and a clinical vignette. The in-depth interviews comprised two patient cases in which dentists were asked to explain their treatment decisions with regard to the management of defective dental amalgam restorations. The interviews were coded, transcribed and analysed using the Atlas.ti ® software package. Responses

were analysed using the Framework Method. Ethics approval was received from the Senate Research Committee of the University of the Western Cape.

Results: This study found that almost two-thirds of dentists reported repairing defective dental restorations in their practices. The majority of those who did not repair restorations felt that there was a lack of predictability in the technique. The interview findings also suggested that it was not an 'appropriate treatment' although the majority of dentists learnt their repair technique through their own clinical experience. Dentists had outdated concepts regarding the diagnosis of micro-leakage and secondary caries. Results from the vignettes indicated that the majority of the dentists in the study were more inclined to replace defective restorations, while the presence of a marginal gap (OR=0.594, 0.311–1.133) and secondary caries (OR=0.434, 0.224–0.842) were significant predictors for the repair of a defective restoration. Dentists with more than 21 years of experience were more likely to repair defective restorations (p<0.0001). Cost to patient, uncertainty in diagnosis and dental school were the most influential non-clinical factors.

Conclusion: The findings of this study suggest that there is a lack of translation of evidence-based information to everyday general practice dentistry in South Africa. This results in the use of outdated knowledge to make treatment decisions that affect patient outcomes. As a result, there is a need for updated teaching, specifically regarding secondary caries and micro-leakage. This study also suggests that the influence of non-clinical factors such as dental schools and uncertainty in diagnosis are influential in the clinical decision-making process.

DECLARATION

I declare that the thesis entitled *Management of Defective Dental Amalgam Restorations – A Mixed-Methods Study* is my own work, that it has not been submitted before for any degree or examination at any other university, and that all the sources I have used or quoted have been indicated and acknowledged as complete references.

_____ _____

Razia Zulfikar Adam Date

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DEFINITION OF TERMS (Mjör *et al*., 2000)

Secondary caries:

Frank caries: Clearly visible caries adjacent to the existing restoration.

Limited caries: Evidence of limited caries whether visible or not associated with marginal defects or discoloration.

Marginal discoloration: Discoloration at the tooth/restoration interface sufficient to warrant replacement of the restoration.

Bulk discolouration: Mismatch of shade between the body of the restoration and the tooth, which justifies replacement of the restoration.

Marginal fracture/degradation: Refers only to those restorations that are well adapted to the remaining tooth structures but with marginal fractures or defective margins with no evidence of caries.

Bulk fracture: Includes isthmus fracture or any fracture through the main body of the restoration.

Fracture of tooth: Tooth fracture adjacent to the restoration, for example, the fracture of a cusp.

Poor anatomic form: Loss of substance due to material degradation and wear, sufficient to result in loss of restoration form and possibly function.

CHAPTER 1: INTRODUCTION

Worldwide, dental caries is the most common chronic disease that affects nearly all adults (Petersen, 2003) and is the "primary cause of oral pain and tooth loss" (Selwitz *et al*., 2007). Although there has been a widespread decline in the prevalence of caries in permanent teeth in high-income countries, there are reports of a growing burden of dental caries for adults in low- and middle-income countries (Petersen *et al*., 2009). This is attributed to increasing urbanisation and changes in living conditions (Petersen *et al*., 2009). Once sound tooth structure is destroyed through the caries process, a "lifelong cycle of repair and maintenance" awaits (Elderton and Nuttall, 1983; Selwitz *et al*., 2007).

A recent study, "Global Economic Burden of Dental Diseases", estimated the cost of dental disease in 2010 at $442 billion, of which $298 billion was attributable to direct treatment costs and $144 billion to indirect costs in terms of productivity losses due to caries, periodontitis and tooth loss (Listl *et al*., 2015).

It is widely accepted that dental caries is an "initially reversible, chronic, disease process with a known multi-factorial aetiology"(Pitts, 2004). However, since the 20th century, dentists have regarded dental restorations as a cure for dental caries (Selwitz *et al*., 2007). With a focus on caries lesion detection and the fee for service remuneration systems, there is a bias towards operative dentistry (Fejerskov and Kidd, 2009). However, in recent years, there has been a trend in caries management to move away from the operative model towards a more preventive approach – minimum intervention dentistry (Petersen, 2003; Petersen *et al*., 2009). This includes strategies that curb the disease process and conserve tooth structure. However, restorative treatment as a method of caries management dominates in many countries such as the United States of America (USA) (Ismail *et al*., 2001; Elderton, 2003) although in some regions such as Scandinavia, a more preventive approach has been adopted (Selwitz *et al*., 2007).

The establishment of effective preventive programmes at country and community levels has yielded a decline in the levels of dental caries in children and an improved dentate status in adult populations (Petersen *et al*., 2009). Research has identified high-caries risk groups to include:

> [P]eople living in poverty, people with poor education or low socioeconomic status, ethnic minority groups, individuals with developmental disabilities, recent immigrants, individuals with human immunodeficiency virus (HIV) or acquired immunodeficiency syndrome (AIDS), elderly people who are frail and people with several lifestyle factors. (Selwitz *et al*., 2007)

However, a lack of these preventive programmes in middle- and low-income countries has meant that these populations are in need of comprehensive oral healthcare, including restorative treatment (Selwitz *et al*., 2007; Petersen *et al*., 2009). Using amalgam, an estimated cost of between US$1 618 and US$3 513 per 1 000 children would be required to restore the permanent teeth of the child population between the ages of 6 and 18 years of low-income countries (Kathmandu, 2002). The prevalence and recurring nature of dental caries and periodontal disease "makes the mouth among the most expensive parts of the body to treat" (Listl *et al*., 2015).

A wide variety of dental restorative materials exists today. The principal material types for direct restorations include dental amalgam, composites, glass ionomers and resin ionomers (Rekow *et al*., 2013). The use of dental amalgam for the restoration of posterior teeth has decreased because of the need for a more aesthetic material as well as concerns regarding its safety; however, it remains an effective restorative material (Petersen *et al*., 2009). A number of tooth-coloured materials are also currently available. The use of composite restorations is limited by the technique sensitivity and the intention for use in patients with excellent oral hygiene (Rekow *et al*., 2013). The use of glass ionomers as a group of restorative materials is best suited for long-term provisional restorations (Rekow *et al*., 2013).

The last available data records dental amalgam being used by 85.8% of dentists in South Africa (Lombard *et al*., 2009). Extensive research has been conducted over the years to investigate the longevity of direct restorations (Elderton, 1976; Hickel and Manhart, 2001; Mitchell *et al*., 2007; Moraschini *et al*., 2015) and indirect restorations. Studies conducted by Manhart *et al*. (2004) and Opdam *et al*. (2007)

found that newer resin composite restorations have an improved longevity. However, a Cochrane Review published in 2014 concluded that the failure rate for composite restorations was twice that of amalgam restorations (Hurst, 2014). Despite this, increasing concern over aesthetics, the recent Minamata Convention on Mercury (Mackey *et al*., 2014) and advances in adhesive dentistry have globally decreased the favourability of dental amalgam among dentists and patients alike (Burke *et al*., 2003).

Hurst (2014) surmised that the failure rate of composite restorations could be four times more than that of amalgam restorations in a patient with a high caries experience. In addition, if dental amalgam were no longer available as a restorative material, populations with high caries rates could be disadvantaged as the composite restorations replace dental amalgam restorations (Hurst, 2014). It is in these instances that extending the longevity of defective dental amalgam restorations with a repair or refurbishment may be an excellent alternative for increasing the longevity of the restoration and ultimately, the tooth.

South Africa is classified as an upper- to middle-income country with a population of approximately 54 million people (Gray and Vawda, 2015). A legacy of apartheid has left South Africa with many disparities, including access to health care in both public and private health care sectors. The South African Demographic and Health Survey (2014) reported that only 14% of the population has access to medical aid or some form of health benefit. This means that the majority of individuals seeking dental treatment need to pay for the service.

There are 5 856 dentists and 611 dental therapists registered with the Health Professions Council of South Africa (HPCSA) (Gray and Vawda, 2015) and of these, 1 137 and 309 respectively work in the public sector. Most of the treatment delivered at public health facilities is for pain relief and the treatment of sepsis. These statistics imply that more than 80% of trained dentists are employed in the private sector. There has been very little research conducted on the range of services provided by oral health care workers and specifically, on the management of defective dental amalgam restorations.

Research regarding the knowledge and the preferences for restorative dental materials and treatment as well as whether or not they conform to evidence-based dentistry is scarce.

It is reported that two-thirds of all restorative work completed in dental practice involves the replacement of existing restorations (Wilson *et al*., 2004). In a bid to break the "restorative cycle" of a tooth, recent research has focused on the management of defective restorations (Henry, 2009). The restorative cycle has been described as a sequence of three events in which there is loss of tooth structure: (i) trauma or the original disease process; (ii) tooth preparations to receive a restoration; and (iii) the eventual failure of the restoration and replacement thereof. Research has shown that the replacement of restorations results in larger restorations or a choice between complex restorations, costly indirect restorations or extraction of the offending teeth (Mjör *et al*., 1998). Little research has been conducted on patient outcomes with the repair and refurbishment of restorations. Initial reports suggest that these procedures are more time-efficient, require no local anaesthetic and could potentially cost the patient less (Javidi *et al*., 2015). Other research conducted has affirmed that the repair of a defective restoration increases the longevity of the restoration (Gordan *et al*., 2015; Moncada *et al*., 2015a; 2015b).

Current management options for the management of defective amalgam restorations include repair, refurbishing and sealing of the restoration (Gordan *et al*., 2011). The clinical decision-making process for determining the treatment approach in the management of defective dental restorations is naturally complex. The decision to intervene is influenced by patient factors, tooth factors, material factors and dentist factors. Studies conducted around the world confirm that there is much variation in clinicians' decisions to intervene and although the repair and refurbish approach has been included in teaching curricula, there is a slow translation to the dental practice (Blum *et al*., 2002; Blum *et al*., 2003a, 2003b; Blum and Lynch, 2011; Gordan, 2013; Hasan and Khan, 2013).

It is clear that dentists perform repair restorations but the factors that they consider when deciding to repair or replace a restoration are unclear. In addition,

most of the research is conducted in countries in which patients have access to a well-run health care system and where caries risk levels are low.

There has been a limited number of studies focusing on clinical decision-making and the management of defective amalgam restorations (Gordan *et al*., 2009; Gordan *et al*., 2012a; 2012b). Little research has reported on the factors influencing clinical decision-making, specifically in the context of South Africa where "generations of heavy metal patients have multiple restorations that are likely to need replacement or maintenance throughout their lifetime"(Rekow *et al*., 2013). This gap in the knowledge provides a unique opportunity to understand the influence dentists have on treatment choices.

Significance of the study

The significance of this study was to explore and to understand the treatment decisions regarding the management of defective dental amalgam restorations in South Africa. Inappropriate, clinical decision-making adversely affects patient outcomes, and it was anticipated that this study would yield a summary of the varying restorative treatments that dentists are providing for the South African population and compare them with best practice. Furthermore, this study identifies inappropriate decision-making behaviour, which would be important in developing appropriate and continuing education as well as informing curricula in South African dental schools.

CHAPTER 2: LITERATURE REVIEW

2.1 INTRODUCTION

This chapter is presented in four sections and describes the key concepts of the study. Section 1 introduces the conceptual framework used in the present study. Section 2 explores clinical decision-making in dentistry and restorative treatment variation among dentists as well as discusses certain factors influencing treatment decisions in general. Section 3 reviews the literature on the use of amalgam as a restorative material, longevity of restorations, replacement of restorations and current techniques in the management of defective dental amalgam restorations. Lastly, Section 4 focuses on clinical decision-making for the replacement or repair of defective restorations and the factors that affect this.

2.2 SECTION 1: CONCEPTUAL FRAMEWORK

Bader and Shugars (1992) proposed a model of the decision-making process in order to assist in the investigation of factors associated with dentists' treatment decisions. According to this model, assessment, decision to treat and the selection of treatment are separate steps in the decision-making process. A variety of dentist and patient factors were identified from the literature and included in the model because they were known or expected to affect dentists' intervention decisions and treatment (Bader and Shugars, 1992).

In 1997, the model was amended to focus on caries-related treatment decisions (Bader and Shugars, 1997). In order to understand the clinical decision-making process regarding the management of defective dental amalgam restorations, the present study used Bader and Shugars' (1997) conceptual model on caries-related treatment decisions (Figure 1).

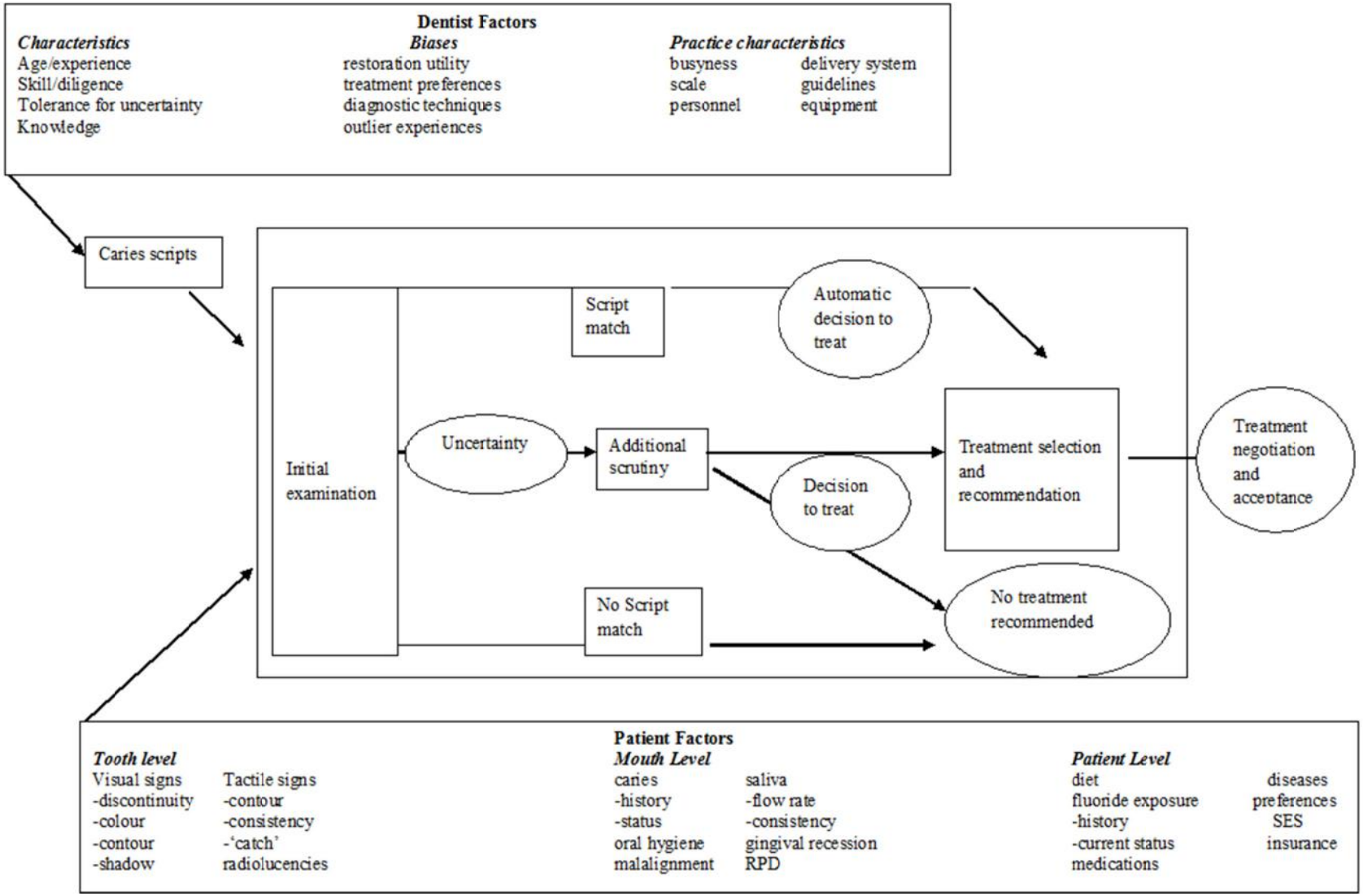

Figure 1: Conceptual model of dentists'caries-related treatment decisions (Bader and Shugars, 1997)

2.2.1 Understanding the process

Bader and Shugars (1997) proposed that dentists do not 'diagnose' caries in the classic sense but rather evaluate a single hypothesis whenever a tooth is examined for caries. Depending on the opinions or experiences of the dentist, the hypothesis could be the tooth has caries or the tooth does not have caries. This process is repeated for every tooth and every surface, and the result of the process is expressed as a decision to intervene. The recognition of caries depends on the similarity to previous encounters by the dentist. Bader and Shugars (1992) liken this pattern recognition to illness scripts.

Bader and Shugars (1992) describe illness scripts as "summaries of a provider's cumulative experiences with similar clinical presentations of health and disease". However, the important difference is that pattern recognition ends in a decision to intervene rather than a diagnosis. However, not all caries scripts end in a decision to intervene, and these events of uncertainty are often noted in patients' folders and monitored for change. Bader and Shugars (1997) cite Kahneman and Tversky's (1982) hypothesis of uncertainty as a possible explanation. The hypothesis states, "the more uncertainty is tolerated, the less likely a decision to intervene will be made" (Bader and Shugars, 1997).

In addition to the description of the decision-making process, the model also included a variety of patient and dentist factors that may influence the decision to intervene. The following paragraphs summarise these factors.

2.2.2 Patient factors

Three types of patient factors are included in this model: (i) those involving a specific tooth or tooth surface; (ii) those describing intra-oral conditions; and (iii) those related to patient history, behaviour preferences and socioeconomic status (Bader and Shugars, 1997). Bader and Shugars (1997) suggest that tooth and intra-oral factors are included in caries scripts, but patient-level factors influence the decision and the eventual treatment selection. For the purpose of this study, the diagnosis of secondary caries, the presence of a marginal gap and the cost to patient were the only factors explored.

2.2.3 Dentist factors

There are three types of dentist factors included in the model (Bader and Shugars, 1997). Biases, including dentists' beliefs of treatment preferences, utilities and preferred diagnostic methods are believed to play a role in the decision to intervene as well as in the nature of the intervention. The personal characteristics of a dentist, including age/experience, skill/diligence, knowledge and tolerance for uncertainty are also part of the model. In this instance, knowledge is referred to as "accurate information describing the epidemiology and pathophysiology of caries and the outcomes of its treatments" (Bader and Shugars, 1997). Practice-related characteristics such as busyness, scale, personnel and equipment are also included. Outlier experiences are defined as "unexpected outcomes of treatment decisions which may then influence subsequent treatment decisions" (Bader and Shugars, 1997). In this study, the influence of knowledge, age/experience and treatment preferences on the clinical decision-making process were investigated.

In summary, this conceptual model was used to frame the investigation of the present study into the clinical decision-making process for the management of defective dental amalgam restorations. Section 2 reviews the literature on clinical decision-making in dentistry, restorative treatment variations in practice and the influence of patient and dentist factors.

2.3 SECTION 2: CLINICAL DECISION-MAKING

Clinical decision-making is defined as a "multifactorial process involving the assimilation of information from clinical experience, relevant research, and patient preferences and goals for anticipated outcomes" (Matthews, 1994). Grembowski *et al*. (1988) suggested that clinical decision-making is a social process that includes the dentist, the patient and sometimes, family members and insurers as well.

Previous studies in clinical decision-making concentrated on the cognitive processes in medical diagnosis and treatment planning, while very little research was done in dentistry (Higgs *et al*., 2008; Maupomé *et al*., 2010).

Decision-making is an important component of the clinical activities of a dentist, whether deciding to extract a tooth or to replace a defective restoration. Formal decision-making methods and techniques have been applied to studies addressing radiology, caries prevention and treatment (Kay *et al*., 1992; Nuttall *et al*., 1993; Kay and Nuttall, 1994; White and Maupome, 2001; Doméjean-Orliaguet *et al*., 2009; Gordan *et al*., 2010; Weber *et al*., 2011; Buchalla *et al*., 2011), variation in decisions among dentists (Maryniuk, 1990; Kay *et al*., 1992; Bader and Shugars, 1995a; Bader and Shugars, 1995; Kay and Locker, 1996; Lewis *et al*., 1996; Choi *et al*., 1998; Brennan and Spencer, 2007; Maidment *et al*., 2010) and factors that influence dentists' decisions (Eisenberg, 1979; Kay and Blinkhorn, 1996; Brennan and Spencer, 2002; Brennan and Spencer, 2006). In addition, they have been applied to studies addressing the extraction of third molars, full mouth extractions (Bouma *et al*., 1987) and the specialities of geriatrics, prosthodontics (Soderfeldt *et al*., 1996; Kronström, 1999), endodontics, orthodontics, oral medicine and paedodontics (McCreery and Truelove, 1991a, 1991b).

2.3.1 Clinical decision-making models

As early as 1979, Eisenberg concluded that socio-cultural factors also influence medical decision-making (Eisenberg, 1979). The report identified five factors. The factors included: sociologic characteristics of the patient; the sociologic characteristics of the physician; the physician's interaction with his profession and the health care system; and the physician's interpersonal relationship with the patient (Eisenberg, 1979). The author believed that clinical decisions are influenced by interactions between the dentist and the patient, the sociocultural environment and biomedical considerations.

The cognitive theoretical framework of Gale and Marsden (1983) described clinical decision-making through the identification of the specific psychological processes that occurred as the resolution of a clinical problem progressed. These processes are referred to as diagnostic thinking processes (DTP). The authors suggest that the perception of a problem is dependent on the way knowledge is structured in memory.

The link between knowledge structure and a clinical situation is formed by significant features within pieces of information called “forceful features” (Gale and Marsden, 1983) or “caries scripts” as referred to by Baders and Shugars (1997). These are derived from experience and are part of the memory structure. Gale and Marsden (1983) identified 14 DTPs.

A model such as suggested by Ettinger (1984) represents the types of decision-making related to diagnosis, treatment planning and maintenance decisions as seen in Figure 2. It combines elements of the anatomical model and medical model of diagnosis. In the anatomical model of diagnosis, the emphasis is on disease identification. Once the disease has been identified, it can be linked with a specific curative treatment. However, in dentistry, dentists are confronted by mainly two diseases, dental caries and periodontal disease. These are not linked to any specific therapeutic treatment, so dentists are more concerned with the alternatives related to treatment planning. In the medical model, the clinician collects three sets of data. The first set is about the host and the host’s environment, the second set is descriptive and related to the morphology or microbiology of the disease, and the third set describes the interaction between the disease and its environmental host.

Kay and Nuttall (1997) proposed a Rational Decision-Making Model (Figure 3). The advantages of using this technique were that it focused the dentists’ thinking on factors that truly influenced the decision to treat and thus helped structure the thought process. It also ensured that all possible options were explored (Kay and Nuttall, 1997).

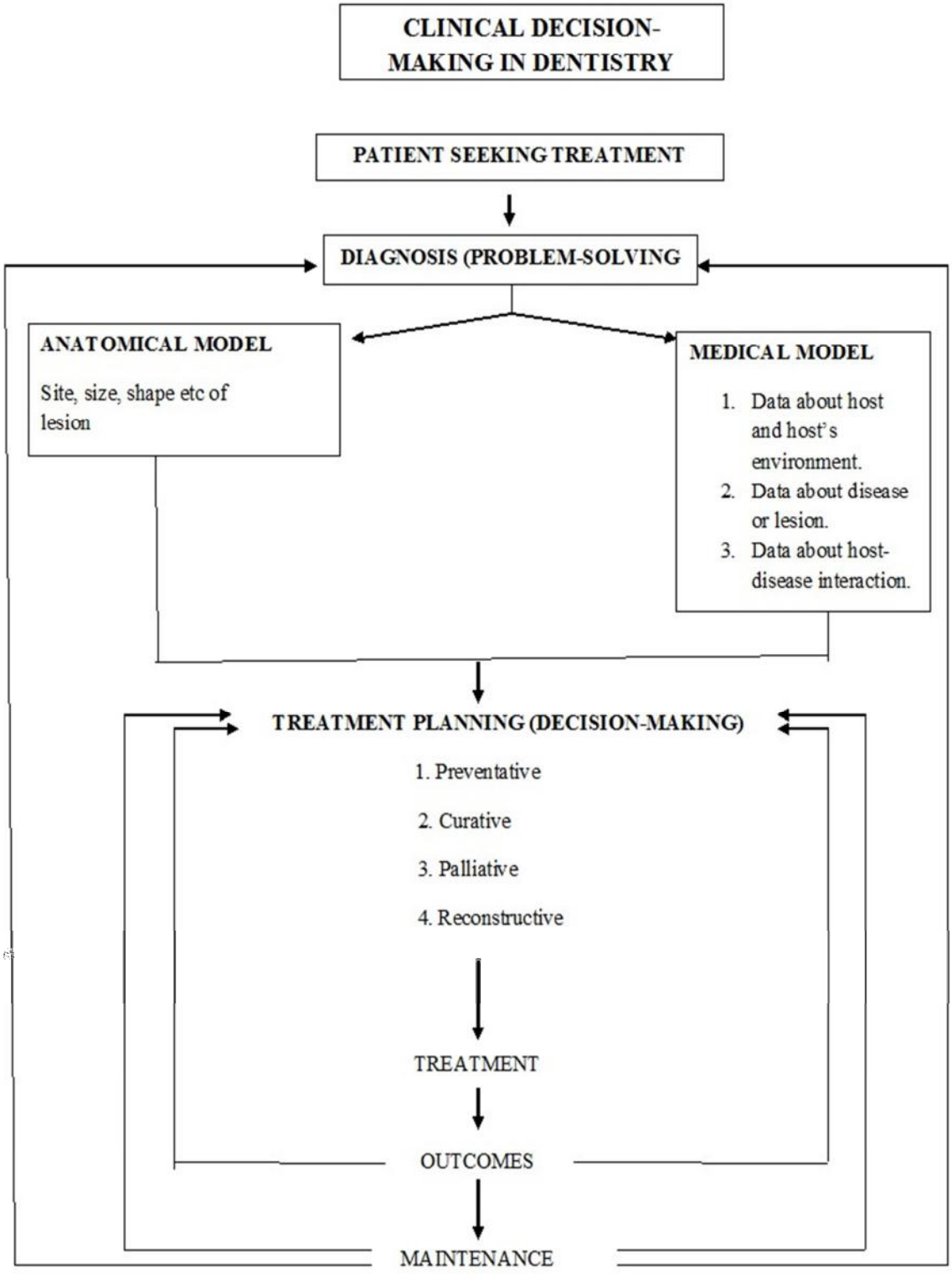

Figure 2: Clinical decision-making in dentistry (Ettinger, 1984)

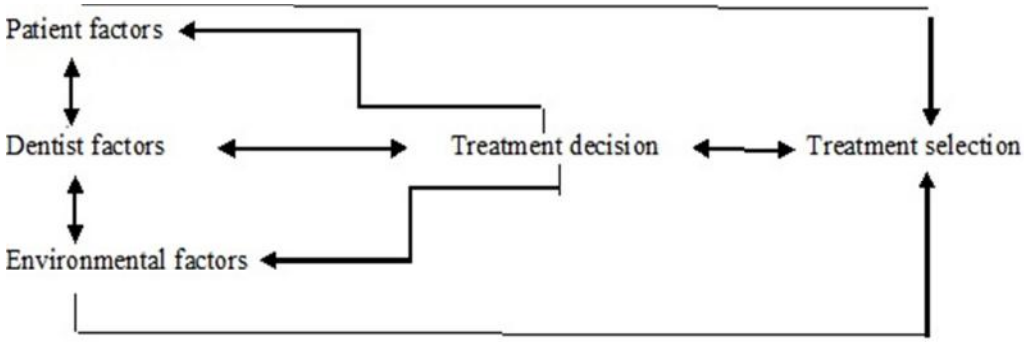

Figure 3: Dental decision-making (Adapted from Kay and Nuttall, 1997)

Bader and Shugars (1997) improved on their 1992 conceptual model for the decision-making process of dentists regarding treatment (Figure 1). The authors admit that the model is not based on any theoretical framework but borrows from several theories of decision-making and incorporates the authors' empirical observations. The model reflects decision-making processes employed by experienced dentists as opposed to learners or novices. The model suggests that dentists do not use a hypothetico-deductive reasoning process but rather identify caries through pattern recognition that is linked to decisions to intervene. The scripts comprise salient factors that are dependent on individual characteristics and biases and thus, they vary among dentists (Bader and Shugars, 1997).

Maupome and Sheiham (2000) argued that previous studies described what clinicians ought to be doing, how they process information while making decisions can be replicated by numeric algorithms and what clinicians seem to be doing when making sense of information. Actual research on what clinicians do while processing information for diagnostic/management applications was rare. Maupome and Sheiham (2000) proposed the use of the Gale and Marsden cognitive theoretical framework (Gale and Marsden, 1983) in an educational setting. In contrast to other studies, there was no significant differences in the range of DTPs available to either experienced or novice clinicians (Maupomé and Sheiham, 2000). A key finding of this research was that non-clinical, non-biological issues affected the appraisal of needs (Maupomé and Sheiham, 2000).

Following on from this, Maupome and Sheiham (2002) shifted their conceptual framework to case-study research of explanatory models (EM) of illness using simulated patients. The decision was based on the assumption that EMs are the personal representations of a specific illness entity – the cultural models used to interpret some aspect of reality. The authors acknowledged, however, that the findings from their study could not be transferred to practising dentists or to other dental-education settings but encouraged researchers to judge the applicability or to reproduce the work (Maupome and Sheiham, 2002).

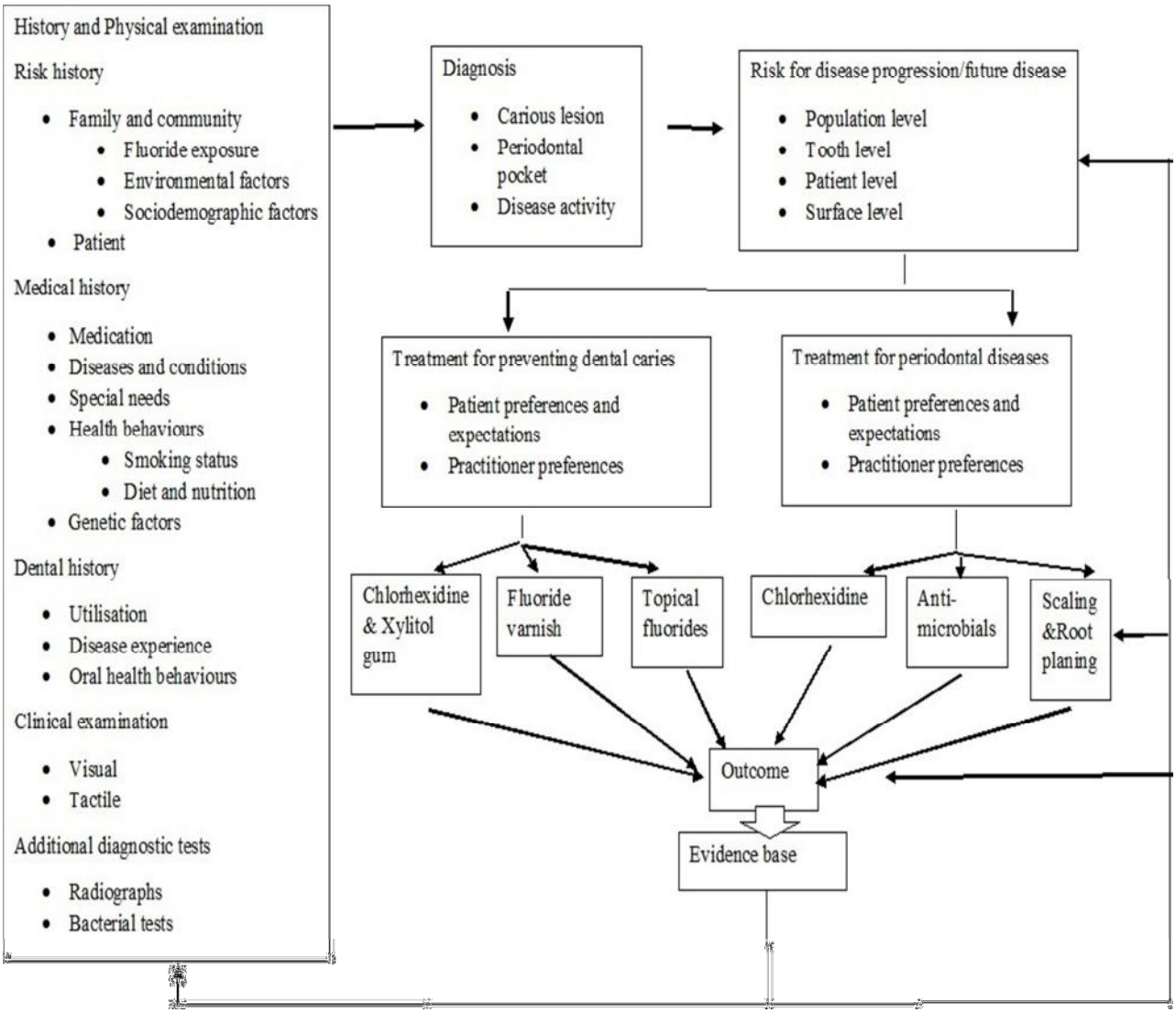

Figure 4: Hypothetical decision model (White and Maupomé, 2003)

Decision-analysis methods include Bayes theorem, decision tree design, receiver-operating-characteristic curves, sensitivity analysis and utilities assessment (McCreery and Truelove, 1991a). A hypothetical decision model is another clinical example of applying the clinical decision framework as seen in Figure 4.

It is apparent from the evidence that the decision-making process is complex but generally involves several important steps in which patient involvement is essential (Kay and Nuttall, 1997; White and Maupomé, 2003; Hajjaj *et al*., 2010). These steps involve:

- Recognising and clarifying the problem
- Identifying potential solutions
- Discussing the options and uncertainties
- Providing tailor-made information
- Checking understanding and reactions
- Checking patient's preferences
- Exploring the patient's view
- Agreeing with the patient about a course of action
- Implementing the chosen course of action
- Arranging follow-up with the patient
- Evaluating the outcome

2.3.2 Restorative treatment variation in practice

Internationally, there is a growing body of literature describing variation in rates and practice patterns among dental practices (Bader and Shugars, 1995a; Palotie, 2009; Alexander *et al*., 2014). Measuring these differences among practices usually includes descriptive rates of procedures viz. number of extractions per 100 patient visits or income for a specific procedure. These are useful in comparing procedures regionally or nationally.

It is accepted that not all dentists will make the same treatment choice when confronted with the same clinical situation (Maryniuk, 1990; Bader and Shugars, 1992; Bader and Shugars, 1995b). The differences among professionals are commonly accepted as reflections of the "art of dentistry" and are described as natural variations in dentists' "clinical judgments" (Maryniuk, 1990).

Maryniuk (1990) attempted to explain the variation in dentists' treatment decisions, exclusive of clinical data. The author rationalised that the development of clinical judgement during dental school training ultimately shapes the way they think, solve problems and make decisions. Two explanatory models of practice variation were suggested. The first model that depicted the dentist as a self-fulfilling practitioner proposed that a large proportion of dental care was driven by the dentist's desire for an income. This model of financial gain meant that dentists were acting for self-gain, which included a desire for a certain style of practice, their own preferences, practice setting and influence over fellow professionals. The second model that depicted the dentist as the patient's agent had several components. Dentists would primarily defend patients' economic well-being, which may be in conflict with their own self-interests. This may be explained where cast restorations are recommended over conventional amalgam or composite restorations because the dentists' profit margins would be greater.

These variations in judgement highlight the aspects of dentistry in which there is uncertainty or disagreement concerning the most effective approaches to treatment, and this may also compromise the effectiveness of the care. Kay and Nuttall (1997) suggested that differences in treatment variations could stem from two main sources, perceptual variation and judgemental variation. Perceptual variation is when people perceive things differently. For example, when dentists examining the same tooth disagree about what they are observing, they 'see' different conditions (Kay and Nuttall, 1997). Consequently, their treatment decisions will differ because they think they are seeing different levels of the disease. Judgemental variations occur when people have different opinions, for example, dentists examining the same tooth may agree about what they see but disagree about how it should be treated.

This variability in treatment decisions and the consequences have encouraged the development of guidelines that aim to reduce variation and assure quality of care for all patients (Kay and Nuttall, 1997; Weber *et al*., 2011)

Marinho *et al*. (2001) reported that evidence chronicled yearly by the Dartmouth Atlas of Healthcare indicated that variation in healthcare is associated with three factors: (i) poor quality of science underlying clinical care; (ii) poor quality of clinical decision-making; and (iii) variations in clinical skill.

A review of patient and dentist factors associated with restorative treatment variation in practice follows.

2.3.3 Patient factors

Several characteristics of the patient have been associated with the decision to treat. Patients who changed dentists received twice as many restorations as those who did not (Bader and Shugars, 1992). In a study conducted in Dutch adults, more restorations were classified as requiring replacement among older patients and patients who visited the dentist regularly (Bader and Shugars, 1992). This supports the Elderton and Nutall (1983) finding that placing a restoration "invites lifelong repair and maintenance".

Alternative treatments varying in effectiveness, permanence, appearance and cost usually exist for most dental problems (Grembowski *et al*., 1988). Similarly, in the USA, patient choice often influences treatment selection, mainly because caries and periodontal disease are not life-threatening and because the majority of dental costs are paid out-of-pocket by the patient (Grembowski *et al*., 1988). Dentists recommend various levels of restorative care based on the patient's ability to pay (Maryniuk, 1990). The availability of dental insurance has been seen to influence treatment decisions by dentists (Bader and Shugars, 1992). Dentists may choose not to prescribe the best course of treatment and deny certain services to those who cannot afford them or make judgements about patients' preferences and abilities to pay.

However, selecting treatment alternatives primarily on the basis of cost raises issues of the appropriateness of care. This may be because dentistry has been regarded as a discretionary service, and dentists and patients are sensitive to cost considerations. This variation in treatment decisions may also introduce inappropriate treatment such as over- and under-treatment, both of which have long-term economic health implications (Bader and Shugars, 1992).

In a study conducted by Brennan and Spencer (2002), cost emerged as a major determinant of treatment choice where significantly cheaper alternatives existed. In a subsequent study by Brennan and Spencer (2006), the factors considered in the choice of alternative treatments by dentists were investigated. Dentists were asked to list the five main factors when choosing an alternative treatment for the following treatment pairs: 'crown v. build-up', 'root canal v. extraction', 'bridge v. denture' and 'prophylaxis v. scaling' (Brennan and Spencer, 2006).

2.3.4 Tooth level

Dentists' decisions with respect to caries vary in the diagnosis and detection phase. Evidence that differences in the criteria for diagnosis exist are found in studies involving diagnosis and identification (Maryniuk, 1990). Variation in diagnosis due to differences in tactile skills is also demonstrated in a few studies (Maryniuk, 1990). This can influence both the detection of disease and the evaluation of an existing restoration. Baders and Shugars (1995b) suggested that these differences could be attributed to two factors: skill and diligence in the examination; and the definition and criteria employed for the identification of disease.

Findings from a study conducted by Grembowski *et al*. (1988) found that technical factors such as age of patient, caries rate, extent of tooth damage and future plans for the tooth dominated over patient considerations when choosing alternative treatments.

There is ample evidence of variation among dentists' decisions to intervene, and this may be associated with the dentists' knowledge of the course of the disease (Nuttall *et al*., 1993). Most dentists also accept the notion that the course of the

disease and the effectiveness of any treatment are heavily influenced by a number of risk factors (Bader and Shugars, 1995b).

Since restorations and replacement of teeth account for large portions of practice time and dental expenditures, variations in treatment decisions may have substantial cost and policy implications (Bader and Shugars, 1997). Differences in how dentistry is practised locally or regionally are acknowledged but have not been studied frequently in South Africa.

2.3.5 Dentist factors

Research has indicated that factors specific to dentists such as age, education, practice arrangement and gender have also affected clinical decision-making and practice patterns. Dentists who were solo practitioners were more inclined to be more patient orientated (Grembowski *et al*., 1988).

In a study conducted in Brazil to assess the treatment decisions of clinicians in the Public Health Service regarding deep carious lesions, it was observed that younger dentists were more likely to adopt a more conservative treatment (Weber *et al*., 2011).

Other research focusing on productivity and gender implied that female dentists worked fewer hours, saw fewer patients and provided less services to the community (Spencer and Lewis, 1988; Atchison *et al*., 2002). A practice-based study investigating differences in male and female practice patterns found that female dentists adopted a more conservative restorative treatment approach. However, this finding was related to females in the sample who had fewer years since graduation and were prone to restoring at a greater depth when compared with their male counterparts (Riley *et al*., 2011).

Grembowski *et al*. (1988) also presented dentist-practice beliefs that they maintained could influence clinical decision-making. These beliefs were divided into five main categories: patient characteristics, practice characteristics, volume of services, manpower and the dental market. Dentists with preventive practice beliefs took fewer patient factors into consideration in their decision-making,

whereas patient-oriented dentists tended to work longer hours, be solo practitioners and have lower fees (Grembowski *et al*., 1988).

Kay and Blinkhorn (1996) conducted a qualitative investigation of factors governing the treatment-decision philosophies of dentists and found that clinical decision-making relied on a number of factors, not only on the disease process and treatment options. This paper presented a list of non-clinical factors that are considered when formulating treatment options (Table 1) (Kay and Blinkhorn, 1996).

Similarly, Brennan and Spencer (2001) referred to "belief scales", where attitudes, values and habits could lead to the development of preferences for particular techniques or procedures. Their study revealed that patient expectations were matched with practice beliefs and service patterns of dentists (Brennan and Spencer, 2001).

It is important to note that the selection of restorative materials is also influenced by dentists' educational background and experience. Dental training experiences have a major impact on the development of clinical judgement and practice patterns (Maryniuk, 1990). Dentists prescribe treatment based not only on principles and experience learnt during dental school but also on other sources following graduation, such as continuing education, dental journals, advice from colleagues or simply experiences in dental practice (Grembowski *et al*., 1989; McCreery and Truelove, 1991b; Kay and Nuttall, 1994; Bader and Shugars, 1997; White and Maupomé, 2003; Doméjean-Orliaguet *et al*., 2009). In addition, their decisions are influenced by fear of malpractice and financial self-interest (Grembowski *et al*., 1989).

A review on posterior amalgam restorations reported on changes to teaching approaches with regard to amalgam and resin composite (Mitchell *et al*., 2007). There was an increase in the teaching of resin composites for posterior restorations, and one dental school in the Netherlands reduced the time devoted to dental amalgam (Mitchell *et al*., 2007). In 2001, the Nijmegen dental school became the first amalgam-free dental school (Roeters *et al*., 2004).

Table 1: A classification of issues and questions relevant to treatment decision-making in general dental practice (Kay and Blinkhorn, 1996)

	Practitioner	**Patient**	**Profession**
Cost and benefits	How long will it take to do this treatment? Will this treatment be difficult to do? Is it financially viable to undertake this treatment?	Will the patient 'gain' anything by having this treatment? How well does the patient cope with the process of treatment? How much can the patient realistically afford to spend?	Will the patient think dentistry is beneficial if I take this option? Am I providing society with the benefits that they pay for?
Attitudes and values	Am I doing what is morally right? Is it ethical to undertake this treatment?	Will the patient feel as if I've made a good judgement? Does this patient trust me? Will the patient like me/my practice?	Does this treatment decision fit with what is generally regarded as 'right' by my peers? Would my peers think that this was the best option?
Actualisation of expectations	Am I behaving in the way I believe to be the best? How will this decision affect the way I feel about myself?	What does the patient expect as a result of this treatment? Will this treatment give the patient the outcome he/she will value most highly?	Am I doing my professional duty? Am I providing the treatment that the profession would expect to be provided?

2.4 SECTION 3: AMALGAM AS A RESTORATIVE MATERIAL

Dental caries is one of the most common diseases in the world, with approximately 80% of the population having experienced the condition (Sheldon and Treasure, 1999). In clinical practice today, dental restorations are regarded as a treatment for this disease. Currently, there are a number of restorative materials available on the market, with dental amalgam being one of the most controversial materials used. Numerous papers have reported on the trends of dental amalgam use (Widström *et al*., 1997; Widström and Forss, 1998; Ylinen and Löfroth, 2002; Burke *et al*., 2003; Du Preez *et al*., 2003; Rosenstiel *et al*., 2004; Burke, 2004; Wilson *et al*., 2004; Mitchell *et al*., 2007; Norlund *et al*., 2009; Kovarik, 2009; Khalaf *et al*., 2014). Dental amalgam continues to be used because of its low cost, durability and ease of manipulation and placement.

According to Alexander *et al*. (2014), the advantages of dental amalgam compared with resin-based composite include:

- increased wear resistance;
- reduced micro leakage;
- less effect on subgingival microflora and biofilm;
- less risk of enlarging the original cavity preparation during removal; and
- less time-consuming.

The disadvantages are that the material is not tooth-coloured, it cannot adhere to the tooth and so requires a macro-mechanical retention, and it contains mercury (Petersen, 2003). Opposition to the use of dental amalgam has centred around two issues, the potentially negative effect on a person's health and the environmental issues regarding dental amalgam waste management and disposal.

A review of the current debate with regard to the use of dental amalgam both globally and in the South African context follows.

2.4.1 Regulation of dental amalgam as a restorative material

Following the distribution of the WHO/FDI Consensus Statement on Dental Amalgam in 1995, the World Health Organization (WHO) received numerous

requests from WHO member states, organisations and individuals on various aspects related to the use of dental amalgam (Mitchell *et al*., 2007).

The United States Public Health Service (USPHS) issued a comprehensive report on the risk management of dental amalgam in 1993. The report concluded that there was no need to place restrictions on the use of dental amalgam. This was reaffirmed in 1995 (Widström *et al*., 1997). At the time that the WHO report was being prepared, available data indicated a 38% decrease in the number of dental amalgam procedures (Mitchell *et al*., 2007). This was attributed to a declining incidence in caries, widespread use of fluoridated water, availability of fluoride-containing toothpastes, rinses and gels, wider use of dental sealants and a greater public awareness of the need for and access to dental healthcare (Listl *et al*., 2015).

Recommendations for the use of dental amalgam emerged in some Nordic countries together with a requirement for the use of amalgam separators in dental surgeries (Ylinen and Löfroth, 2002; Burke *et al*., 2003). The safety of dental amalgam was emphasised, and it was recommended that use be avoided in pregnant women and children. In Norway, a general ban on the use of dental amalgam was introduced in 2008 and a complete ban in January 2011 (Burke, 2004; Lynch and Wilson, 2013b). Sweden and Denmark joined the ban due to concerns regarding the environmental impact (Lynch and Wilson, 2013b). Growing global concern around the environmental effects of the continued use of dental amalgam, a shift towards minimally invasive dentistry and patients' increasing demands for more aesthetic dentistry expressed the need for a world-wide reduction in the use of dental amalgam.

In Geneva (Switzerland), the recent Minamata Convention on Mercury (named after a city in Japan where serious health damage occurred as a result of mercury pollution in the mid-20th century) saw 90 nations undertaking to reduce and ultimately to cease the global production and use of mercury-containing products by 2020 (Mackey *et al*., 2014). The major highlights of the Minamata Convention on Mercury included a ban on new mercury mines, the phasing-out of existing mercury mines, control measures for air emissions and the international regulation

of the informal sector for artisanal and small-scale gold mining. Dental amalgam fillings are exempt from the 2020 ban, but delegates agreed to a "phase-down in the use of dental fillings using mercury amalgam" (Lynch and Wilson, 2013a). Some of the measures to reach that goal include (Mackey *et al*., 2014):

- minimising the need for dental restoration by setting national objectives aimed at dental caries prevention and health promotion;
- setting national objectives aimed at minimising its use;
- promoting the use of cost-effective and clinically effective mercury-free alternatives for dental restoration;
- promoting research and development of quality mercury-free materials for dental restoration;
- encouraging representative professional organisations and dental schools to educate and train dental professionals and dental students in the use of mercury-free dental restoration alternatives and to promote best management practices;
- discouraging insurance policies and programmes that favour dental amalgam use over mercury-free dental restorations;
- encouraging insurance policies and programmes that favour the use of quality alternatives to dental amalgam for dental restorations;
- restricting the use of dental amalgam to its encapsulated form; and
- promoting the use of best environment practices in dental facilities to reduce releases of mercury and mercury compounds to water and land.

The FDI (Federation Dentaire Internationale) and the ADA (American Dental Association) have given their support to the Minamata Convention. It is envisaged that this could result in a fundamental change in the clinical practice of dentistry and the training of future dentists.

2.4.2 Use of dental amalgam in clinical practice internationally

A questionnaire was developed from the questionnaire used by Widström and Forss (1998) in Finland to determine dentists' attitudes towards the use of dental

amalgam and resin-based composite (RBC) restorations in general practice (Burke, 1992). Fifty-nine percent of respondents reported a decrease in the use of amalgam over the previous five years, and 44% reported that their use of amalgam remained stable (Burke, 1992). In the USA, dental amalgam was considered the most commonly used posterior tooth restorative material in 2001 (Burke *et al*., 2003). Despite the various local, regional and global research projects by different expert groups, about 250 000 dentists within the European Union continued to treat their patients using amalgam restorations (Burke *et al*., 2003). There was little evidence to indicate whether this trend was also apparent in the United Kingdom (UK) (Burke *et al*., 2003).

When the data from the study of Burke *et al*. (2003) is compared with that of Widström and Forss (1998), the use of amalgam decreased by 58% in Finland between 1996 and 2001, and only 2% of British dentists reported not using amalgam compared with 37% of Finnish dentists. These differences may be due to the guidance issued by the Ministry of Social Affairs and Health in 1994, which recommended that the use of dental amalgam be decreased due to environmental reasons, as well as the different methods of funding in oral health care in the two countries. A 2007 review by Mitchell *et al*. (2007) on posterior amalgam restorations between 1996 and 2006 indicated a decline in the use of dental amalgam and an increase in the use of resin composites worldwide.

2.4.3 Use and teaching of dental amalgam in clinical practice in Africa

In low-resource communities, oral health services are either not available or poor, especially in rural and remote areas (Gray and Vawda, 2015). Where oral health services do exist, dental amalgam is a still the best choice in restorative dental care because of its affordability, ease of use and longevity (Rekow *et al*., 2013). Composites are favoured by private practitioners and patients for aesthetic reasons (Rekow *et al*., 2013). However, dental amalgam is regarded as a more forgiving and predictable material.

In 1997, Thorpe reported to the WHO that in the African region, dental amalgam is the most extensively used restorative material for the repair of decayed posterior teeth, mainly because of its advantages (Petersen et al., 2009).

A paper by Oginni and Olusie published in 2002 on the longevity of restorations in Nigeria stated that "[i]n Nigeria … dental amalgam has been used extensively as a tooth restorative material". However, no data was presented to support the statement. Burke (2004) reported that there was very little data available regarding the usage of amalgam in Africa.

In a 1999 survey regarding the use of dental materials by dentists in South Africa, it was found that 85.8% of respondents were still using amalgam as a restorative material (DuPreez *et al*., 2003). This was lower than the 99,7% reported in 1990 (DuPreez *et al.*, 2003). In 2009, Lombard *et al*. (2009) conducted a study to investigate and compare the teaching approaches regarding direct restorative techniques and materials in dental schools in South Africa with the teaching approaches in American, Canadian, Irish and United Kingdom schools. All four South African dental schools agreed that dental amalgam should still be included in teaching as a restorative dental material (Lombard *et al*., 2009). This was in accordance with research conducted at Canadian, Irish and United Kingdom dental schools (Lombard *et al*., 2009). Equal time was spent on the preclinical teaching of composites and dental amalgam. Conversely, five out of the eight dental schools in Canada placed a greater emphasis on silver amalgam.

2.4.4 Longevity of restorations

Evidence suggests that dental restorations have a limited lifespan and that once a tooth is restored, the filling is likely to be replaced many times in the patient's lifetime – "the restorative cycle" (Chadwick *et al*., 2001). The durability or longevity of a dental restoration is a salient factor in determining its effectiveness as a treatment for caries (Downer *et al*., 1999). Long-lasting dental restorations foster patient confidence in the practitioner and the profession and reassure that a cost-effective service is being provided.

The examination of patients for treatment needs frequently reveals restorations that do not conform to criteria for successful restorations but are capable of further clinical service and do not necessarily require replacement. A comparison of the longevity of dental amalgam restorations in different studies reported by different authors is problematic for various reasons (Downer *et al*., 1999).

The variables in the study designs are often poorly described or omitted. Differences in clinical procedures, materials used and variations in study characteristics make direct comparisons impossible (Hickel and Manhart, 2001). Similar sentiments were published by Chadwick *et al*. (2001) with regard to the challenges when conducting systematic reviews about the longevity of restorations.

In a clinical trial, a new restoration is the initial event, which is followed by a subsequent event, a replacement. The time between these two events is called survival time. The results of longevity of restorations can be represented in different ways, but the difference is that the subsequent event (i.e. the replacement) may not have occurred for all restorations. Controlled clinical trials are a necessary part of long-term evaluation, but they are time-consuming and costly. Controlled clinical trials do not adequately portray the general dental practice setting. Cross-sectional studies differ from longitudinal studies in which clinicians operate under ideal conditions for the materials investigated. Downer *et al*. (1999) pointed out that cross-sectional studies involving retrospective case record examinations by non-standardised examiners can give insights into effect modifiers such as the dental care system, but such studies do not rate highly in the hierarchy of acceptable evidence. The authors have also cautioned about the confusion in the nomenclature; median survival time is the life-time that any individual restoration has a 50% change of exceeding. The expression is routinely used in cross-sectional studies, but it would be more correct to speak of median functional periods of failed restorations (Downer *et al*., 1999; Forss and Widström, 2001; Chadwick *et al*., 2001). As a result, cross-sectional studies give an underestimation of the average lifespan of routine restorations. The value of the cross-sectional study is that it clarifies the decisions made by ordinary dentists in general dental practice.

In an attempt to investigate the treatment patterns of dentists more accurately, studies have been conducted to determine restoration longevity by using dental insurance-claim databases (Bogacki *et al*., 2002) and more recently, practice-based research (Mjor *et al*., 2005; Gilbert *et al*., 2011 and Gilbert *et al*., 2013). Despite these limitations, certain trends are apparent.

Numerous studies have investigated the longevity of direct restorative materials and more specifically, have compared dental amalgam with resin-based composite. Table 2 summarises the results of selected clinical studies on the longevity of amalgam restorations. In these studies, annual failure rates range from 0.6–15%. The main causes of failure of the restorations were secondary caries, bulk and tooth fractures and marginal ditching. Advances in the technology of resin-based composites and the placement techniques have occurred; the evidence suggests that dental amalgam still exhibits better survival rates than resin-based composites although the evidence is conflicting (Bogacki *et al*., 2002; Van Nieuwenhuysen *et al*., 2003; Lucarotti *et al*., 2005a; Bernardo *et al*., 2007).

Downer *et al*. (1999) conducted a systematic review in 1999 and found insufficient evidence to compare amalgam and composite restoration longevity. A more recent Cochrane Review published in 2014 found only two studies could be included. A review conducted by Moraschini *et al*. (2015) included eight studies, using the Newcastle-Ottawa scale that includes non-randomised cohort studies. Moraschini *et al*. (2015) confirmed that occlusal and occlusoproximal amalgam posterior restorations have a greater longevity than composite restorations. Both studies compared the longevity of amalgam versus resin composite, with a mean survival rate of 92.5% and 85.8% respectively, with a mean follow-up of 72 months in 2014 and a mean survival rate of 92.8% and 86.2% respectively with a mean follow-up of 55 months in 2015 (Hurst, 2014; Moraschini *et al*., 2015).

Bonsor and Chadwick (2009) compared the longevity of conventionally placed dental amalgam restorations with bonded amalgam. They concluded that bonded amalgam restorations had no significant effect on the longevity of restorations and that conventionally placed amalgam displayed a more gradual decline in survival (Bonsor and Chadwick, 2009).

Table 2: Longevity of dental restorations (1969–2015)(updated from (Hickel and Manhart, 2001)

Year	First author	Observation period (yrs.)	GV Black	Restorative materials	Number of restorations (n)	Number of patients (n)	Study design	Survival Rate (%)	Annual failure rate (%)	Median Survival Time (yrs.)	Remarks
1969	Allan	10	I II	Amalgam (alloys not specified, gamma-2 alloys)	78 92		Cross-sectional	54 39	4.6 6.1		Slightly better performance in class I cavities
1971	Robinson	20	I II	Amalgam (alloys not specified, gamma-2 alloys)	145		Cross-sectional	22, 8	3, 9	10	75% of the amalgam restorations lasted >5 years
1976	Lavelle	20	I II	Amalgam (alloys not specified, gamma-2 alloys)	6000		Cross-sectional		4, 8		Main failure reasons: secondary caries, fracture
1976	Lavelle	20	I II	Amalgam (alloys not specified, gamma-2 alloys)	400		Longitudinal		7	<10	
1977	Allan	20	I II	Amalgam (alloys not specified, gamma-2 alloys)	148		Cross-sectional	14	4,3	8	
1981	Crabb	10	I II	Amalgam (alloys not specified, gamma-2 alloys)	269 530		Cross-sectional	59.5 37.2	4.1 6.3	>10 8	Slightly better performance in class I cavities
1984	Paterson	15	I II	Solila	854 1490		Cross-sectional			8, 7	No difference between class I and class II amalgams

Table 2: Longevity of dental restorations (continued)

Year	First author	Observation period (yrs.)	GV Black	Restorative materials	Number of restorations (n)	Number of patients (n)	Study design	Survival Rate (%)	Annual failure rate (%)	Median Survival Time (yrs.)	Remarks
1984	Paterson	15	I II	Solila	854 1490		Cross--sectional			8, 7	No difference between class I and class II amalgams
1989	Letzel	5-7	I II	Conventional and high copper alloy	2341		Longitudinal	88–91			
1989	Moffa	5	I II	Amalgam (alloys not specified)	314			90 75	2 5		
1990	Qvist		I II	Amalgam (alloys not specified)			Cross-sectional			9.5 8	
1990	Smales	3	I	Dispersalloy	13		Longitudinal	100	0		Small restorations
1990	Welbury	5	I	Amalcap	150	103	Longitudinal	92, 7	1,5		All amalgams failed due to recurrent caries
1991	Jokstad	7-10	II	4 non-gamma-2 alloys; 1 conventional alloy	256	141		73, 5	2.7–3.8		Main failure reasons: secondary caries and bulk fracture; no significant difference between gamma-2 and non-gamma-2 alloys

Table 2: Longevity of dental restorations (continued)

Year	First author	Observation period (yrs.)	GV Black	Restorative materials	Number of restorations (n)	Number of patients (n)	Study design	Survival Rate (%)	Annual failure rate (%)	Median Survival Time (yrs.)	Remarks
1991	Osborne	14	I II	5 gamma-2-alloys and 7 non-gamma-2 alloys	367	40	Longitudinal	87,2	0, 9		Gamma-2 amalgams had 84% success rate, non-gamma-2 alloys had 91.6%
1991	Pieper	9-11	I II	Amalgam (alloys not specified)	129 413		Cross-sectional	85,3	1.3–1.6		
1991	Smales	Nov 18	I II	New True Dentalloy, Dispersalloy,Shofu Spherical	1680		Cross-sectional		1.0–1.7 and 6.3		Shofu Spherical showed an annual failure rate of 6.3% while the other alloys failed 1–1.7% a year
1991	Smales	15	II	Amalgam(alloys not specified)	768			72	1,9		No difference in survival time between cusp-covered class II amalgam and restorations without cusp-coverage.
1992	Mjor			Amalgam(alloys not specified)	360		Cross-sectional			4,7	

Table 2: Longevity of dental restorations (continued)

Year	First author	Observation period (yrs.)	GV Black	Restorative materials	Number of restorations (n)	Number of patients (n)	Study design	Survival Rate (%)	Annual failure rate (%)	Median Survival Time (yrs.)	Remarks
1993	Mjor	5	II	Dispersalloy	88		Longitudinal	95	1		Estimated survival function. Small class II cavities
1994	Jokstad	>10	I II	Amalgam (alloys not specified)	803 >3000		Cross-sectional			14, 7-11	Increasing number of affected surfaces of class II restorations results in a lower median longevity
1994	Mahmood	>14	I II	Amalgam (alloys not specified)	245(P) 455(A)		Cross-sectional			7.99	Study conducted in Pakistan(P) and Australia (A)
1996	Smales	15	II	Amalgam (alloys not specified)	160		Cross-sectional	47,8	3,5		Cusp-covered amalgam restorations
1996	Wilson	5	I II	High copper alloys (Sybralloy, Dispersalloy, Tytin)	172		Longitudinal	94, 8	1		Deterioration was greater in molars and large-sized restorations
1997	Hawthorne		I II	Amalgam (alloys not	1371		Cross-sectional			22, 5	Life-table method.

Table 2: Longevity of dental restorations (continued)

Year	First author	Observation period (yrs.)	GV Black	Restorative materials	Number of restorations (n)	Number of patients (n)	Study design	Survival Rate (%)	Annual failure rate (%)	Median Survival Time (yrs.)	Remarks
				specified)							
1997	Letzel	13	I II	Conventional zinc-free, conventional zinc containing, high copper zinc-free, high copper zinc-containing	3119			25 70 70 85	5.8 2.3 2.3 1.2		Zinc and copper content of the alloy contributed to the corrosion resistance of the amalgams Main failure reasons: fractures, marginal ditching, recurrent caries
1997	Mjor	>25	I II	Amalgam (alloys not specified)	282		Cross-sectional			9	Main failure reasons: secondary caries (50%), fracture (29%)
1997	Roulet	6	I II		163	43	Cross-sectional	87, 5	2, 1		Kaplan-Meier method. Main reasons for replacement: fracture

Table 2: Longevity of dental restorations (continued)

Year	First author	Observation period (yrs.)	GV Black	Restorative materials	Number of restorations (n)	Number of patients (n)	Study design	Survival Rate (%)	Annual failure rate (%)	Median Survival Time (yrs.)	Remarks
1997	Smales	5, 10	II	Amalgam (alloys not specified)	160		Cross-sectional	77.6 66.7 47.8	4.5 3.3 3.5	14, 6	Extensive amalgam restorations with cusp replacement
1998	Kreulen	15	II	New True Dentalloy, Tytin, Cavex	1117	183	Longitudinal	83		1, 1	Replacement risk for MOD is significantly higher than for MO/OD replacement
1998	Mair	10	II	New True Dentalloy, Solila Nova	35		Longitudinal	94,3	0,6		
1998	Plasmans	8	II	Cavex (non-gamma-2)	266	130	Longitudinal	88	1,5		Large amalgam restorations in molars with cusp replacement
1999	Burke		I II		268 1142		Cross-sectional			7.4 6.6	

Table 2: Longevity of dental restorations (continued)

Year	First author	Observation period (yrs.)	GV Black	Restorative materials	Number of restorations (n)	Number of patients (n)	Study design	Survival Rate (%)	Annual failure rate (%)	Median Survival Time (yrs.)	Remarks
1999	Circhon	8	1,2, 3 S	Amalgam (alloys not specified)	820		Cross-sectional	80 73.2 71.1	2.5 3.4 3.6		Severe mentally and/or physically handicapped patients
1999	Kamann	6	I II		62 21		Longitudinal	83.9 66.7	2.7 5.6		Main failure reasons: secondary caries
2007	Soncini	5		Amalgam	509	534	Longitudinal		15, 9		Need for replacement increased with the size of the restoration
2007	Opdam	5 10	I II	Amalgam Dispersed phase	912	621	Longitudinal	89.6 79.2			
2007	Bernado	7	1,2, 3,4	Amalgam Dispersed phase			Longitudinal	0,8,2			Study conducted in subjects aged 8–12 years
2009	Kakilehto	20			19892		Retrospective				Data mining of 4 patient record centres in Finland

Table 2: Longevity of dental restorations (continued)

Year	First author	Observation period (yrs.)	GV Black	Restorative materials	Number of restorations (n)	Number of patients (n)	Study design	Survival Rate (%)	Annual failure rate (%)	Median Survival Time (yrs.)	Remarks
2010	Opdam	5 12	II 4/5	Dispersalloy	1202		Retrospective		0.98 2.05		Practice-based research of 1 dentist
2012	Kopperud	4	II	Amalgam, compomer, resin composite, glass ionomer	4030	1873	Practice based	93 % (Hg), 88% (Au)			Practice-based research of 27 dentists
2015	Laske	15		Composite, amalgam, compomer, glass Ionomer	432044	76071	Longitudinal descriptive		4.5, 5.1, 7.1, 10.7		Practice-based research of 67 dentists

Some disparity also exists in the results from longitudinal clinical trials, which present a more comparable or slightly better longevity of amalgam restorations as opposed to cross-sectional retrospective studies. Furthermore, practice-based research found that the longevity of amalgam restorations was twice as much as the composite restorations (Opdam *et al*., 2007). This could be explained by the fact that in longitudinal studies, operators are well trained and calibrated whilst in cross-sectional studies, they may have more experience in working with amalgam than with posterior composites (Opdam *et al*., 2007).

The longevity of restorations is dependent on a variety of factors such as patient- , dentist- and material-related factors as summarised in Table 3. Studies have also reported that proportionally, more resin composite restorations failed (77.9%) because of secondary caries than amalgam restorations (22.1%) (VanNieuwenhuysen *et al*., 2003; Hurst, 2014). Reasons for this include the formation of oxides at the amalgam-tooth interface that seal the margin, thereby reducing caries, as well as adhesive failures in the resin composite restorations that increase the development of recurrent caries, thus creating a difference in caries risk in the amalgam and resin-composite sample groups (Moraschini *et al*., 2015).

The number of surfaces involved in the restoration may also influence the longevity of the restoration. Lucarotti *et al*. (2005b) found that 58% of single-surface amalgam restorations survived better compared with 43% of mesial-occlusal-distal (MOD) amalgams. Similarly, Bernardo *et al*. (2007) found that large restorations and those with three or more surfaces had the lowest survival rate. Findings from the New England Children's Amalgam Trial were consistent with previous reports that in permanent teeth, the need for replacement increased significantly with the size of the restoration (Soncini *et al*., 2007).

In everyday clinical practice, several factors relating to the patient and the clinician may have an unfavourable effect on the survival of a restoration, but there is very little information available regarding this. The factors may include the age of the patient, the gender of the clinician, operator skill, the materials and

techniques used, patient compliance with oral hygiene advice, caries susceptibility and possibly, the means by which the treatment is funded (Table 3).

Burke *et al*. (2001) confirmed that although the influence of high caries activity was not clear, good oral hygiene enhanced restoration longevity, heavy occlusal function decreased the restoration longevity, increased patient age improved restoration longevity and the patient's gender had no effect.

Table 3: Factors influencing the longevity of dental restorations (Hickel and Manhart, 2001)

Patient	**Dentist**	**Material**
Oral hygiene	Correct indication	Strength (fractures)
Preventive measures	Cavity preparation (size, type, finishing)	Fatigue/degradation
Compliance in recall	Handling and application (e.g.	Wear resistance (occlusal contact areas, contact-free
Oral environment	incremental vs. bulk	areas)
(quality of tooth	placement)	Bond strength
structure, saliva, etc.)	Curing mode (device,	
Size, shape, location of	time, light intensity)	Chemical compatibility of
the lesion and tooth	Mode of finishing and	restorative systems (DBA,
(number of surfaces,	polishing the restoration	composite)
vital vs. non-vital,		
premolar vs. molar)		
		Technique sensitivity
Cooperation during	Correct occlusion	Caries-inhibiting effects
treatment	Experience (with	(release of substances)
Bruxism/habits	material)	

A practice-based study that included three private practices with twenty dentists was conducted by Hawthorne and Smales (1997). This study examined the effects on restoration longevity of dental practice, age of patient when restoration was placed, frequency of attendance for treatment, change of dentist, experience or graduation age of dentist and restoration placement (initial or replacement). The study reported excellent survival times for all the restorative materials, possibly due to the regular attendance of motivated patients, the fairly low turnover of dentists and the remuneration system in which the majority of the cost was borne by the patient. Hawthorne and Smales (1997) determined that a change of dentist had no effect on the longevity of restorations. Conversely, Bogacki *et al.* (2002) used an insurance-claim database and observed that amalgam and resin composite restorations had a greater chance of failure when patients changed dentists.

Dobloug and Grytten (2015) estimated dentist-specific variation in the longevity of restorations in first permanent molars for children aged 6–18 years over a 12-year period. The authors reasoned that if the dentist variation was considerable, then the focus should shift to reassessing the teaching practices in restorative dentistry. If the patient variation was large, then the focus should be on strategies to improve their dental behaviour. The results of the study confirmed that variation between dentists was low and, therefore, most of the variation was attributed to patient factors such as secondary caries and the age of the patient (Dobloug and Grytten, 2015). These findings may be difficult to extrapolate to the South African context since the study was conducted in Norway. In Norway, all children under the age of 18 years receive free dental treatment, and there are no economic incentives that could influence treatment decisions (Dobloug and Grytten, 2015).

A more recent retrospective, practice-based study reported on the largest dataset of 400 000 restorations placed by general dental practitioners between 1996 and 2011 (Laske *et al*., 2016). The research focused on the longevity of restorations and explored the effect of practice/operator, patient and tooth/restoration factors on restoration survival. Considerable variation in longevity of restorations among the practices was found, with the annual failure rate (AFR) showing values between 2.1% and 6.4% (Laske *et al*., 2016). A lower restoration survival was

recorded for larger team practices (Laske *et al*., 2016). One could assume that in large practices, patients are more often seen by different dentists and hence, changing dentists could lead to a higher replacement rate of fillings (Laske *et al*., 2016).

2.4.5 Replacement of restorations

Dental restorations are often described as "permanent" but in reality, do not last a lifetime (Fejerskov and Kidd, 2009). Each time an amalgam restoration is replaced, there is loss of healthy tissue, thus increasing the size of both the preparation and the restoration (Gordan, 2000; Gordan, 2001 and Gordan *et al*., 2004). Although the cost of replacing an existing restoration is about the same as the original restoration, the complete replacement of large restorations is time-consuming, technically difficult and may be potentially damaging to the pulp (Moncada *et al*, 2008).

Approximately 72% of amalgam restorative treatment is performed to replace existing restorations, and the two primary reasons are recurrent caries and faulty margins (Gordan *et al*., 2009). Dentists are frequently faced with a clinical decision either to replace or repair a defective amalgam restoration. However, there is evidence to suggest that the replacement restoration may incorporate many of the inherent faults of the original restoration (Smales and Yip, 2012).

A recent study in the USA revealed that 30% of posterior restorations are replaced within a two-year period (Palotie and Vehkalahti, 2012). The data reviewed in previous studies indicate that every day, clinical practice in Scandinavia, the UK and the USA included and continue to include more replacements than new restorations (Burke *et al*., 1999; Deligeorgi *et al*., 2001). In one of the few studies conducted in Africa, only 24.8% of amalgam restorations placed were replacements (Oginni and Olusile, 2002), which is in contrast to studies conducted elsewhere. These findings could possibly be attributed to a decrease in caries incidence in developed countries and an increase in developing countries.

2.4.5.1 *Diagnosis for restoration replacement*

Numerous studies have been conducted in different countries and in different settings to record the reasons for restoration replacements (Appendix A). Information from these types of studies is important in order to determine treatment patterns and to prevent future failures. Maupomé and Sheiham (1998) cited Boyd (1989) who maintained that "reasons of failure" included different concepts assembled according to the judgement of a given clinician.

The principal reason for the replacement of amalgam and resin composite restorations has been secondary caries (Mjör and Toffenetti, 2000). Deligeorgi *et al*. (2001) reviewed findings of the last two decades concerning the placement and replacement of restorations. In order to clarify dentists' diagnoses of secondary caries, Mjor *et al*. (2000) sought to differentiate between frank and limited caries in their study of the replacement of restorations in student clinics in Manchester, England and Athens, Greece. Recurrent caries refers to caries of the tooth at the margin of restorations, and although secondary caries is histologically similar to primary caries, diagnostically, it is a challenge for dental practitioners because many lesions are not always at the interface of the tooth and restoration (Gordan *et al*., 2009).

Micro-leakage has been traditionally linked to the presence of secondary caries, but research has proved that it is not a predictor of secondary caries (Dennison and Sarrett, 2012). This uncertainty in diagnosis often means that a clinical diagnosis is made when the probe catches any gap between the enamel and a restoration. Recent research suggests that operative intervention be delayed unless "there is clear evidence of soft dentin in marginal gaps larger than 250 µm" (Ozer,1997 and Dennison and Sarrett, 2012).

The majority of surveys regarding the reasons for replacement of amalgam restorations indicated the frequency of secondary caries diagnosis as being between 50% and 60% (Mjor, 1981; Klausner and Charbeneau, 1985; Klausner *et al*., 1987; Mjör and Toffenetti, 1992; Friedl *et al*., 1994; Mjör, 1997; Mjor *et al*., 2000). Dennison and Sarrett (2012) reported that the diagnosis of secondary caries

and the determination of appropriate treatment are among the most clinically challenging tasks.

The visual, tactile and radiographic information used by dentists is often not linked to the diagnostic criteria that are universally accepted or taught in dental schools (Dennison and Sarrett, 2012). Ongoing research has described secondary caries as a combination of an outer lesion and a wall lesion (Mjör and Toffenetti, 2000; Fejerskov and Kidd, 2009). The outer lesion is typically found as primary caries in the tooth structure adjacent to the restoration. Histologically, there is no difference between primary and secondary caries. Clinically, secondary caries is found most often on the gingival margins of restorations and less frequently at occlusal margins (Mjör, 2005).

Although more recent studies have reported lower frequencies (Oginni and Olusile, 2002; Tyas, 2005; Olaleye, 2013; Bahsi *et al*., 2013; Silvani *et al*., 2014), the decline in frequency could be attributed to an improved diagnostic ability of dentists or a decrease in the use of amalgam. Findings from a cross-sectional, retrospective, records-based study in Nigeria contradicted earlier studies when it was found that secondary caries was not a major reason for the amalgam replacements, with a frequency of only 11.6% (Olaleye, 2013).

Other common reasons to replace a defective amalgam restoration include bulk fracture of the amalgam as well as marginal fracture and marginal degradation. Tooth fracture accounted for 10–15% of the reasons for amalgam replacement in other controlled and longitudinal studies (Burke, 1992; Mjör, 1997). Tooth fracture is a common clinical problem, which may vary from a minimal enamel fracture to the fracture of an entire cusp or a longitudinal fracture that may lead to the eventual loss of the tooth (Burke, 1992). It may be caused by a faulty cavity preparation in which insufficient, unsupported enamel has been removed or in which the remaining enamel is too thin (Burke, 1992). Food and the patient's chewing habits may also contribute to the development of restoration or tooth fractures (Akerboom *et al*., 1986). In the study conducted by Oginni and Olusile (2002), bulk amalgam fracture was the most frequent reason for amalgam replacement at 47%.

There have been conflicting reports on the value of marginal degradation as a good predictor of loss of amalgam restorations. Hamilton and Moffa (1983) reported marginal failure was not a predictor for restoration longevity. As early as 1988, the replacement criteria developed clearly stated that the "the presence of a marginal gap alone is not a criterion for restoration replacement" (Anusavice, 1988). In 1991, Osborne maintained it was a good predictor for the loss of amalgams, while Mjor (1997) concluded that marginal degradation as a reason for replacement of amalgam remained controversial.

It is anticipated that restorations with limited defects but with many serviceable years left will not be replaced (Mjor and Toffenetti, 2000). The recommendation is that the defective margins should be ground and polished and repaired with amalgam or sealed with fissure sealant (Mjor and Toffenetti, 2000). In addition, "marginal defects without visible evidence of soft dentin on the wall or the base of the defect should be monitored for change or repaired or sealed and then monitored" (Dennison and Sarrett, 2012). Dennison and Sarrett (2012) also advocate removing some of the existing restorative material to visualise the walls and base of the defect better prior to repair or sealing.

Interestingly, only one paper reported aesthetics as a main reason for the replacement of dental amalgam restorations (Silvani *et al*., 2014). In this study, which was performed in a dental clinic at a Brazilian university, 36.59% of amalgam restorations were replaced for aesthetic purposes based on the patients' desires to have restorations similar to the tooth structures, despite the restorations being clinically satisfactory.

2.4.6 Management of defective restorations

Clinical studies conducted provide evidence for clinicians that repair is a safe alternative to replacement for restorations that present with localised defects in marginal areas, including gaps with exposed dentin, loss of anatomic form, altered contact or secondary caries (Moncada *et al*., 2008; Moncada *et al*., 2009; Moncada *et al*., 2010; Fernández *et al*., 2011; Martin *et al*., 2013; Moncada *et al*., 2015a, 2015b) (Appendix B).

Moncada *et al*. (2015a, 2015b) in their 10-year longitudinal study noted that all repaired restorations experienced deterioration over the period of time, but they were still clinically acceptable. Reasons for the downgrade of scores were not explored and are opportunities for further research. The findings of this study are in contrast to a similar study conducted by Smales and Hawthorne (2004). The data in the study by Smales and Hawthorne (2004) was collected from established private practices because the authors believed it provided a more stable environment to evaluate the success of dental treatments. Another difference was that treatment decisions were based on the clinical judgements of the individual dentists and not on calibrated clinicians and USPHS criteria (Smales and Hawthorne, 2004).

Although there was no statistically significant difference between the survival of replaced and repaired amalgams (p=0.37), approximately 63% of the replaced amalgams were still present at 10 years and 50% at 15 years, while only 37% of the repaired amalgams were still present at 10 years (Smales and Hawthorne, 2004). It could be postulated that in the study by Smales and Hawthorne (2004), only dental amalgam restorations with an actual clinical failure were repaired as opposed to criteria on a specific list. Similar findings were reported in a longitudinal, retrospective, practice-based study on repaired restorations by Opdam and Bronkhorst (2012).

The lack of standardised criteria may be a failing of practice-based studies, but they offer unique opportunities for follow-up restorations in real-world settings. In addition, using standardised criteria required that restorations that may not have been ordinarily treated were treated, as in the studies by Moncada *et al*. (2015a, 2015b), Martin *et al*. (2013), Moncada *et al*. (2010) and Moncada *et al*. (2009). This could imply a potential for overtreatment.

Cochrane Reviews evaluating the evidence for effectiveness of replacement versus repair of defective amalgam and composite restorations in permanent molar and premolar teeth found that none of the studies reviewed provided reliable evidence (Sharif *et al*., 2010). They called for more methodologically sound, randomised controlled trials to be conducted. Balevi (2014) acknowledged

that “while Sharif *et al*. (2014) ‘s updated review is relevant and appropriate, it is unlikely that any future study would ever meet the strict criteria”. It would be unethical randomly to assign a patient with obvious caries around an amalgam restoration to the ‘no treatment’ group.

It is accepted that more clinical studies are required to support the current evidence regarding the benefits of repairing defective dental amalgam restorations. However, the present study focused on the clinical decision-making process of selecting a treatment option in the management of defective dental amalgam restorations.

2.4.7 Treatment options for defective dental restorations

The current management options for defective dental amalgam restorations are repair, refurbishing and replacement of the restoration. These options are in line with the contemporary, minimally invasive concept in restorative dentistry (Mjör, 2007). Setcos *et al*. (2004), in their study of treatment decisions of repair or replacement of amalgam restorations at a school in the USA and the UK, described sealing, refurbishment and repair together with indications for each approach. These were redefined and published by the Word Dental Federation in 2010 (Hickel *et al*., 2010) (Appendix C). In addition, a helpful guide for clinical situations with recommendations regarding repair or replacement was published in 2013 (Hickel *et al*., 2013) (Table 4).

Table 4: Clinical situations with recommendations for repair or replacement (Hickel *et al*., 2013)

Clinical Problem	Repair	Replacement
1. Marginal Problems Marginal Staining	Pronounced localised marginal staining	Deep marginal staining, not accessible
Marginal adaptation	-Gap >250 µm or dentine/base exposed -Severe ditching or marginal fractures (tooth or restorative material) -Larger irregularities or (negative) steps	-Restoration (complete or partial) is loose but in situ -Generalised major gaps or irregularities
Caries adjacent to restoration (secondary caries)	Severe marginal demineralisation or caries with cavitation and suspected undermining caries but localised and accessible	Deep caries or exposed dentine that is not accessible for repair
2. Surface problems Surface lustre	Voids or rough surface, cannot be masked by saliva film, simple polishing is not sufficient	Generalised very rough and unacceptable plaque retentive surface
Aesthetic anatomical form	Form is affected and unacceptable aesthetically Intervention/correction is necessary	Form is unsatisfactory and/or lost Repair not feasible or reasonable
Approximal anatomical form	Contact form too weak and possible damage due to food impaction or inadequate contour	Contact form too weak and/or clear damage due to food impaction and repair not feasible/possible
Occlusal contour and wear	Wear considerably exceeds normal enamel wear, occlusal contact points are lost	Generalised excessive wear, repair not feasible
3. Fractures and bulk loss		
Closure of access cavity after endodontic treatment	Remaining restoration (larger filling or crown) is sufficient	Remaining restoration is insufficient, repair not feasible.
Fracture of restorative material	-Chip fractures that damage marginal quality or proximal contact or contour -Bulk fractures with partial loss (less than one-half) of the restoration	Partial or complete loss of restoration and/or multiple fractures
Tooth integrity (enamel cracks, tooth fracture)	-Larger cracks >250 µm, probe penetrates -Large enamel chipping or wall fracture -Cusp fractures (that are easily accessible for repair)	Large cusp or tooth fracture
4. Patient's view	Desire for improvement in aesthetics or function e.g. tongue irritation and reshaping of anatomic form or refurbishing impossible/insufficient	Completely dissatisfied and/or adverse effects, including pain

There are four management options for defective restorations as first introduced by Mjor and Gordan (2002) and more recently by Hickel *et al*. (2010):

1. **No treatment (monitoring)**: indicated if minor shortcomings are present (e.g. unfavourable colour/staining or sub-optimal margins) with no clinical disadvantages if untreated.
2. **Refurbishment**: can be done if shortcomings are adjustable without damage to tooth (e.g. removal of overhangs, recontouring of surface, removal of discoloration, smoothening or glazing of surface including sealing of pores and small gaps), which can be improved without adding new restorative material (except glaze or bonding).
3. **Repair**: is indicated mainly in cases of localised shortcomings that are clinically unsatisfactory and no longer acceptable. Repair is a minimally invasive approach that implies the addition of new restorative material (not only glaze or adhesive) with or without a preparation in the restoration and/or dental hard tissues.
4. **Replacement**: is indicated for generalised or severe problems in which intervention is necessary, and a repair is not reasonable or feasible. Replacement is the complete removal of the restoration, usually combined with more loss of tooth structure.

A brief summary of the current available evidence and preferred clinical techniques is introduced below.

2.4.7.1 *Refurbishing a defective dental amalgam restoration*

Refurbishment is considered when there is poor anatomic form or marginal ditching. Refinishing of defective areas is done using carbide burs, and silicone-impregnated points are used for polishing. Proximal areas may be smoothed with aluminium oxide finishing strips. In the case of dental amalgam restorations where there is some expansion, recontouring and polishing of the restoration, specifically the marginal areas, could extend the lifetime of the restoration. This would also mean that the plaque retentive areas are reduced since the surface is smooth. In vitro studies confirmed that sealing marginal, non-carious defects in dental amalgam restorations significantly reduced marginal

microleakage compared with control groups, delaying the need for replacement of the old amalgams and potentially providing protection for the tooth from secondary marginal caries (Cassin *et al*., 1991; Roberts *et al*., 2001). Results from a five-year clinical trial confirm that refinishing defective restorations with localised anatomic form defects is a useful and minimally invasive treatment option (Martin *et al*., 2013).

2.4.7.2 *Sealing defective margins*

This procedure is defined as the application of a resin-based sealant on the defective site or margin. Previous in vitro studies have indicated that the sealed margins of a defective restoration may perform better than those that are not sealed (Cassin *et al*., 1991; Roberts *et al*., 2001). All defective amalgam restorations that received sealants did not show signs of significant degradation in a two-year longitudinal study (Gordan *et al*., 2006). A three-year clinical trial conducted by Moncada *et al.* (2009) supported this. The authors noted that sealed margins may deteriorate over time and encouraged dentists to check them regularly. However, no investigation into the cause of deterioration has been conducted. When defective margins are sealed, a median survival time of three years can be expected (Martin *et al*., 2013). The placement of sealants on marginal gaps that are not larger than 1mm is a simple, non-invasive strategy to improve the overall clinical properties of a restoration (Moncada *et al*., 2015b).

2.4.7.3 *Repairing a defective restoration*

The repair of a defective restoration rather than the replacement of the entire restoration is not widely accepted as an alternative treatment (Christensen, 2007). The rationale for repairing a defective restoration is aligned with the current, minimally invasive approach in dentistry. The repair of a defective dental restoration preserves existing sound tooth structure and conserves the pulp, which could mean less treatment time and cause less anxiety for the patient since most repair procedures may be completed without local anaesthesia (Javidi *et al*., 2015). Other advantages include reduced costs and increased longevity of the restoration (Strassler, 2012; Hickel *et al*., 2013; Blum *et al*., 2014).

Once the decision has been made that the restoration is unsuitable, the dentist needs to distinguish the conditions and determine repair or replacement. The following conditions are more suited to repairing a dental restoration: large marginal opening/ditching (250 µm); severe (localised) marginal staining (aesthetically unacceptable); secondary caries (also known as caries adjacent to a restoration) without deep undermining caries (can be controlled after opening); marginal fracture of restorative material; chipping or partial fracture of restorative material; marginal breakdown of enamel; erosive/abrasive loss of tooth structure at a restoration margin; wear of restoration; minor cusp fracture; and filling of access cavity after endodontic treatment (Hickel *et al*., 2007; Hickel *et al*., 2010; Hickel *et al*., 2013) (Table 4).

However, more recent studies have investigated the longevity between alternative treatments and replacement of defective dental amalgam restorations. Gordan *et al*. (2006) published two-year longitudinal results assessing the longevity of amalgam restorations that had been clinically diagnosed as defective and treated by repair, sealant or refurbishment. The final outcome of this study showed there was no difference between the repair and replacement groups. This implies that repair would be a more conservative treatment option, given that tooth structure is preserved. Gordan *et al*. (2015) reported that repaired restorations (7%) were more likely to receive additional treatment compared with 5% of replaced restorations. However, the replaced restorations were more likely to require endodontic treatment (29%) compared with the repaired restorations. Another significant finding was that molar teeth received more additional treatment than premolars or anterior teeth (Gordan *et al*., 2015).

Similarly, Moncada *et al*. (2015a) published results from a prospective blind, randomised, ten-year clinical trial conducted at a dental clinic at the University of Chile on the effectiveness of repair of localised clinical defects in amalgam restorations. Limited and localised defects, which were clinically and radiographically detected, were defined as the presence of secondary caries, under-contoured or over-contoured anatomic form and marginal failures of occlusal, proximal and cervical areas. Significant findings from this study confirm the findings of previous studies, which state that repair is a safe alternative to

restoration replacement and could increase the longevity of the restoration by an additional 10 years. The authors acknowledged that selection criteria in the clinical decision-making for repair have yet to be determined (Moncada *et al*., 2015a).

2.4.7.3.1 Clinical procedure for the repair of a defective dental amalgam restoration

According to data from laboratory and clinical studies, the following recommendations for repair were made by Blum *et al*. (2014);

- administer local analgesia as indicated;
- remove any unsupported, undermined tooth tissue and the surface of the amalgam restoration adjacent to the fracture to provide a fresh surface as a potential bonding substrate;
- prepare retention features within the amalgam restoration to provide mechanical retention for the composite material;
- ensure adequate moisture control by using a rubber dam, cotton rolls and salivary ejectors;
- prepare adjacent amalgam and tooth tissue surfaces using intraoral aluminum oxide sandblaster or a diamond bur;
- provide pulp protection if indicated;
- acid etch the tooth surface for 1–30 seconds and wash and dry the tooth surface;
- apply an adhesive bonding system to the conditioned tooth surface;
- apply an alloy-resin bonding agent to the prepared amalgam surface;
- place the repair composite, using an incremental technique and light curing each increment fully prior to applying subsequent layers of material;
- finish working from composite to amalgam carefully; and
- check the occlusion and remove any interferences.

2.5 SECTION 4: CLINICAL DECISION-MAKING FOR RESTORATION REPLACEMENT OR REPAIR

There are only a small number of publications available regarding how dentists determine the need for replacement of restorations (Moncada *et al*., 2008; Gordan *et al*., 2009; Doméjean-Orliaguet *et al*., 2009). In order for dentists to diagnose a defective restoration, there is a need for clear criteria of what constitutes an unacceptable restoration and guidance on how to evaluate the quality of dental restorations. Two clinical evaluation systems have been widely used in research. The original *Criteria for the clinical evaluation of dental restorative materials* was developed by Cvar and Ryge in 1971 for use by the USPHS. A similar system regarding the standards of quality of dental care was published by the California Dental Association. Both systems have been widely used in research and since been modified. However, these systems were criticised because they only described deviations from an "ideal restoration" and due to all the modifications, comparisons between studies became increasingly difficult (Jokstad *et al*., 2001).

In 1988, the symposium, *Criteria for placement and replacement of dental restorations,* was convened in which criteria for the replacement of restorations were introduced, and a recommendation was made that the California Dental Association evaluation system should be introduced into the dental curriculum. Paterson *et al*. (1995) attempted to develop a policy document with valid criteria for the replacement of amalgam restorations using a modified Delphi technique in collaboration with dental schools and experts in health services research. There was unanimous agreement that lost amalgam restorations should be replaced and that fractured amalgam should be repaired/replaced. The group also agreed that 'catching' of the probe was not an indication for replacement of dental amalgam restorations (Paterson *et al*., 1995).

In 2001, the FDI published a comprehensive report reviewing all factors that affect the quality of dental restorations as well as reviewing the studies that investigated these issues (Jokstad *et al*., 2001). Hickel *et al*. (2007) proposed new clinical evaluation criteria for direct and indirect restorations with a more discriminant scale. This system was consequently updated in 2010 (Hickel *et al*.,

2010) (Appendix C). These criteria are suitable for teaching in dental schools, as well as when patients are recruited for clinical trials to evaluate a new restorative material or operative technique. They may also be used by practitioners who experience problems deciding reproducibly when a filling is unacceptable and should be repaired or replaced.

Despite this attempt to guide clinical decision-making around defective dental amalgam restorations, Sharif *et al*. (2014) suggest that:

> In the absence of any high quality evidence, clinicians should base their decisions on clinical experience (anecdotal evidence), individual circumstances and in conjunction with patients' preferences where appropriate. (Sharif *et al*., 2014)

2.5.1 Factors affecting the decision to replace or repair defective restorations

There are a variety of factors that affect dentists' decisions to replace defective restorations. The decision to replace a restoration is often influenced by subjective factors such as the dentist's interpretation of the restoration condition, health of the tooth, criteria used to define failure and patient demand (NHS, 1999) (Table 5). These may be divided into operator factors, material factors, tooth factors (number of surfaces, tooth type) and patient factors. Some of the evidence related to this is briefly summarised below.

2.5.1.1 *Patient factors*

The type of tooth and the number of tooth surfaces involved are significant variables in the clinical decision-making process of repairing restorations. Two studies found that dentists were more likely repair a restoration in a molar tooth (Gordan *et al*., 2012b; Gordan *et al*., 2015). Gordan *et al*. (2012b) also reported that dentists were more likely to repair teeth with a single surface restoration than teeth with multiple restored surfaces. However, the converse was found in their 2015 study (Gordan *et al*., 2015).

One of the first studies to report the impact of repair versus replacement of failed restorations clinically with patient-related outcomes was published in 2015 (Javidi

et al., 2015). Although the sample was small (*n*=38), some significant findings were reported. The authors concluded that patients were more uneasy and anxious when having a restoration replaced compared with having it repaired. Fewer patients who underwent a repair required a local anaesthetic, and the procedure was completed in a significantly smaller time interval (Javidi *et al*., 2015). Despite this, fewer repairs of restorations are performed in dental practice compared with replacements (Sharif *et al*., 2010).

Table 5: Factors affecting replacement of defective dental amalgams (NHS, 1999)

POSSIBLE OBJECTIVE INFLUENCES	
General patient factors	**Subjective factors**
Exposure to fluoride	Incentives
Caries status	Clinical setting
General health	Country
Parafunction	Clinician's diagnostic, treatment and
Age	maintenance philosophy
Tooth factors	
Tooth location/type/size	
Cavity design/type	
Dentition	
Occlusal load	
Tooth quality	
Operator and restoration process	
Material type	
Physical properties	
Quality of finish	
Moisture control	
Anaesthesia during restoration	
Expertise	
Training	

2.5.1.2 *Dentist factors*

Gordan *et al*. (2009) conducted a cross-sectional study in order to determine how dentists evaluate and manage existing restorations. Dentists from the Dental Practice-Based Research Network (DPBRN) formed the sample for this study. Participants were asked to assess photographs of defective amalgam and composite restorations. Potential variables were selected from the literature and analyses conducted. Dentists in solo or small group practices chose replacement for all the scenarios more often than dentists in large group practices or public health practices (Gordan *et al*., 2009). These results were confirmed by a subsequent study involving the same study population (Gordan *et al*., 2012b).

Javidi *et al*. (2015) investigated the relationship between repair versus replacement and the type of dental practice. In contrast to other studies, the repair and replacement rates of National Health Service (NHS) dental practices were comparable with private dental practices, with repair rates being approximately 30% and replacement rates being approximately 40%. Because dentists are service providers who may directly benefit from their professional actions, it could be assumed that private dentists would increase the treatment prescribed to private patients. A study by Tuominen *et al*. (2012) confirmed "that dentists working on a fee-for-service basis classify their treatment mix in a way that provides financial rewards".

No relationship has been reported among variables such as dental-insurance status of the patient and dentist's decision to treat. However, significant differences have been reported for gender and full-time versus part-time practice.

Dentists who did not determine the caries risk of patients were more likely to choose a surgical intervention than a preventative treatment (Gordan *et al*., 2009). Studies have also proved that dentists were more likely to replace restorations that were not placed by themselves (Bader and Shugars, 1992; Gordan *et al*., 2009; Gordan *et al*., 2012b). However, dentists who recently graduated from dental school were more likely to repair defective restorations (Gordan *et al*., 2009). This could be due to changes in the dental school curriculum as teaching shifts to a more minimally invasive approach.

Experiences of a dental student during training form the foundation of all future clinical behaviour. Thus, the quality and content of the learning material should be current and relevant. There are few studies recording the teaching practices of repair and refurbishment of amalgam restorations compared with composite restorations as amalgam use dwindles in developed countries.

Findings from a study conducted by Setcos *et al*. (2004) suggest that students with little clinical experience were more confident with the choice to replace than to repair despite having been taught both repair and refurbishment of defective dental amalgam restorations. These findings are consistent with a study conducted in the UK, which found that despite being taught repair techniques, these were lost on entering private practice (Burke and Lucarotti, 2009). A more recent study of dental schools in Pakistan reports that 60% of dental faculties teach the repair of dental amalgams, and those who were not advocating the technique cited the lack of an established technique as the main reason (47%) for not adopting it (Hasan and Khan, 2013). There is no information currently available with regard to the teaching practices at South African dental schools concerning the repair and replacement of amalgam or composite restorations.

Summary

This chapter introduced clinical decision-making in dentistry. It also explained the variety of factors that may influence a dentist in selecting the appropriate treatment for a patient. In this specific study, the clinical decision-making process and the factors involved are discussed in reference to the management of defective dental amalgam restorations.

CHAPTER 3: HYPOTHESIS, RESEARCH AIMS AND OBJECTIVES

3.1 PROBLEM STATEMENT

Much has been published internationally about the reasons for the replacement of defective amalgam restorations and the longevity of amalgam restorations (Burke *et al*., 1999; Maupomé and Sheiham, 2000; AlNegrish and AlNegrish, 2001; Udoye and Aguwa, 2008; Alomari *et al*., 2010). Clinical procedures with respect to repair and replacement of restorations have largely evolved in a piecemeal and anecdotal way, and there is little understanding of how widely repair of restorations has been adopted by dentists in South Africa (Sharif *et al*., 2010).

3.2 HYPOTHESES

1. South African dentists routinely replace all defective dental amalgam restorations.
2. Practises of South African dentists with regard to defective dental amalgam restorations vary in their personal and dental practice characteristics.
3. Attitudes of South African dentists towards amalgam as a restorative material influence their decisions to replace defective dental amalgam restorations.

3.3 AIM

The aim of this study was to provide information concerning the practices, knowledge and attitudes of South African dentists with regard to the management of defective dental amalgam restorations.

3.4 OBJECTIVES

- To examine the knowledge of South African dentists with regard to the management of defective dental amalgam restorations

- To evaluate the practices of South African dentists in the diagnosis and management of defective dental amalgam restorations using vignettes
- To explore the attitude of South African dentists regarding the management of defective dental amalgam restorations
- To explore the extent to which the presence of a marginal gap, secondary caries and the mechanism of reimbursement affects the dentist's decision to manage defective dental amalgam restorations.
- To make recommendations to enhance the decision-making in the management of defective dental amalgam restorations.

CHAPTER 4: METHODOLOGY

4.1 INTRODUCTION

In this chapter, an overview of the research design and research setting is provided. This section is divided into a quantitative and a qualitative segment. For each segment, addition detail regarding the study design, research participants, data collection methods, mechanisms for ensuring rigour, approach to data analysis and ethical considerations are discussed.

4.2 RESEARCH DESIGN AND METHODS

4.2.1 Mixed-methods research

Creswell and Plano Clark (2011) described mixed methods as: "A research design where the use of quantitative and qualitative approaches, in combination, provides a better understanding of research problems than either approach alone". Combining qualitative and quantitative methods in a single study is not uncommon in social research. Within health research, there has been an upsurge of interest in the combined use of qualitative and quantitative methods, commonly referred to as mixed-methods research (Creswell *et al*., 2004; Borkan, 2004; O'Cathain, 2009).

Research in dentistry has been largely quantitative in nature, mainly because of the need for evidenced-based research. Yet it is now widely recognised that qualitative research methods such as in-depth interviews can offer dentistry more unique insights into the understanding of knowledge and attitudes than a self-administered questionnaire. A mixed-method approach was used in the study to give a comprehensive view of decision-making in the management of defective dental amalgam restorations.

4.2.2 Research methodology

An Explanatory Sequential Design with two distinct interactive phases was used as shown in Figure 5 below. The quantitative component, that is, the electronic survey of general dentists comprised the first phase.

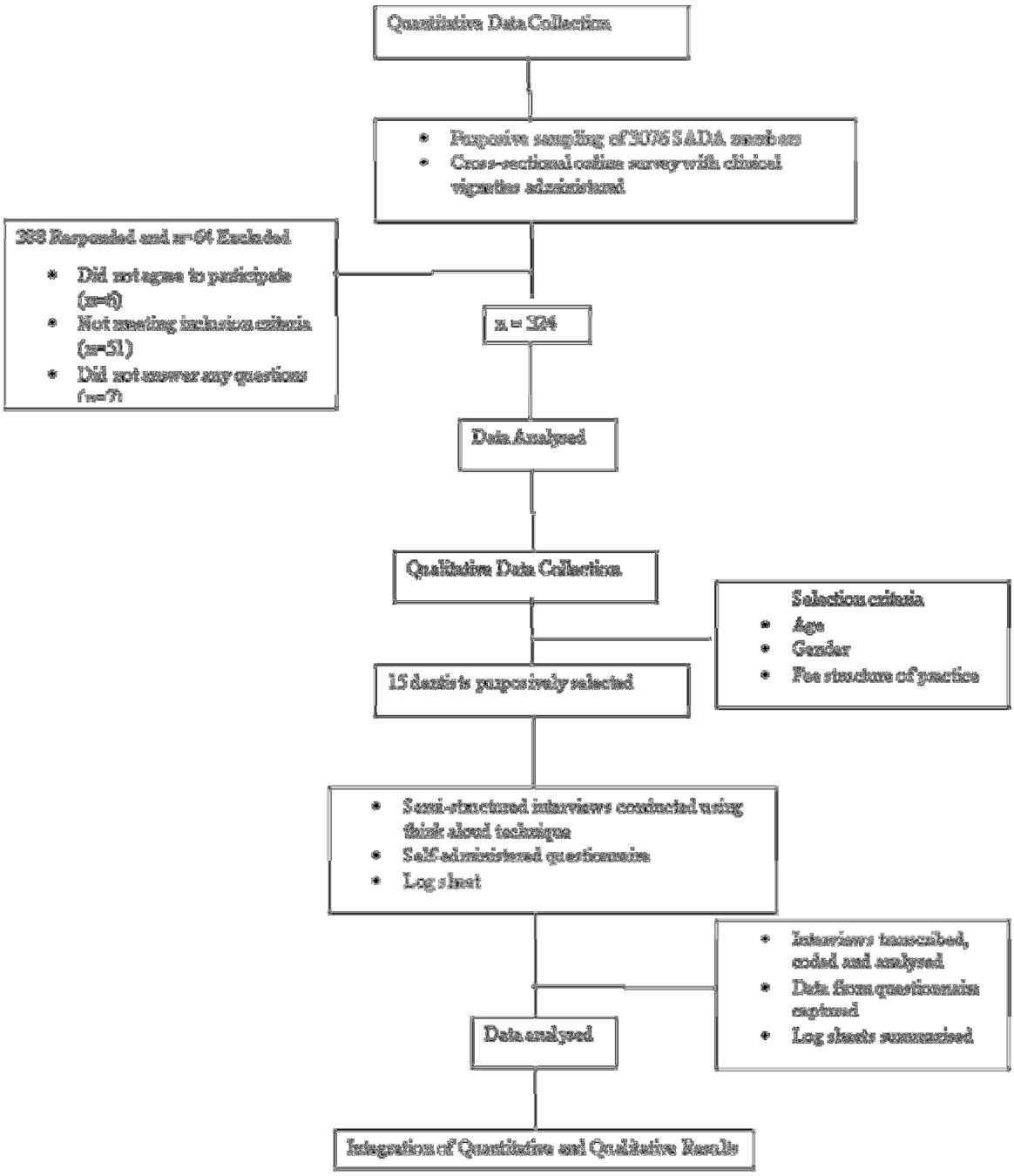

Figure 5: Workflow diagram for the research process (Adapted from Creswell and Plano Clark, 2011)

Quantitative data was collected in order to reach the objective of exploring the treatment patterns of defective dental amalgam restorations. The second phase of the study included qualitative data. Semi-structured interviews explored the factors that influence the management of defective dental amalgam restorations, including the participants' attitudes towards amalgam as a restorative material and the practice of repair and replacement. Finally, the findings of both the qualitative and quantitative components of the study were integrated.

4.2.3 Sampling

In mixed-method research, sampling schemes must be selected for each phase of the research project. Currently, there are many mixed-method research designs in existence, and their typologies differ in levels of complexity (Onwuegbuzie and Collins, 2007; Tashakkori and Teddlie, 2010). In this research project, a parallel sampling design relationship was used. This specifies that the samples of the quantitative and qualitative phases of the research are different but are drawn from the same population of interest (Onwuegbuzie and Collins, 2007). A detailed explanation of the sampling is provided in each phase.

4.2.4 Research setting

> If we want more evidenced-based practice, we need more practice-based evidence. (Green, 2008)

The primary aim of conducting research is to provide a scientific basis for the best possible patient care. Major research achievements have been made relating to dental caries and periodontal disease, but there has been a significant delay between the generation of breakthroughs and the transfer of these to individual patients. One of the ways to accelerate this translation of research is to create an environment in which the researchers and the end users, that is, the dentists, collaborate to find solutions to key issues in the field. Practice-based research (PBR) is an appropriate vehicle for this because it has two advantages: it generates evidence-based knowledge with a broad spectrum that can be more readily generalised to the public; and it accelerates translation of research findings

since passive absorption of knowledge is usually ineffective or is very slow (Mjör *et al*., 2005).

The management of defective dental amalgam restorations is an important health concern for patients, dentists and healthcare funders. Longitudinal studies are appropriate for providing insight into the longevity of dental amalgam restorations. However, in order to understand the clinical decision-making process for the management of defective dental amalgam restorations, it is only logical to proceed to a practice-based research approach because it reports on 'real world dentistry'.

4.3 QUANTITATIVE DATA COLLECTION AND ANALYSIS

4.3.1 Study design and study population

A cross-sectional quantitative survey with purposive sampling was completed. The study population consisted of 3 076 general practice dentists who were members of the South African Dental Association (SADA) at the time of the study.

4.3.1.1 *Sample*

There were 388 dentists who participated in the online survey, resulting in a response rate of 12.6%.

4.3.1.2 *Inclusion and exclusion criteria*

The membership of SADA includes active specialists and dentists in the public or private sector. The main purpose of the study was to determine the treatment patterns among general practice dentists in private practice. The dentists who indicated that they were employed in the public sector or at an academic institution were excluded. This resulted in a final sample of 324 dentists.

4.3.2 Data collection

A cross-sectional survey was conducted using a self-administered online questionnaire. Responses were collected through the Survey Monkey® program

and automatically generated into a spreadsheet. The South African Dental Association distributed the link to the online survey to all its members. Responses were collected for three months and reminders were emailed at 14-day intervals for two months.

4.3.2.1 *Using an online questionnaire*

The use of the commercial website, SurveyMonkey®, allowed the researcher to present a variety of item types such as multiple-choice questions, ranking and open-ended responses.

4.3.2.2 *The research instrument*

The questionnaire consisted of closed and open-ended questions (Appendix D). It elicited information such as age, gender, years of experience in practice and highest qualification achieved. The questionnaire also gathered information regarding the dentists' practices in the management of defective dental amalgam restorations, their knowledge and attitudes and the factors affecting the decision-making in the management of defective dental amalgam restorations. A clinical vignette with a clinical photograph was included. The questionnaire was adapted from research conducted by Moncada *et al*. (2008), Dental PBRN (Gordan *et al*., 2009) and Palotie and Vehkalahti (2012) (Appendix D).

4.3.2.3 *Clinical vignettes*

Researchers agree that vignettes, as any other research tool, can never recreate the reality and dynamism of people's lives, but they do provide valuable insights into decision-making (Gould, 1996; Hughes and Huby, 2002; Green *et al*., 2003). Research findings have shown that people exhibit the same behaviour that they would exhibit when faced with real-life information needs (Donnell *et al*., 2013).

The last question of the survey was a vignette with a clinical photograph (Appendix D). Each respondent was randomly allocated a clinical vignette with a brief explanation and a clinical photograph. The clinical photograph was the same in each vignette. Each respondent was presented with one of eight scenarios. The vignette examined three factors relating to the effects of dentists' treatment

decisions. The factors were: presence and absence of a marginal gap; presence and absence of secondary caries; and the patient's ability to pay for treatment. There were three response categories, repair, replace or refurbish. The vignette was randomly allocated to the participants by the online programme, Survey Monkey®.

1. A 35-year-old unemployed patient presents at your practice for a routine visit. The 37 has an amalgam restoration occlusally and buccally. On clinical examination, you find that there is a marginal gap on the 37 between the restoration occlusally. There is no evidence of caries radiographically or clinically. What would your treatment for the 37 entail?
2. A 35-year-old unemployed patient presents at your practice for a routine visit. The 37 has an amalgam restoration occlusally and buccally. On clinical examination, you find caries on the mesial surface. The occlusal restoration has no marginal gaps. What would your treatment for the 37 entail?
3. A 35-year-old unemployed patient presents at your practice for a routine visit. The 37 has an amalgam restoration occlusally and buccally. On clinical examination, you find an occlusal marginal gap between the tooth and the restoration, and you detect caries occlusally. What would your treatment for the 37 entail?
4. A 35-year-old unemployed patient presents at your practice for a routine visit. The 37 has an amalgam restoration occlusally and buccally. The restorations on the 37 are intact and caries free. What would your treatment for the 37 entail?
5. A 35-year-old patient on medical aid presents at your practice for a routine visit. The 37 has an amalgam restoration occlusally and buccally. On clinical examination, you find that there is a marginal gap on the 37 between the restoration occlusally. There is no evidence of caries radiographically or clinically. What would your treatment for the 37 entail?

6. A 35-year-old patient on medical aid presents at your practice for a routine visit. The 37 has an amalgam restoration occlusally and buccally. On clinical examination, you find caries on the mesial surface. The occlusal restoration has no marginal gaps. What would your treatment for the 37 entail?
7. A 35-year-old patient on medical aid presents at your practice for a routine visit. The 37 has an amalgam restoration occlusally and buccally. On clinical examination, you find an occlusal marginal gap between the tooth and the restoration, and you detect caries occlusally. What would your treatment for the 37 entail?
8. A 35-year-old patient on medical aid presents at your practice for a routine visit. The 37 has an amalgam restoration occlusally and buccally. The restorations on the 37 are intact and caries free. What would your treatment for the 37 entail?

4.3.3 Pilot study

The questionnaire was piloted among 10 dentists who were sessional employees of the University of the Western Cape. They were not included in the final study sample.

4.3.4 Ethical considerations

Each participant was asked to complete an online informed consent form (Appendix D). Ethics approval was received from the Senate Research Committee of the University of the Western Cape (Project registration: **11/1/46**) (Appendix E).

4.3.5 Validity

Both the questionnaire and clinical vignettes were validated by members of the Restorative Dentistry Department at the University of the Western Cape. In addition, the results of the pilot study were analysed to ensure that face validity of the questionnaire and vignette was achieved.

4.3.6 Data analyses

The Survey Monkey® program collected responses and automatically converted them into an Excel spreadsheet. Data analyses are explained in three sections: (i) analysis of the responses to the vignettes; (ii) responses to the close-ended questions where only one response was selected; and (iii) questions where more than one response could be selected.

The data was analysed in the following steps:

- Sample size calculation after application of the exclusion criteria and analysis of cases
- The frequency distributions of all the demographic variables, dental practice profile, continuing professional development, selection of restorative materials and attitudes to repair and replacements of defective amalgam restorations

There were several different statistical tests used for this analysis. When both variables were categorical, a Chi-square test was used. When one variable was categorical and the other was ordinal, then a Wilcoxon Rank-Sum test or a Kruskal-Wallis test was used. When both variables were ordinal, the Spearman's correlation was used. Results are presented as frequency distributions and mean scores. For the Analysis of Variance (Anova) tests, Chi-square tests and paired t-tests, a *p*-value of <0.05 was considered as statistically significant.

4.3.6.1 *Analysis of vignette responses*

In the vignette study, the effects of the three factors on the decision of the dentist relative to the hypothetical patient needing treatment were examined. The three factors each had two levels. The factors were: presence of a marginal gap with levels of yes and no; presence of secondary caries with levels of yes and no; and the patient's ability to pay with levels of yes and no. Consequently, there were eight factor combinations that could be presented. Each respondent was randomly presented with one of the eight scenarios. The response was a categorical, multinomial variable with three choices, repair, replace or refurbish. With this type of response, an appropriate method of analysis is to use a generalised logistic

model. The design is similar to a three-way analysis of variance, but since the response variable is multinomial rather than continuous and normally distributed, the standard analysis of variance is not appropriate. The analysis was performed using the logistic procedure in the statistical software SAS (SAS Institute Inc., Cary, NC, USA). The initial analysis included two-way and three-way interaction terms for the factors. If any of these interactions were not significant, simpler models for the main effects were used. In addition to determining which factors demonstrated coefficients in the model that were significantly different from zero, various odds ratios and their corresponding confidence intervals were given as an indication of the impact of the factor.

Analysis of the vignette responses were stratified on the eight scenarios and the Cochran-Mantel-Haenszel tests used. These are stratified versions of the tests described above (Chi-Square Test of Association, Kruskal-Wallis test and Spearman's correlation). Since one of the three responses, repair, was considered to be the best alternative, a secondary analysis was done with the outcome being dichotomous, namely 'best option chosen' and 'best option not chosen'. In this case, a simpler logistic regression model could be used for analysis. As with the generalised logit model, the initial analysis was done considering all interaction terms. If appropriate, simpler models were then analysed. Odds ratios and their confidence intervals were given as well.

4.3.6.2 *Questions for which only one response could be selected*

A frequency of responses for each question was completed.

4.3.6.3 *Questions for which more than one response could be selected*

In some cases, participants were able to select more than one appropriate response. The analyses explain how frequently each item was chosen. To determine whether or not these proportions were significantly different from each other, the Friedman's test was used to determine these differences. The Friedman test is a non-parametric test for testing the differences between several related samples. The null hypothesis for the Friedman test is that there are no differences between the proportions of times the items were chosen. If the calculated *p*-value

is low (*p* is less than the selected significance level), the null-hypothesis is rejected, and it can be concluded that at least two of the items have proportions that are significantly different from each other. Pairwise differences and adjusted *p*-values for multiple testing were also determined. The data analyses and re-codings were carried out using statistical software SAS (SAS Institute Inc., Cary, NC, USA).

4.4 QUALITATIVE DATA COLLECTION AND ANALYSIS

4.4.1 Study design and study population

The case-study method was used as a research strategy for this phase. Case studies may be regarded as limiting because no generalisations can be made (Yin, 2009; Darke *et al*., 1998; Rule and Vaughn, 2011; Crowe *et al*., 2011). Lack of calibration and lack of verification and validation of actual diagnoses are inherent difficulties in this type of survey, but it has the advantage of reflecting real-life dentistry.

4.4.2 Sample

The key focus of this research was to obtain insights into the factors affecting a dentist's treatment choice when managing a defective dental amalgam restoration. In order to appreciate the complexities of clinical decision-making in private practice, the unit of analysis was a dentist in private practice in the Western Cape. Purposive sampling was used to select dentists to participate in the semi-structured interviews. The criteria that were considered were:

- **Age:** to ensure a balanced demographic sample
- **Gender:** to ensure balance and because treatment patterns/choices differ slightly between men and women
- **Fee structure of practice:** it was hypothesised that the mechanism of reimbursement could affect treatment pattern/choice of the dentist

Sample size in qualitative studies is determined not by statistical power considerations but by reaching a complete understanding of the problem being studied, and this is referred to as saturation (Rubin and Rubin, 1995). Central concepts have reached saturation when the researcher finds that new interviews do not add new information and the central concepts are understood (Guest, 2006).

4.4.3 Data collection

In this phase of the research, multiple data sources in the form of semi-structured interviews, a self-administered questionnaire, a log of treatment procedures provided over a two-week period and field notes were used as a strategy to enhance data credibility (Patton, 1990; Yin, 2009). A summary of each method follows.

4.4.3.1 *Semi-structured interviews*

Qualitative interviewing is a way of uncovering and exploring the meanings that underpin people's lives, routines, behaviours, feelings, etc. (Rubin and Rubin, 1995; Britten, 1995; Gill *et al*., 2008). Semi-structured interviews are defined by DiCicco-Bloom and Crabtree (2006) as usually scheduled in advance and organised around a set of predetermined, open-ended questions, with other questions emerging from the dialogue between the interviewer and interviewee. The semi-structured interviews consisted of a clinical vignette that elicited specific responses from the dentists in order to gather information regarding the dentists and their decision-making.

4.4.3.2 *Clinical vignettes*

Two clinical case vignettes were created apropos the management of defective dental amalgam restorations using two actual patient records. These clinical vignettes were presented to academic staff in the Restorative Dentistry Department at the University of the Western Cape for validation. Each case had a panoramic radiograph and bitewings taken as per routine visits to the Faculty of Dentistry for treatment. Intraoral images were collected of each arch and the individual teeth that were restored with amalgam. The teeth were dried prior to imaging. After being captured, each picture was reviewed and once it was deemed

appropriate, it was saved to a data file and subsequently serialised in an MS Office PowerPoint® presentation (Appendix F).

Each dentist examined both cases and reported a diagnosis and treatment plan for tooth 26 in each case. Conventional audio-recording equipment was used to record the treatment planning until terminated by the dentist. This recording of the dentist's thoughts was carried out in the presence of the researcher to gather information regarding the strategies used in the treatment planning and relevant knowledge about the diagnosis and treatment plan. The think-aloud technique was used to elicit information about underlying thinking processes and actions.

4.4.3.3 *The think-aloud technique*

Think aloud is a technique that allows for the examination of an individual's thinking processes and decisions that are being considered at that point in time; health professionals are confronted with large volumes of information that can only be partially processed at any one time. Think-aloud research is widely used in nursing, and it has focused on the approaches that nurses use to decide on a diagnosis, with little emphasis on the management of the problem. Payne (1994) also suggested that the think aloud technique may be useful for:

- Providing early insight into behaviours
- Pre-testing questionnaires to improve clarity
- Comparing data with data collected by other methods
- Testing an hypothesis about behaviour
- Building and testing models of behaviour such as expert systems

Participant numbers in think-aloud studies are generally low due to the depth and richness of the data usually gained from each participant, with some reports suggesting that as few as five or six participants may produce stable results (Gerrish and Lacey, 2010; Lundgrén-Laine and Salanterä, 2010).

Limitations of this technique include reactivity, verbal participants, verbal abilities and data validity (Hughes and Huby, 2002; Young, 2009). Reactivity relates to the ability of the participant to think and attend to a task simultaneously. Most often, the participant is required to verbalise their thoughts during an

activity that is normally performed in silence. The technique also draws attention to the underlying cognitive processes of a task.

Training participants in the technique is an important component of data collection and provides the researcher with an opportunity to explain to the participants that they should only be attempting to verbalise and not rationalise their thinking processes. One of the most common exercises requested is an arithmetic exercise such as asking them to 'count the number of windows in their home' since this requires sequential progression through the various rooms in their home.

4.4.3.4 *Data recording procedures*

The participants were given training in the think-aloud technique as described above. An interview protocol was used to keep the discussion focused. The semi-structured interviews were audio taped and supplemented with the field notes.

4.4.3.5 *Self-administered questionnaire*

A self-administered questionnaire was chosen to collect information from the participants to ensure standardisation of information (Appendix G). The questionnaire was adapted from that used in the Dental PBRN study (Gordan *et al*., 2009). The questionnaire was piloted prior to its administration.

4.4.3.6 *Treatment log*

Participants were also asked to complete a patient log form for each restoration placed over a two-week period (Appendix H) .The data collected included the patient's age, gender, tooth number, cavity classification, the new restorative material choice, possible reasons for placement, reasons for replacement and the previous restorative material used. The patient log form was adapted from the Dental PBRN study (Gordan *et al*., 2009).

4.4.3.7 *Field notes*

Field notes are defined as the notes of observations or conversations taken during the conduct of qualitative research (Thorpe, 2008). They may be taken throughout

the research process. As each interview was being conducted at the practice of the participating dentist, field notes were made, including descriptions of the context of the conversation and interpretations of the data.

4.4.4 Qualitative data analysis

4.4.4.1 *Framework analysis*

The Framework approach was developed by researchers, Jane Ritchie and Liz Spencer, from the Qualitative Research Unit at the National Centre for Social Research in the UK in the late 1980s for use in large-scale policy research (Ritchie and Lewis, 2003). It has gained popularity in health research largely due its effectiveness in managing qualitative data and analyses systematically (Smith and Firth, 2011). The approach is inductive but allows for the inclusion of a priori as well as emergent concepts. Its characteristic feature is the matrix output: rows (cases), columns (codes) and cells of summarised data, providing a structure into which the researcher can systematically reduce the data in order to analyse it by code. This allows the researcher to explore the data at great depths whilst maintaining transparency. This in turn contributes to the rigour of the study and enhances the credibility of the findings (Ritchie and Lewis, 2003).

4.4.4.2 *Stages of thematic analysis*

A glossary of terms is provided to assist in understanding the stages of analysis in this method (Table 6).

Stage 1: Transcription

The verbal data was converted from an audio recording into a verbatim transcription using ATLAS.ti®. In this programme, each transcript is called a Primary document.

Stage 2: Familiarisation with the interview

All the recordings were listened to again together with the field notes made by the researcher and amendments were made if necessary. A random sample of transcripts was checked by a more experienced researcher for accuracy.

Stage 3: Coding

Coding is a process that provides the researcher with a formal system to organise the data, uncovering and documenting additional links within and between concepts and experiences described in the data (Braun and Clarke, 2006; Bradley *et al*., 2007). Codes are tags or labels that are assigned to whole documents or segments of documents (i.e. paragraphs, sentences or words) to help catalogue key concepts while preserving the context in which these concepts occur (Miles and Huberman, 1994).

In the ATLAS.ti® package, a typical screen has the transcript on the left-hand side, with a wide margin on the right-hand side to allocate codes or notes/memos. The researcher highlights the relevant passage of text and using the ATLAS.ti® package, applies a label (a 'code') that describes what they have interpreted in the passage as important.

Stage 4: Developing a working analytical framework

After coding the first few transcripts, the codes were grouped together into categories. These categories formed the analytical framework. The categories were drawn from the literature as well as from the interviews. A search for patterns and explanations was performed to determine, for example, whether or not certain codes could be grouped together under a more general code. This process was constantly refined throughout the data analysis process and as new insights emerged, theoretical saturation was reached (Bradley *et al*., 2007).

Table 6: Glossary (Gale *et al*., 2013)

Analytical framework: A set of codes organised into categories that have been jointly developed by researchers involved in analysis that can be used to manage and organise the data. The framework creates a new structure for the data (rather than the full, original accounts given by participants) that is helpful to summarize/reduce the data in a way that can support answering the research questions.

Analytic memo: A written investigation of a particular concept, theme or problem, reflecting on emerging issues in the data that captures the analytic process.

Categories: During the analysis process, codes are grouped into clusters around similar and interrelated ideas or concepts. Categories and codes are usually arranged in a tree diagram structure in the analytical framework. While categories are closely and explicitly linked to the raw data, developing categories is a way to start the process of abstraction of the data (i.e. towards the general rather than the specific or anecdotal).

Charting: Entering summarized data into the Framework Method matrix.

Code: A descriptive or conceptual label that is assigned to excerpts of raw data in a process called 'coding'.

Data: Qualitative data usually needs to be in textual form before analysis. These texts can either be elicited texts (written specifically for the research, such as food diaries), or extant texts (pre-existing texts, such as meeting minutes, policy documents or weblogs), or can be produced by transcribing interview or focus group data, or creating 'field' notes while conducting participant-observation or observing objects or social situations.

Indexing: The systematic application of codes from the agreed analytical framework to the whole dataset.

Matrix: A spreadsheet contains numerous cells into which summarized data are entered by codes (columns) and cases (rows).

Themes: Interpretive concepts or propositions that describe or explain aspects of the data, which are the final output of the analysis of the whole dataset. Themes are articulated and developed by interrogating data categories through comparison between and within cases. Usually a number of categories would fall under each theme or sub-theme.

Transcript: A written verbatim (word-for-word) account of a verbal interaction, such as

Stage 5: Applying the analytical framework

The framework was applied to all subsequent transcripts.

Stage 6: Charting data into the framework matrix

A spreadsheet was used to generate a matrix into which the data was charted. Codes that specifically referred to the objectives of the study, demographic attributes and practice-profile attributes were charted against the specific cases. This allowed the researcher to assess both the patterns of association (*how often* features vary under different circumstances) and the nature of the associations (*in what ways* certain features might vary under particular or different circumstances) (Bazeley, 2009).

Stage 7: Interpreting the data

Gradually, connections between themes and other data were mapped.

4.4.5 Generalisation, validity and reliability of qualitative research

In this study, the process of peer review was adopted whereby another suitably experienced researcher reviewed and explored the transcripts, data analyses and emergent themes. The reliability of data collection may be affected by the timing of the data collection. Retrospective data collection is more open to error through inaccurate memory of the decision task or the requirement to explain a long procedure.

4.4.6 Pilot study

A pilot study was conducted at two dental practices to determine the length of the interviews, appropriate questions and the feasibility of data-collection strategies.

4.4.7 Ethical considerations

Ethics approval was granted by the Senate Research Committee of the University of the Western Cape (Project Registration 11/1/46) (Appendix E). In this research project, participants were asked to complete an informed consent form that outlined the research objectives and recorded their permission to participate in the study (Appendix H).

Participants were informed on how confidentiality was to be maintained throughout the project. The information gathered was only to be used for academic purposes, and research findings would be reported to the institution and other researchers in the field. In order to protect the identity of the participants, their names would be removed, and they would only be identified by Dr J, Dr S, Dr LD, etc. Participants were informed of the use of a recording device and verbatim transcriptions, and written interpretations were made available to the participants. All records were securely stored in a lockable filing cabinet in a locked office. All electronic records were stored on a computer with a password.

Summary

In this chapter, the research design was introduced. The mixed-methods approach and the rationale for the research setting was explained. An overview of the research methodology with its quantitative and qualitative components was presented.

CHAPTER 5: RESULTS

In this section, the research findings of both the quantitative and qualitative phases are presented. Firstly, a description of the samples for the quantitative and qualitative components are given. Secondly, excerpts of the semi-structured interviews regarding Case Study 1 are presented alongside the quantitative data. The interview data enriches the findings of the national survey. Lastly, a summary of the findings from the treatment log sheets is presented.

5.1 QUALITATIVE STUDY: DEMOGRAPHY OF THE SAMPLE

Because the number of participants in the qualitative component is small, a summary table of the demographic details is provided (Table 7).

5.2 GEOGRAPHIC LOCATION

Dentists across Cape Town were selected to participate in interviews (Figure 6).

Figure 6: Geographic location of interviewees' practices

Table 7: Summary of profiles of interview participants

Dentist	Gender	Age group (years)	Graduation year	Highest qualification	Practice arrangement	Full or part-time
Dr J	M	36-45	2001	BChD	Self-employed as a partner in a complete partnership	Full time
Dr S	F	36-45	2000	BChD	Self-employed without partners (solo practice)	Part-time
Dr A	M	56-65	1991	BChD	Self-employed without partners (solo practice)	Full time
Dr LD	M	36-45	2000	BChD	Self-employed without partners but share costs	Full time
Dr M	F	20-25	2012	BChD	Employed by Group	Full time
Dr LA	F	36-45	2001	PDD	Other (please specify)	Full time
Dr LE	F	26-35	2006	BChD	Employed by another dentist	Full time
Dr K	F	36-45	1993	BChD	Employed by another dentist	Full time
Dr F	M	>66	1980	BChD	Self-employed as a partner in a complete partnership	Full time

Dentist	Gender	Age group (years)	Graduation year	Highest qualification	Practice arrangement	Full or part-time
Dr LI	M	26-35	2009	BChD	Other (please specify)	Full time
Dr RI	F	26-35	2005	BChD	Other (please specify)	Full time
Dr RA	M	46-55	1991	BChD	Self-employed without partners (solo practice)	Full time
Dr N	F	36-45	1997	PDD	Employed by another dentist	Part-time
Dr Y	M	36-45	1993	BChD	Self-employed without partners (solo practice)	Full time

5.3 QUANTITATIVE COMPONENT: DEMOGRAPHY OF THE SAMPLE

The electronic survey was distributed to 3 607 dentists who are members of SADA. A total of 388 dentists completed the online questionnaire, a response rate of 10.7%. Of the 388, six respondents did not agree to participate in the study. Another seven respondents agreed but did not answer any of the survey questions. Only 375 responses could be used. However, with the application of the exclusion criteria, all dentists with a qualification of MChD (*n*=13) were excluded. Dentists who were employed at a public health institution (*n*=28) or academic institution (*n*=7) were also excluded. Retired dentists (*n*=3), a postgraduate student (*n*=1) and a consultant geologist (*n*=1) were also excluded. Note that some dentists met more than one exclusion criteria. A final sample of 324 dentists was included in the study.

5.3.1 Gender

Females accounted for 36% (*n*=112) of the sample.

5.3.2 Age

A high percentage (78%) of the respondents were younger than 55 years old, with almost one-third (32%) of the sample being in the age group of 26–35 years.

5.3.3 Highest qualification

More than two-thirds of the sample (67.7%) of dentists had a BChD degree as their highest qualification, and some (26.7%) had a postgraduate diploma as shown in Table 8.

5.3.4 Dental-practice profile and years of experience in private practice

Only respondents who were currently employed as dentists in the private sector were included in the sample. More than one-half of the sample (55%) were self-employed without partners, and less than one-half (41%) of the sample had at least 21 years in private practice. One-third (33%) of all respondents were not contracted to medical aid or third-party funders.

Table 8: Frequency distribution of highest qualification (*n*=322)

Highest qualification	Frequency (n)	%
PhD/DSc	2	0.62
MSc	16	4.97
PG Dip	86	26.71
BChD/BDS	218	67.70

5.4 CONTINUING PROFESSIONAL DEVELOPMENT

Thirty-three per cent (*n*=33) of the dentists reported reading a dental journal more than once a month, and 40% (*n*=122) spent between five and ten days a year attending postgraduate meetings or courses. Dentists were asked to select all the activities they had completed for their Continuing Professional Development (CPD) portfolio for the previous year.

From Table 9, it is clear that participants preferred to attend lectures and answer journal questionnaires as CPD activities. There was a statistically significant difference in how Continuing Education Units (CEU) was earned, which was determined by the selection, $X^2(2) = 649.73$, $p<0.0001$*. From pairwise comparisons, participants preferred answering journal questionnaires significantly more than all the other activities, apart from attending lectures organised by the profession ($p<0.0001$*).

5.5 AMALGAM AS A RESTORATIVE MATERIAL

A high percentage of respondents (62%) seldom used amalgam as a restorative material in their practice, while only a small group (7%) reported using amalgam as a rule.

Data from the interviews indicated that most of the participants were generally in favour of the use of dental amalgam because of its excellent lifespan as a restorative material.

Table 9: Frequency of Continuing Professional Development activities

(*n*=303)

Item	Frequency	%
Answering journal questionnaires	219	72
Attending lectures organised by dental companies	218	72
Attending lectures organised by my profession	222	73
Attending refresher courses	128	42
Attending congresses	150	50
Enrolling in a postgraduate course	42	14
Attending small study groups	65	21
Teaching	23	8

> *I am for amalgams. They have proved themselves over and over* (Dr LD).
>
> *I have such a huge faith in amalgams. They last for very long. It doesn't look fantastic but it doesn't leak, it doesn't break and if it does, then you address it* (Dr RI).

The interview data also suggested that the increase in complications following the placement of posterior composite restorations could be attributed to the continued use of dental amalgam as a restorative material.

> *We have seen so many times … the disasters of large posterior composite space and big cavities … and from my experience, this is where the people who are still using amalgams, use amalgams because of failed composites* (DR Y).

5.6 DISCUSSION WITH PATIENT REGARDING CHOICE OF DENTAL RESTORATIVE MATERIAL

Approximately one-half of the respondents (57%) indicated that generally, they discussed the choice of dental material with the patient, whilst only 11% (*n*=33) seldom did.

Participants of the interviews were acutely aware of the concern some patients expressed regarding the safety of dental amalgam as a restorative material:

> *[A] lot of our patients that come in ... you know patients are becoming very knowledgeable now, and they have Internet now and smart phones so when they walk through the door, they can tell you exactly what they want or what they need, and you are like okay. In the past as well, there was a whole fear of amalgams and mercury* (Dr J).

5.7 REPAIR OF DEFECTIVE DENTAL AMALGAM RESTORATIONS

Almost two-thirds (63%) of the dentists repaired defective dental amalgam restorations in their practice. Of the 37% (*n*=112) who did not repair, 81 dentists provided reasons when asked (Table 10). Most of the respondents (72%) felt there was a lack of predictability in the technique, and this was a major factor in their decision not to repair defective dental amalgam restorations.

There was a statistically significant difference in the reasons for repairing defective dental amalgam restorations depending on the selection, $X^2(2) = 71.29$, $p<0.0001$*. From pairwise comparisons for not repairing, lack of predictability of the technique was chosen significantly more often than all the other reasons ($p<0.0001$*). With regard to reasons for not repairing defective dental amalgam restorations, ‘lack of supporting scientific evidence’ was not significantly different from ‘the absence of an established technique’ and ‘no professional code and fee for the procedure’.

Table 10: Frequency of reasons for not repairing defective dental amalgam restorations

Reasons	Frequency	%
Lack of predictability in the technique	58	72
Lack of supporting evidence	16	20
Absence of an established technique	21	26
No professional code and fee for the procedure	7	8.6

Data from the interviews revealed that one interview participant was quite amused about the idea of repairing a dental amalgam restoration.

> *(Laughs at the thought. So ridiculous.) I have just never done it [repair an amalgam restoration]. We were not taught how to* (Dr S).

The interviews also suggested that some participants felt that repairing a defective dental amalgam restoration was a practical solution but had reservations about the longevity of the repaired restoration and stressed the importance of informing the patient that it was not a 'permanent treatment'. There was a lack of confidence in the technique as a treatment option for the management of defective dental amalgam restorations. As one participant said, "if that tooth is still symptomatic after we have worked, then things become questionable".

> *I think anything that is practical and it works, I don't see a reason why it shouldn't be done. And it is one of those cases where it is neither right nor wrong. If it works, and it is a much less expensive option* (Dr A).

> *I don't see it as a long term or something that is going to last forever. I explain to them, you can have the patchwork if you want it done* (Dr RI).

Interestingly, some participants felt that repairing a defective dental amalgam restoration was not the 'right' thing to do as a health professional. The appropriateness of the treatment was questioned.

I just find if I am going to have a breakdown on a tooth or a filling that is broken down I will ... Maybe the right thing to do is to replace the whole thing (Dr J).

I don't think that it [repairing a defective dental amalgam restoration] is the best you can do (Dr LE).

5.8 AMALGAM REPAIR TECHNIQUE USED

Table 11 indicates that the most commonly used repair technique was a bur to create mechanical retention (77%). There was a statistically significant difference in the technique used in repairing defective dental amalgam restorations depending on the selection, $X^2(2) = 428.98$, $p<0.0001$*.

When pairwise comparisons were completed, using a bur to create mechanical retention was chosen significantly more often than all the other technique options ($p<0.0001$). The application of a silica coating to the amalgam prior to bonding was chosen significantly less than the use of dentine bonding agents or placement of a pin-retained restoration ($p<0.0001$*). The use of a total-etch dentine-bonding system was also chosen significantly more often than a self-etch dentine-bonding system, a glass ionomer as a dentine-bonding system or the placement of a pin-retained restoration ($p< 0.0001$).

Table 11: Frequency of techniques (*n*=246)

Techniques	Frequency	%
Use a bur to create mechanical retention	189	77
Apply silica coating to the amalgam prior to bonding	3	1.2
Apply silane coating to the amalgam prior to bonding	15	6
Apply total-etch dentine-bonding system	120	49
Apply self-etch dentine-bonding system	53	21.5
Apply glass ionomer as a dentine-bonding system	79	32.1
Place a pin-retained restoration	81	33

5.9 ORIGIN OF TECHNIQUE USED

More than two-thirds (68%) of the participants learnt their technique through their clinical experience, while only 27% learnt it through attending a continuing professional development course or lecture (Table 12).

There was a statistically significant difference in where the technique was learnt depending on the selection, $X^2(2) = 343.10$, $p<0.0001$*(Appendix J). From pairwise comparisons conducted regarding the origin of their repair technique, undergraduate dental school was chosen significantly more than attending a CPD course or lecture, reading a journal article, learning from the Internet or learning from a fellow colleague ($p<0.0001$*) but chosen significantly less than their clinical experience.

Table 12: Frequency of individual items chosen for learning resources (*n*=262)

Activities	Frequency	%
Undergraduate dental school	131	50
CPD course or lecture	70	27
Reading journal	47	18
Internet	7	12.6
Fellow colleague	45	17
My clinical experience	177	68

5.10 RESTORATIVE MATERIAL OF CHOICE FOR REPAIRING A DEFECTIVE DENTAL AMALGAM RESTORATION

It is evident from Table 13 below that resin-based composites were chosen significantly more often than all the other dental restorative materials when repairing a defective dental amalgam restoration. The Friedman test was used to determine if one dental restorative material was consistently chosen above another in repairing a defective dental amalgam restoration with a probability of <0.05. There was a statistically significant difference in the choice of restorative material used depending on the selection, $X^2(2) = 259.17$, $p<0.0001$* (Appendix H).

From pairwise comparisons conducted, resin-modified glass ionomer was chosen significantly less than resin-based composite but significantly more than silorane-based composite, flowable composite and compomers when choosing a restorative material to repair a defective dental amalgam restoration. There was no significant difference found between resin-modified glass ionomer and amalgam as restorative materials of choice when repairing a defective dental amalgam restoration (p=0.44).

Table 13: Frequency of times individual items were chosen for restorative material of choice (*n*=250)

Restorative Material	Frequency	%
Resin-modified glass ionomer	91	36
Resin-based composite	154	62
Silorane-based composite	7	2.8
Flowable composite	57	22.8
Compomer	22	8.8
Amalgam	74	30

Interestingly, data from the interviews revealed there was concern when repairing a defective dental amalgam restoration with a material other than dental amalgam. Participants questioned the science behind using two different materials.

> *It sounds— (hesitant). I don't like mixing materials. It is not that I am averse to doing that, but I am not keen on it. Mixing materials like amalgam and composite simply because the composite is not going to adhere* (Dr Y).
>
> *Well, I find that if I do that then the filling mostly, it could fail. I don't want anybody really to come back with problems and tell me, 'But you could have told me, or you could have done something more expensive for me, and why didn't you do that in the first place?'* (Dr LE).

5.11 RESTORATIVE MATERIAL OF CHOICE FOR REPLACING A DEFECTIVE DENTAL AMALGAM RESTORATION

From the data, 56% of the participants (*n*=20) would replace a defective dental amalgam restoration with a resin-based composite restoration, and 12% (*n*=34) would choose either a resin-based restoration or a crown (Table 14).

From Table 14, it is evident that resin-based composites were the material of choice when replacing a defective dental amalgam restoration (78%). The

treatment choice of a crown was also popular, with 58% of the participants choosing this treatment option. Using the Friedman test, there was a statistically significant difference in selecting a dental restorative material depending on the selection, $X^2(2) = 563.57$, $p<0.0001$*.

When pairwise comparisons were completed, resin-based composites were chosen significantly more often than all the other possible treatment choices for replacing a defective dental amalgam restoration ($p<0.0001$*).

Table 14: Frequency of restorative material choice for replacing a defective dental amalgam restoration

Restorative Material	Frequency	%
Resin-modified glass ionomer	68	24
Resin-based composite	219	78
Silorane-based composite	14	5
Compomer	27	9.6
Amalgam	71	25
Ceramic inlay	75	27
Ceramic onlay	68	24
Crown	164	58

5.12 FACTORS TAKEN INTO CONSIDERATION WHEN MANAGING A DEFECTIVE DENTAL AMALGAM RESTORATION

Participants were asked to list the three main factors that they considered when managing a defective dental amalgam restoration. This open-ended question was analysed by grouping responses into five categories as displayed in Table 15.

From Table 16, it is clear that tooth factors such as remaining tooth structure, the size and depth of the restoration and the presence of caries are ranked as the most important considerations when managing a defective dental amalgam restoration. Material factors were ranked as the least important consideration.

Table 15: Response categories for factors taken into consideration when managing a defective dental amalgam restoration

Category	Responses
Patient factors	Occlusion, finances, presence of pain
Tooth factors	Remaining tooth structure, size of restoration, depth of restoration, presence of caries, etc.
Clinician factors	Experience, available time
Material factors	Longevity of restorative material, condition of existing restoration
Do not repair defective dental amalgam restorations	

Table 16: Ranking frequencies for factors taken into consideration when managing a defective dental amalgam restoration

First Position	%	Second Position	%	Third Position	%
Tooth factors	85	Tooth factors	70	Patient factors	47
Patient factors	10	Patient factors	22	Tooth factors	43
Do not repair restorations	2	Material factors	7	Material factors	8
Material factors	2				

5.13 KNOWLEDGE REGARDING THE MANAGEMENT OF DEFECTIVE DENTAL AMALGAM RESTORATIONS

Only 8% of the participants agreed that there is no correlation between a marginal gap and secondary caries, but 60% agreed that the size of the marginal gap present is directly related to the chance of secondary caries (Table 17). There was very

little difference in the response to the statements: 'I replace faulty margins when there is no clinically or radiographically datable caries because chances are good that there is caries below the margins that cannot be detected' and 'I replace faulty margins when there is no clinically or radiographically detectable decay because chances are good that decay will set in, in the near future'. The majority of the participants were in favour of repairing defective dental amalgam restorations as a treatment.

Table 17: Responses to statements

Statements	Agree %	Undecided %	Disagree %
There is no correlation between a marginal gap and secondary caries	8	9	83
I replace faulty margins when there is no clinically or radiographically detectable decay because chances are good that decay will set in, in the near future	44	16	40
The size of the marginal gap between amalgam and tooth structure is directly related to the chance of secondary caries	60	19	21
There is no relationship between the decision to replace an existing restoration and refurbishing an amalgam restoration	18	44	38
I do not repair defective dental amalgam restoration because it is not an acceptable form of restorative dentistry	21	14	65
I replace faulty margins when there is no clinically or radiographically detectable caries because chances are good that there is caries below the margins that cannot be detected	39	19	41

5.14 DIAGNOSIS OF SECONDARY CARIES

The most common diagnostic method was the use of radiographs, followed by the presence of soft, discoloured dentine or enamel and the use of a sharp probe (Table 18).

Table 18: Frequencies for diagnosis of secondary caries (*n*=285)

Diagnostic Methods	Frequency	%
Radiographs	282	99
Probing with a sharp probe	239	84
Probing with a blunt probe	31	11
Intuition or clinical experience based on clinical appearance	178	62
Discoloured margins of a restoration	181	63
Frank or definite caries cavitation	205	72
Presence of soft, discoloured dentine or enamel	248	87
Exploratory preparation to inspect the lesion	63	22

Using the Friedman test, there was a statistically significant difference in the diagnosis of secondary caries depending on the selection, $X^2(2) = 820.79$, $p<0.0001$*. With the use of pairwise comparisons, radiographs were chosen significantly more often than any other diagnostic method ($p<0.0001$*). The use of a sharp explorer was also chosen significantly more often than all other diagnostic methods except in the presence of soft, discoloured dentine or enamel.

5.15 FACTORS AFFECTING TREATMENT DECISIONS

Dentists were asked to indicate the three most important factors in replacing a defective dental amalgam restoration, repairing a defective dental amalgam restoration and refurbishing a defective dental amalgam restoration. The following data represents the respondents who included at least three main factors (Table 19).

Table 19: Factors affecting treatment decision: Percentages of individual factors chosen

	Cost to patient	Future plans for tooth	Caries risk	OH	Pt. preference	Age of patient	Aesthetics	Pain	Visible caries	Possibility of caries	Remaining tooth structure
My decision to REPLACE a defective dental amalgam restoration	22	20	22	12	16	5.2	19	42	60	17	48
My decision to REPAIR a defective dental amalgam restoration	64	27	17	9.5	25	17	4	14	24	15	50
My decision to REFURBISH a defective dental amalgam restoration	59	23	26	24	30	17	23	5.5	5.5	17	25

Table 20: Factors affecting treatment decisions: Ranking of factors

	1st	%	2nd	%	3rd	%
My decision to REPLACE a defective dental amalgam restoration	Visible caries	60	Remaining tooth structure	48	Pain	42
My decision to REPAIR a defective dental amalgam restoration	Cost to patient	64	Remaining tooth structure	50	Future plans for the tooth	27
My decision to REFURBISH a defective dental amalgam restoration	Cost to patient	59	Patient preference	30	Caries risk for the patient	26

There was a statistically significant difference in the factors taken into consideration when replacing a defective dental amalgam restoration depending on the selection, $X^2(2) = 282.71$, $p<0.0001$* (Table 20). With pairwise comparisons, the considerations of cost to the patient and future plans for the tooth were chosen significantly less often than pain, visible caries and remaining tooth structure ($p<0.0001$*). Similarly, the cost to the patient was chosen significantly more often than all the other options when deciding to repair or refurbish a defective dental amalgam restoration ($p<0.0001$*) (Appendix M).

5.16 FUTURE OF AMALGAM

More than one-half of the respondents (58%) felt that dental amalgam should be available for use in the future, and an almost equal number (54%) thought that dental amalgam posed an environmental risk.

5.17 RELATIONSHIPS BETWEEN DEMOGRAPHIC VARIABLES, USE OF AMALGAM, FUTURE USE OF DENTAL AMALGAM, REPAIRING DEFECTIVE DENTAL AMALGAM RESTORATIONS AND REPLACING DEFECTIVE DENTAL AMALGAM RESTORATIONS

Different statistical tests were performed to examine the relationships between factors in the categories: dentists' individual characteristics, practice profiles and biases (Table 21). A Chi-square test was used when both variables were categorical. When one variable was categorical and the other was ordinal, a Wilcoxon Rank-Sum test or a Kruskal-Wallis test was used. When both variables were ordinal, the Spearman's correlation was used. Cross-tabulations were only completed for the pairs that were significant at the 0.005 level (Appendix M).

Table 21: Factors tested for their association

Dentists' Individual Characteristics	**Practice Profile**	**Biases**
Age	Practice arrangement	Use of repair as a treatment option
Gender	Practice location	Choice of material to repair
Years of experience	Contracted to third-party funders	Future use of amalgam
CPD activities		Choice of material to replace amalgam
		Treatment option chosen in vignette

5.17.1 Relationship between repair of dental amalgam and future use of dental amalgam as a restorative material

There was a statistically significant relationship and a trend that dentists who repair defective dental amalgam restorations are more likely to believe that there is a future for amalgam as a dental restorative material (p<0.005*) (Table 22).

Table 22: Repair of dental amalgam and future use of the material

Repair amalgams		**Future use of amalgam**			
		Yes	No	Do not know	Total
Yes	Frequency (*n*)	118	43	12	173
	%	68.21	24.86	6.94	
No	Frequency (*n*)	43	50	11	104
	%	41.35	48.08	10.58	
Total		161	93	23	277

Frequency missing = 75

5.17.2 Relationship between contracted to medical aid and repair or replacement of defective dental amalgam restorations

There was a statistically significant relationship and a trend that dentists who are contracted to third-party funders are more likely to repair defective dental amalgam restorations than replace (p<0.005*) (Appendix M).

5.17.3 Relationship between age and repair of defective dental amalgam restorations

There was a statistically significant relationship and a trend that dentists who repair defective dental amalgam restorations are more likely to be between the ages of 56 years and 65 years (p<0.0001). Dentists between the ages of 26 years and 35 years do not choose amalgam as a restorative material for repair (Appendix M).

5.17.4 Relationship between years of experience and choice of material to repair

There was a statistically significant relationship and a trend that dentists who have more than 21 years of experience are more likely to use amalgam as a restorative material when repairing a defective amalgam ($p<0.0027$) (Appendix M).

5.17.5 Relationship between use of amalgam as a restorative material and repair of defective dental amalgam restorations

There was a statistically significant relationship and a trend that dentists who never repair amalgams almost never use amalgam in practice ($p<0.0001$) (Appendix M).

5.17.6 Relationship between use of amalgam as a restorative material and discussion of material choice with a patient

There was a statistically significant relationship and a trend that dentists who routinely discuss restorative material choice with patients very rarely use amalgam ($p<0.0001$) (Appendix M).

5.18 ANALYSIS OF CLINICAL VIGNETTE RESPONSES IN THE ONLINE SURVEY

The clinical vignettes formed part of the online survey distributed to members of SADA. The vignette examined the effects of three factors regarding dentists' treatment decisions. The factors were: presence and absence of a marginal gap; presence and absence of secondary caries; and the patient's ability to pay for treatment. There were three response categories, repair, replace or refurbish. The vignettes were randomised in SurveyMonkey®, and each dentist answered one vignette. There were 274 respondents who answered the clinical vignette questions.

Preliminary analysis indicated that the ability to pay (AP) was not important to predicting the response, so it was excluded in later stages. The interaction term between Marginal Gap (MG) and Secondary Caries (SC) was not significant, so a

simpler main-effect model was fit. There were three choices: Refurbish, Repair and Replace. Repair was chosen as the best option, and two scenarios were analysed: Refurbish versus Repair and Replace versus Repair.

5.18.1 Replacement versus Repair

5.18.1.1 *Secondary Caries as a factor*

The odds ratio for choosing Repair over Replacement when Secondary Caries is present (SC=1) compared with when Secondary Caries is absent (SC=0) must be considered. The restoration is less likely to repair when SC=1 (approximately 25% probability) than when SC=0 (approximately 41% probability) (Table 21). Hence, the odds ratio is expected to be less than 1. The estimated odds ratio from the model with two factors is 0.434, with a 95% confidence interval of 0.224, 0.842 (Table 22). Since both end points of the confidence interval are less than 1, the *p*-value for testing the null hypothesis that the odds ratio equals 1 would be less than 0.05 (i.e. the odds ratio is significantly different from 1).

Data from the interviews revealed that 2 of the 15 dentists were of the opinion that the presence of secondary caries necessitated the replacement of the defective dental amalgam restoration. There was a further suggestion that caries was linked to the presence of a marginal gap. One dentist was more defensive in his response, stating that all dentists experience secondary caries.

> *[B]ut I would prefer to remove the entire restoration and then clean out under the restoration in case of secondary caries* (Dr J).
>
> *I think the gap is always a problem for caries* (Dr N).
>
> *Every dentist experiences secondary caries. Even under the fillings I placed. Secondary caries will develop if the initial caries was not removed 100%* (Dr RA).
>
> *Secondary caries can develop under any restoration, and it's something we can't guarantee* (Dr RA).

5.18.1.2 *Marginal Gap as a factor*

The odds ratio for choosing Repair over Replacement when Marginal Gap is present (MG=1) compared to when Marginal Gap is absent (MG=0) must also be considered. Hence, the odds ratio is expected to be less than 1. From Table 23, the estimated odds ratio from the model with two factors is 0.594, with a 95% confidence interval of 0.311, 1.133. Since the lower end point of the confidence interval is less than 1 and the upper end point is greater than 1, it could be reasonably concluded that the odds ratio would be 1. Therefore, the test of the null hypothesis that the odds ratio is equal to 1 would have a *p*-value greater than 0.05 (i.e. the odds ratio is not significantly different from 1).

The data from the interviews inform that 4 of the 15 participants diagnosed tooth 26 as being a 'leaky restoration'. This was described as the amalgam restoration pulling away from the tooth surface and creating a gap where leakage can occur.

Table 23: Replacement versus Repair (MG=0, MG=1; SC=1, SC=0)

Frequency	**Secondary Caries absent SC=0**	**Secondary Caries present SC=1**	**Marginal Gap absent MG=0**	**Marginal Gap present MG=1**	**Total**
Replacement	37	121	50	108	158
	62.71%	78.57%	68.49	77.14	
Repair	22	33	23	32	55
	37.29%	21.43%	31.51	22.86	
Total	59	154	73	140	213

Frequency Missing = 50

This was not the same as diagnosing secondary caries but could predispose the patient to the development of secondary caries. One participant, however, did feel that "the gap is always a problem for caries" (Dr N).

> *It looks like a leaky amalgam … the margins are very uneven and pulled away from the enamel. So I suspect there is a leak* (Dr MA).

It looks like it is a leaking filling … the ridge is broken down around the tooth over there and there is a bit ... There could be a bit of a micro leakage over there or saliva could seep down there (Dr J).

Just looking at that tooth … intraorally, there is definitely micro leakage on that restoration [26]. You can see there is marginal discrepancy as well; there is decay as well as staining (Dr RA).

Other interview participants felt that the presence of a gap alone was not enough clinical evidence to warrant intervention. The presence of any clinical symptom, specifically pain or sensitivity, would indicate the need for an intervention. The intervention would usually be a complete replacement of the defective dental amalgam restoration. Suggestions such as burnishing or repolishing the amalgam restoration were made to improve the appearance of the restoration, specifically the marginal area.

I think one of the things that would be a factor to me clinically, is if there is a clinical symptom on a tooth like this, where there is a gap between the amalgam and the cavity wall. If there is a symptom of sensitivity on it, then I would feel differently about it, but if it is asymptomatic, and there is a space like that and we can burnish it down like this one on the other side, then I would feel … The one thing you don't want to do is over treat the area also (Dr Y).

[T]he amalgam is old. Look at the margins. They may be defective. And it's quite deep, and she is not complaining of pain, and there is no periapical area. Honestly, I would not do anything. If the patient does not come in with a problem, I don't create a problem (Dr S).

5.18.2 Refurbishment versus Repair

5.18.2.1 *Secondary Caries as a factor*

The odds ratio for choosing Repair over Refurbishment when SC=1 compared with SC=0 must be considered. From Table 24, the restoration is more likely to repair when SC=1 than when SC=0. Hence, the odds ratio is expected to be more than 1. The estimated odds ratio from the model with two factors is approximately

53.0 (53.137), with a 95% confidence interval of 11.47, 247. Since both end points of the confidence interval are more than 1, the *p*-value for testing the null hypothesis that the odds ratio is equal to 1 would be less than 0.05.

5.18.2.2 *Marginal Gap as a factor*

Finally, the ratio of odds for choosing Repair over Refurbishment when MG=1 compared with MG=0 must be considered. Table 24 demonstrates that the restoration is more likely to repair when MG=1 than when MG=0. Hence, the odds ratio is expected to be more than 1. The estimated odds ratio from the model with two factors is 5.62, with a 95% confidence interval of 2.32, 13.63. Since both end points of the confidence interval are more than 1, the *p*-value for testing the null hypothesis that the odds ratio is equal to 1 would be less than 0.05.

Table 24: Refurbishment versus Repair

Frequency	Secondary Caries absent SC=0	Secondary Caries present SC=1	Marginal Gap absent MG=0	Marginal Gap present MG=1	Total
Repair	22	33	33	32	55
	27.16	94.29	33.33	68.09	
Refurbishment	59	2	46	15	61
	72.84	5.71	66.67	31.91	
Total	81	35	79	47	

Missing= 50

5.18.3 Analysis of effects of Secondary Caries and Marginal Gap as predictor variables

Based on a multinomial response model using MG and SC as predictor variables (not AP since it was not a significant predictor), it was found that both MG and SC are significant predictors of the outcome ($p<0.0001$* in each case). The

magnitude of the effect is characterised by the odds ratio. This is the ratio of the odds[1] for choosing a particular outcome when, for example, SC=1, compared with the odds for choosing that outcome when SC=0. If the odds ratio is equal to 1, then both of the individual odds are the same, which mathematically means that their ratio is 1. A ratio greater than 1 means the odds are higher when SC=1 than when SC=0. Similarly, a ratio less than 1 means that the odds are lower when SC=1 than when SC=0 (Table 25).

Table 25: Analysis of effects

Effect	DF	Wald Chi-square	Pr>Chi-square
Marginal Gap	2	27.1587	<0.0001*
Secondary Caries	2	41.2585	<0.0001*

5.18.4 Mechanism of reimbursement

Data from the interviews indicate that 2 of the 15 dentists insisted that the method of payment did not affect their treatment. However, there was an awareness of the influence that finances could have when suggesting a treatment plan. Almost all (12 of the 15) participants asked for confirmation of whether or not the patient had medical aid cover.

[1] If *p* is the probability of an event, then *p*/ (1-*p*) is the odds of the event occurring. For example, if *p*=0.6, then the odds are 0.6/ (1-0.6) = 0.6/0.4 = 1.5.

My decision-making is first clinical. Then we see what you require, and then costs get discussed last. So if you are on medical aid, I tend not to look at your medical aid and I tend … if you not on medical aid, either way it doesn't matter. So we see what is needed and then we give you the options, and then you have to decide which way to go. I would first look at what the patient requires before anything else. In private practice, the one thing that I try not to do is to look at what the patient can afford (Dr Y).

Look, I will be honest with you, it doesn't really matter. Even if it was a medical aid case, we will go the conservative route. If the patient says they are quite happy to have the amalgam there and just repair the mesial section, then we go for that. Fine. No issues (DrRA).

Two of the dentists expressed concern in suggesting treatment for patients who had not reported any symptoms and did not have medical aid and thus, may be struggling financially. Treatment was seen as an unnecessary expense:

This woman does not have medical aid, and now you want to open up this thing and you have to put a composite, and it's going to cost you a lot of money. All these things. She is coming to us pain free (Dr RA).

Again, like I said, we see some of these patients and if they don't complain and they are not financially eager to do anything about it, I wouldn't do too much (Dr A).

One participant confirmed that treatments are influenced by funding, whilst two others remained cognisant about the financial well-being of their patients and "work according to their budget" (Dr LE).

You know, treatments are influenced by funding (Dr K).

I normally work according to their budget (Dr LE).

One participant expressed concern that if they were not competitive in the pricing of their treatment, the patients would consult another colleague.

> *In our practice, because we are working with people who want economical dentistry, what tends to happens if I tell a patient that I am going to charge her R650, they rather go somewhere and have it done for whatever the cheapest price is* (Dr A).

5.18.5 Self-administered questionnaire

A summary of the demographic data of these dentists was presented in Table 7. Table 26 provides a summary of the responses with regard to the patient profile of the individual practice. All practices except one reported that more than one-half of the patient population were members of a medical aid. A summary table of the recommended treatment for tooth 26 in the clinical vignette is presented in Appendix N.

Table 26: Summary of profiles of patients treated at the respective practices

	Number of patients per week	% patients with private insurance	% patients without private insurance	% patients 1–18 years	% patients 19–44 years	% patients 45–64 years	% patients 65 years and older
Dr J	60	65	35	30	30	20	20
Dr S	50	90	10	60	15	20	5
Dr A	80	70	30	10	60	20	10
Dr LD	50	70	30	10	50	20	20
Dr M	70	85	15	25	25	40	10
Dr LA	80	80	20	25	25	25	25
Dr LE	60	70	30	25	63	10	2
Dr K	50	50	50	20	40	30	10

	Number of patients per week	% patients with private insurance	% patients without private insurance	% patients 1–18 years	% patients 19–44 years	% patients 45–64 years	% patients 65 years and older
Dr F	50	50	50	30	30	25	15
Dr LI	50	0	100	20	60	10	10
Dr RI	40	70	30	20	70	5	5
Dr RA	100	70	30	30	50	15	5
Dr MA	100	85	15	20	10	20	50
Dr N	25	60	30	10	50	30	10
Dr Y	75	75	25	30	30	25	15

5.18.6 Data from treatment logs

Only 9 out of the 15 dentists submitted treatment logs. Each dentist was asked to complete an entry for every patient who received a direct restoration during a two-week period. A total of 300 patients were treated and 468 individual teeth (Appendix O). The data indicates that the treatment of primary caries was the main service provided.

Using only the unique responses in which new restorations were placed, resin composite was the material of choice in most instances (Table 27). Almost two-thirds of these restorations were due to primary caries (Table 28). However, when the restorations were replaced, only 12% were due to secondary caries (Table 29).

Table 27: Choice of material for 'new restorations'

Material	Frequency	%
Amalgam	11	2.4
Resin composite	357	78
Glass Ionomer	41	9
Compomer	24	5.2
Other	4	0.8
Not answered	21	4.6

Missing= 10

Table 28: Reasons for a 'new restoration'

Reason	Frequency	%
Primary caries	294	63
Non-carious defects	54	11
Other	23	5
Not answered	97	21

Table 29: Reason for replacement of a restoration

Reason	Frequency	%
Secondary caries	56	12
Marginal discoloration	2	0.43
Bulk discolouration	2	0.43
Isthmus/ Bulk fracture	12	2.6
Tooth fracture	17	4
Poor anatomic form	1	0.2
Pain/sensitivity	18	3.9
Not answered	355	77

CHAPTER 6: DISCUSSION

6.1 INTRODUCTION

This chapter discusses the findings of the present study and integrates the findings of both the quantitative and qualitative phases. The first section discusses the model of decision-making for defective dental amalgam restorations and is followed by a discussion on the diagnosis and management practices of South African dentists, factors influencing treatment decisions and the attitudes of dentists. The final section discusses the limitations of the study.

While there has been an increase in practice-based studies conducted in dentistry, this is one of the few studies that focuses on clinical decision-making in South Africa. A worldwide trend towards minimally invasive dentistry and a dearth of information on the restorative treatment practices and clinical decision-making of South African dentists, specifically on how defective dental amalgam restorations are managed by dentists in private practice, motivated the present study. The study is anticipated to make an important methodological contribution with the use of mixed methods and practice-based research in the field of dentistry in South Africa.

The purpose of the present study was to explore the practices, knowledge and attitudes of South African dentists with regard to the management of defective dental amalgam restorations. The findings of the study supported the first hypothesis that South African dentists routinely replace all defective dental amalgam restorations.

This study confirmed that clinical decision-making is influenced by a multitude of factors, not only the disease process. The second hypothesis that dentists' practices differ with respect to personal and practice characteristics was also supported. In addition, the present study combined the 'models' into a single framework for a more comprehensive understanding of the extent of the influence of clinical and non-clinical factors in the management of defective dental amalgam restorations by South African dentists. In examining the influence of treatment preferences on the management of defective dental amalgam

restorations, the research findings supported the third hypothesis that dentists' attitudes towards dental amalgam influences their decisions to replace defective dental amalgam restorations.

6.2 THE PROPOSED MODEL FOR TREATMENT DECISIONS OF DEFECTIVE DENTAL AMALGAM RESTORATIONS

The classification of issues relevant to treatment decision-making in general dental practice by Kay and Blinkhorn (1996) and the conceptual model of caries-related treatment decisions of Bader and Shugars (1997) are similar and form the basis of the new conceptual model proposed by this study and portrayed in Figure 7.

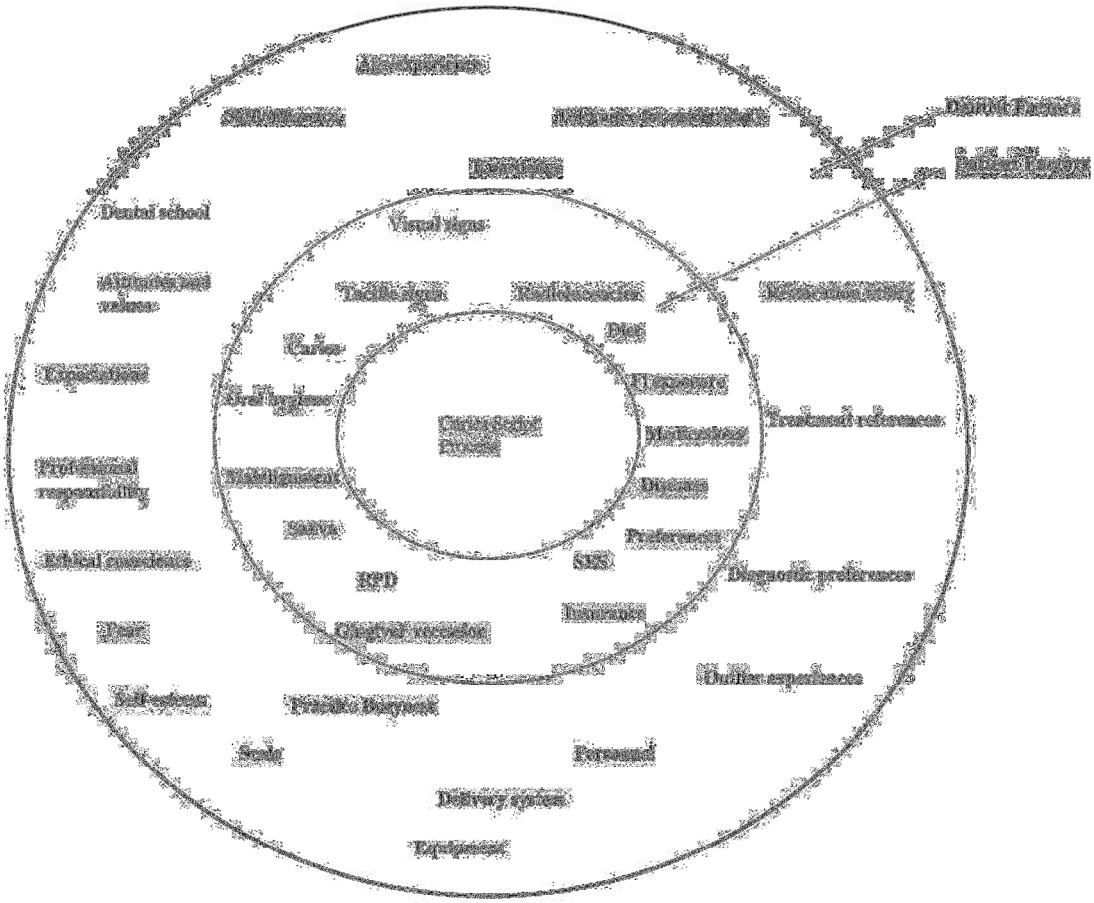

Figure 7: Adapted model for caries-related treatment decisions

The inner circle represents the decision-making process for managing a defective dental amalgam restoration, and the outer rings illustrate the influence of dentist and patient factors (clinical and non-clinical) on the process.

In this study, non-clinical factors such as fear, ethical conscience and dental school had an influence on the decision process. The caries script process as described by Baders and Shugars (1997) remains unchanged.

6.3 CONTEXT OF THE STUDY

In South Africa in 2014, a total of 5 824 dentists were registered with the HPCSA (HPCSA, 2014), of which 3 607 were members of SADA. Despite being reminded of their participation fortnightly for two months, there was a low response rate of 10.7% for the quantitative online survey. However, this is consistent with other studies conducted that used the same study population and similar electronic survey methods (Botha *et al*., 2014; Snyman *et al*., 2016).

This study comprised approximately one-third female participants. A study of the gender distribution among dental graduates between 2000 and 2005 reported a two-fold increase in the number of female graduates (Lalloo *et al*., 2005). Previous research conducted in South Africa also noted differences in the working patterns of male and female dentists. A study in 1997, found that gender, breadwinner status and age of children had a considerable influence on working patterns (DeWet *et al*., 1997). The percentage of male to female dentists working in private practice was 89.7% to 70% respectively (DeWet *et al*., 1997). However, the working hours of female dentists dropped from 86% (practising more than 35 hours per week) to 34%, while male dentists' working patterns remain unchanged (DeWet *et al*., 1997). Only 19% of female dentists were the primary breadwinners, indicating that many female dentists were able to work part-time (DeWet *et al*., 1997). In addition, a greater percentage of female than male dentists worked for a salary in government clinics and at academic institutions (DeWet *et al*., 1997). The present study focused on dentists in private practice and if these working patterns remained unchanged from 1997, this may have influenced the study population.

The sample of the present study comprised 'younger dentists', with the majority of participants being under the age of 55 years and more than one-half having over 15 years of experience. Approximately one-half of the sample was self-employed without partners, and two-thirds were contracted to medical aids.

6.4 MANAGEMENT PRACTICES OF DEFECTIVE DENTAL AMALGAM RESTORATIONS BY SOUTH AFRICAN DENTISTS

The findings of the present study were in line with global trends, revealing a decline in amalgam use, with only 7% of participating dentists using it as a restorative material in South Africa. Despite this, dentists in this study advocated its use due to the excellent lifespan and durability, and a significant number believed it should remain available for clinical use. This is in stark contrast to the 99.7% of dentists who were using dental amalgam in 1990 and the 85.8% in 2003 (Du Preez *et al*., 2003). It should be noted that the 2003 study conducted by Du Preez *et al*. only had 177 respondents as opposed to 324 in this study. The dramatic decline may be due to dentists' increasing perception that the material is outdated and patients' increasing awareness of the possible harmful effects of dental amalgam since "*they are very knowledgeable, and they have Internet now and smartphones*" (Dr J). It could also be the result of demands for a more aesthetic restorative material from both dentist and patient (Petersen, 2003). Concern was also raised with regard to the failure rate of posterior composite restorations, and this was used as a motivation for using dental amalgam.

In 2009, Lombard *et al*. compared teaching practices on dental amalgam with posterior composite restorations in South African dental schools. They reported that an equal amount of time was spent on the preclinical teaching of both materials (Lombard *et al*., 2009). In order to prepare future dentists adequately with the appropriate skills needed in the South African context, dental schools need to review the time spent on teaching amalgam and composites. The present study suggests that more time should be spent on teaching techniques for the successful placement of posterior composite restorations and the repair of defective dental restorations.

Recent studies have confirmed that the repair of defective dental restorations is a clinically viable option to extend the longevity of a restoration without compromising tooth structure or incurring huge costs as in the case of indirect restorations (Gordan *et al*., 2015; Moncada *et al*., 2015a, 2015b). Data from the self-administered questionnaires revealed that the majority of dentists reportedly repair defective dental amalgam restorations.

Most of the dentists in this study who did not repair restorations felt there was a lack of predictability in the technique. This lack of knowledge or competence in the technique potentially means patients are not offered a treatment procedure that has been shown to require less anaesthetic and conserve more tooth structure (Javidi *et al*., 2015). Furthermore, until a decade ago, dental amalgam was the material of choice in South Africa (Du Preez *et al*., 2003). Given that the longevity of dental amalgam restorations varies between 7 years and 20 years, it is anticipated that South African dentists will be treating more patients with defective dental amalgam restorations in the near future (Laske *et al*., 2016). Recent data on improved patient outcomes when choosing to repair a restoration and the continued evolution of dental materials and adhesive dentistry signals a change in the practice of clinical dentistry (Javidi *et al*., 2015). The lack of adequate knowledge and skills among South African dentists on how to repair defective restorations may adversely affect health outcomes for an entire population. This raises issues of ethics and quality of care.

Approximately two-thirds of dentists who were repairing defective dental amalgams learnt the technique through their own clinical experience. The lack of awareness of the accepted repair techniques suggest two possible opinions. Firstly, clinicians often assume that a treatment is successful based on positive outcomes reported for a number of treated patients. Secondly, the perception that the treatment ‘works in my hands’ is often better evidence for general dentists that the treatment is clinically viable and acceptable as opposed to data from ‘artificial clinical trial settings’. While dentists are bombarded with information from dental company representatives, they often lack the ability to evaluate the scientific information critically. This prevents the incorporation of evidence-based dentistry into general dental practice.

While the dentist is responsible for providing appropriate dental care, the responsibility to implement suitable dental care is shared between dental schools and professional organisations (Fejerskov and Kidd, 2009). Dental schools should ensure that their curriculum is based on evidence-based practice. Dentists should be taught how to access sound resources of evidenced-based dentistry and how to incorporate these guidelines into clinical practice. An important part of teaching dental students to think critically includes making them aware of conflicting evidence or the absence of evidence. The fact that dentists have adapted their own 'repair technique' may imply that dental schools in South Africa have not yet formally included repair techniques into their curricula, as have the UK, USA and European schools where they teach the repair of direct restorations (Blum *et al*., 2002; Blum *et al*., 2003a, 2003b; Gordan *et al*., 2003; Setcos *et al*., 2004; Hasan and Khan, 2013). Gilmore *et al*. (2006) stated that "the adoption of evidence-based practice by dentists has been slow". The present study suggests that South African dentists are no different and raises concern regarding the practice of evidence-based dentistry and the competency of acquiring and maintaining evidence-based knowledge.

While no consensus has been reached on a repair technique, recent research has clearly outlined successful and appropriate techniques (Hickel *et al*., 2013; Blum *et al*., 2014). Dental amalgam does not adhere to tooth structure; consequently, in keeping with recent research, a large percentage of the dentists indicated that they would use a bur to create mechanical retention (Blum *et al*., 2014). In addition, dentists in this study reportedly spend approximately five days annually to continuing professional education, yet few of them were aware of published repair techniques or alternatives to the management of defective restorations. This advocates the need to evaluate existing and continuing professional education programmes and to investigate the translation of knowledge into everyday practice. It may also be helpful for professional organisations to advocate the use of clinical guidelines based on well-conducted systemic reviews by organisations such as Cochrane and the National Institute for Health and Clinical Excellence.

Once the decision has been taken to repair a restoration, the focus shifts to the selection of a suitable dental restorative material to repair the defective dental

amalgam restoration. In the present study, more than one-half of the dentists reported discussing the choice of dental material with patients even though it is possible that most patients would not understand the scientific rationale.

Data from the present study was conflicting with regard to the choice of material used when repairing a defective dental amalgam restoration. Consistent with the decrease in amalgam usage worldwide and the findings from the National Dental Practice-Based Research Network (Gordan *et al*., 2012b), resin composite was the restorative material of choice when repairing a defective dental amalgam restoration. However, similar to the findings of Gordan *et al*. (2012b), a very small number of dentists were confident to use amalgam to repair an existing defective dental amalgam restoration. A concern for aesthetics and the perception of a lack of adequate bond strength between dental amalgam and composite could explain these results even though laboratory studies confirmed favourable bond strengths when using resin composite to repair defective amalgam restorations (Machado *et al*., 2007; Özcan and Schoonbeek, 2010; Cehreli *et al*., 2010).

One of the major concerns in repairing a restoration was placing two different types of restorative material adjacent to each other. Dentists queried the validity of the technique because their years of dental schooling had not included this. One particular dentist was extremely shocked at the idea of a single tooth or surface having two different restorative materials. The idea was not plausible "*because we were not taught how*" (Dr S). Another dentist recalled the specific lecturer who was responsible for teaching dental materials and who had affirmed that it was indeed possible to repair a restoration. In this case, the effect of dental training on restorative practice is undoubted and strengthens the argument for a review of current teaching in dental schools and an update for practitioners (Maryniuk, 1990; Bader and Shugars, 1997; Kay and Nuttall, 1994; Doméjean-Orliaguet *et al*., 2009).

6.5 FACTORS TAKEN INTO CONSIDERATION WHEN MANAGING A DEFECTIVE DENTAL AMALGAM RESTORATION

Several factors are responsible for the variation in clinical decision-making in dentistry such as dental training, knowledge of the disease, dentists' preferences and specific factors relating to the tooth or restorative material (Bader and Shugars, 1992; Riley *et al*., 2011). The present study confirmed the decision-making model proposed by Bader and Shugars (1997) and indicated a distinct pattern in the factors taken into consideration when managing a defective dental amalgam restoration.

6.5.1 Tooth factors

Tooth factors such as remaining tooth structure, size and depth of the restoration and the presence of caries were ranked higher than patient factors (viz. occlusion, finances and presence of pain) and material factors. This supports previously published research in which technical factors dominated patient outcomes (Grembowski *et al*., 1988; Brennan and Spencer, 2002). Literature has identified an emphasis in teaching of the technical aspects without creating an awareness of the importance of patient outcome as a possible reason for this (Doméjean-Orliaguet *et al*., 2009).

There is documented evidence that each time a restoration is replaced, the size of the cavity increases and the tooth structure is further compromised with an increased possibility of pulpal involvement (Gordan *et al*., 2004). Costly, advanced dental procedures such as root canal treatment and indirect restorations may be the only alternative to extending the longevity of the tooth. Extraction of the offending tooth is a viable treatment option if the patient is unable to afford costly treatment. However, this could be avoided if the dentist has the knowledge and skills to recommend and perform repairs of defective restorations if appropriate. This may prolong the longevity of the tooth.

Visible caries was the most important consideration when replacing a restoration. A statistically significant relationship was found between repair and replacement and the presence of a marginal gap and secondary caries.

In contrast to Gordan *et al.* (2012b), there was only a 25% probability that dentists would repair a restoration with a diagnosis of secondary caries. Similarly, participating dentists were less likely to repair in the presence of a marginal gap. This could mean that dentists were not confident that a repair would yield a positive treatment outcome in the presence of caries and that caries could recur. In South Africa, there is a high rate of unemployment, and one of the benefits of a good job is access to a healthcare fund. As a result, only 14% of the population are members of a medical scheme (Gray and Vawda, 2015). This means that most individuals have to pay for any health service, including oral health. It would appear that dentists will only recommend repairing a defective dental amalgam restoration if patients are unable to afford an indirect restoration or a complete replacement of the restoration. Data from the interviews illustrated how dentists consider the cost and benefits to themselves as operators (i.e. How long it will take?), to the patient (i.e. Will the patient 'benefit' from the treatment?) and to the profession (i.e. Will the patient perceive dentistry as beneficial?).

It would seem that because recent studies on repairing restorations have reported positive patient outcomes, the technique may also be capable of improving the patient's perception of dentistry (Javidi *et al.*, 2015).

6.5.2 Patient factors

The present study found that dentists ranked 'cost to patient' as the most important consideration in their decision to repair or refurbish a defective dental amalgam restoration. These findings corroborated those reported by Brennan and Spencer (2006). Dentists interviewed in the present study who were sensitive to the financial difficulties that patients experience proposed a treatment plan, and some dentists "*work according to their [patient's] budget*" (Dr LE). Dentists provided different levels of restorative care based on their perception of the patient's ability to pay. This demonstrated their willingness to provide the best level of care within the financial constraints set by the patient (Maryniuk, 1990). However, if patients did not experience any symptoms, dentists were reluctant to suggest treatment, especially if there was concern about the patient's ability to

pay. Dentists would recommend that treatment be delayed until absolutely necessary.

Interestingly, the caries risk of a patient was only considered important when refurbishing a restoration. The lack of preventive dentistry concepts used in these treatment decisions may be explained by factors relating to dentists' knowledge, patient demand, dental training or the health system. Schwendicke *et al*. (2015) cite Black's (1891) concept of 'extension for prevention' that has guided conventional operative treatment of carious lesions for many decades. In addition, given that the majority of dentists in this study had more than 15 years of experience, they may not be familiar or comfortable with the incorporation of preventive strategies in their practices, strategies that may be more time-consuming but not necessarily more financially rewarding. In addition, service health systems in South Africa do not reward dentists for adopting a more preventive approach in caries management. It is also possible that South African dental schools do not specifically and actively incorporate preventive methods in the comprehensive management of adult patients.

Replacement of restorations was only recommended if the patient reported a symptom such as pain. Insight from the interviews suggest that dentists felt uneasy with recommending a treatment such as a repair when they were unsure about the clinical effectiveness.

6.5.3 Dentist factors

The present study was conducted to identify clinical and non-clinical factors that may act as predictors for the repair or replacement of defective dental amalgam restorations by South African dentists.

A significant relationship was found between age of the dentist and the repair of dental amalgam restorations. In contrast to previous studies, older dentists were found to be more inclined to repair than replace defective dental amalgam restorations (Gordan *et al*., 2009; Gordan *et al*., 2012b). Older dentists may have more clinical experience.

In this study, gender did not have any influence on treatment decisions although previous studies noted a difference in treatment approaches (Brennan and Spencer, 2005; Riley *et al*., 2011). Riley *et al*. (2011) found that female dentists were more conservative and more inclined to use caries-preventive measures. The small number of female dentists participating in this study could account for not detecting a difference in treatment approaches.

Preferences for techniques and materials were found to influence clinical decision-making; dentists with more than 21 years of experience were more likely to choose amalgam as the material of choice when repairing a defective dental amalgam restoration. This was not surprising since the majority of them would have more clinical experience using amalgam.

Dentists who were interviewed expressed fear of facing patients as a consequence of an unsuccessful clinical decision and the possibility of incurring additional costs for the patient when a treatment was unsuccessful. This places dentists in conflict with their decision to prioritise the patient's well-being or to benefit financially from their professional recommendation, which may result in overtreatment. The concern is that dentists would only recommend repairing a defective dental amalgam restoration if patients were not able to afford an indirect restoration or a complete replacement of the restoration.

Three practice-related factors, practice arrangement, practice location and contracted to third-party funders, were tested for their association with repair and replacement of defective dental amalgam restorations. The only factor found to have a significant relationship was 'contracted to third party funders'. Surprisingly, dentists who were contracted to medical aids were more likely to repair defective dental amalgam restorations. Data from the interviews and the online survey reported concern among participating dentists in placing an additional financial burden on patients when a defective dental restoration required treatment. The repair of a defective restoration could be classified as a restoration, and no additional authorisation or payment would be necessary from the medical aid. However, if the patient presented with pain, dentists were

reluctant to repair restorations. In this instance, a root canal or crown would be more appropriate, which could incur additional costs to be paid by the patient.

6.5.4 Knowledge of dentists in managing defective dental amalgam restorations

Similar to other studies, dentists in the present study were more likely to replace a restoration if secondary caries was found (Mjör and Toffenetti, 1992; Burke *et al*., 1999; Mjör and Toffenetti, 2000; Setcos *et al*., 2004; Silvani *et al*., 2014). While secondary caries is the most common reason for the replacement of restorations (Mjör and Toffenetti, 1992), previous research has labelled the diagnosis and treatment of secondary caries as clinically challenging (Sarrett, 2009). Secondary caries is histologically similar to primary dental caries (Fejerskov and Kidd, 2009), but because many lesions are not at the interface of the tooth and restoration, diagnosis may be difficult (Gordan *et al*., 2009). This uncertainty means that dentists rely more on radiographs despite the fact that it is not a reliable predictor of cavitation (Schwendicke *et al*., 2015). The most common diagnostic method for secondary caries used in this study was radiographs, followed by the presence of soft, discoloured dentine or enamel.

Any uncertainty in the diagnosis may force dentists to be more invasive and replace restorations rather than repair them. The present study found that the majority of dentists had outdated concepts regarding secondary caries and marginal gaps. The dentists believed there was a correlation between the presence of a marginal gap and secondary caries. Participating dentists were more inclined to replace an entire restoration because of *'faulty margins'*. Replacement criteria developed in 1988 found that "marginal gap alone was not reason enough for a replacement of a restoration" (Boyd, 1989). In 2012, Dennison and Sarrett elaborated on that statement. They maintained "that marginal defects without visible evidence of soft dentin on the wall or the base of the defect should be monitored for change or repaired or sealed and then monitored" (Dennison and Sarrett, 2012).

Related to this misconception is the reference to 'leaking restorations' by participating dentists. Dentists implied a relationship between micro-leakage and

secondary caries even though it has long since been determined that micro-leakage is not a predisposing factor nor a predictor for secondary caries (Dennison and Sarrett, 2012). The present study found a statistically significant relationship between repair and replacement and marginal gap and secondary caries.

In addition, the dentists believed that in the absence of any clinically or radiographically detectable decay around faulty margins, caries could be present below the margins or could develop in the future. They would recommend that these restorations be replaced; it is almost more acceptable to over diagnose than misdiagnose. Uncertainty about when it is appropriate to intervene caused dentists to favour surgical intervention. Gordan *et al*. (2009) reported similar findings and attributed this to the lack of standards in determining the failure of a restoration and the lack of appropriate reimbursement for the procedure. Other possibilities are that dentists would want to remove all possible causes of infection or they are unsure of the diagnosis.

Some of the dentists in the present study also recommended replacing restorations with defective margins. The literature describes this behaviour as "defensive dentistry" in which a dentist adopts an "if in doubt, replace" attitude as opposed to a minimal intervention approach (Blum *et al*., 2014). The effect of these factors may result in dentists over treating and unnecessarily replacing restorations, perpetuating the "restorative cycle" (Elderton and Nuttall, 1983; Elderton, 2003; Alexander *et al*., 2014). A review of the basic concepts in caries diagnosis at dental schools and in continuing education courses for practitioners may prevent this behaviour in the future. Variation in treatment decisions show that positive and false negative diagnoses and treatments occur because of the uncertainty of clinical decisions (Choi *et al*., 1998). It is recommended that dentists are made aware of these uncertainties and how they may affect clinical decision-making.

6.5.5 Dentists' attitudes towards repairing defective dental amalgam restorations

Similar to the qualitative investigation into factors affecting treatment decisions by Kay and Blinkhorn (1996), participating dentists expressed concern over the ethics, cost and benefits of the repair procedure. Some dentists felt that repairing a

restoration was "*not the best treatment a dentist could offer"* (DR LE). This could be because they personally did not place the original restoration, and research has demonstrated that dentists are more likely to replace a restoration that they have not originally placed (Gordan *et al*., 2009). It is also possible that they are drawing from their experience as dental students. Most dental schools in South Africa use the quota system in teaching restorative dentistry, and students are sometimes asked to replace restorations to gain more experience with a technique or a restorative material. While this may improve technical ability, the dental student has also learnt not to trust the work of colleagues by indiscriminately replacing restorations (Boyd, 1989). Dental schools should be aware that students also learn informally (Boyd, 1989). Attitudes, preferences and beliefs are co-curricular activities that students learn consciously and unconsciously. This behaviour shapes the behaviour of the future dentist and affects practice patterns (Brennan and Spencer, 2001).

Other participants regarded the repair of defective restorations as "*patchwork"* and "*not the right thing to do*" (DR LE). This supports the findings of Sharif *et al*. (2010) and could largely be attributed to a lack of knowledge of alternative therapies to replacement and outdated beliefs regarding the relationship between marginal gaps and secondary caries.

Literature has described dentists' fears to include fear of litigation, fear of consequences of clinical decisions, fear of cost to patients and fear of cost to practice/dentists (Fox, 2010). Dentists in this study expressed fear of consequences of clinical decisions, fear of litigation and fear of recommending 'costly' treatment to patients. All of these relate to trust between a dentist and a patient and the belief that the dentist will always act in the patient's best interest. This is an example of Maryniuk's (1990) explanatory model of practice pattern variation in which the dentist's practice patterns are driven by a desire always to act in their patient's best interest. Another fear dentists expressed was losing clientele to colleagues if they were not competitive enough with their costs for treatment. The dentist has to reach a compromise between providing the best appropriate treatment and cost effectiveness for the practice and for the patient.

6.6 LIMITATIONS OF THE STUDY

This study has a number of limitations that the reader should bear in mind:

- **Study design:** The quantitative phase of the research was a cross-sectional design. An inherent flaw in this design is the difficulty to make causal inference and the possibility that the situation may provide different results in another time frame. The generalisability of the results may be difficult since the findings may be more specific to dentists practising in South Africa.
- **Sampling:** The study population was limited to SADA membership, and this may not be representative of all dentists in South Africa. It may reduce the generalisability of the findings. In the qualitative phase, sampling was non-probability based, purposive and convenience. Interviews were conducted with dentists in the Western Cape. The purpose of the interviews was to provide insight and depth to clinical decision-making by dentists in South Africa. Extrapolating findings from data collected in the interviews to the national survey is unlikely to bias the study because of the variation among dentists irrespective of location.
- **Data collection:** The use of an online survey may have automatically excluded dentists who were not fully computer literate. Use of the think-aloud technique is limited by the ability of the participants to think and talk aloud, including their ability to express themselves. This may affect data validity. Data collected from only one case study during the semi-structured interviews was included in the study because the majority of the participants repeated information for the second case. The interviews were also restricted in time due to the fact that most dentists agreed to participate during their lunch time.

CHAPTER 7: CONCLUSION AND RECOMMENDATIONS

In this chapter, the key findings are highlighted and their implications as they relate to teaching, practice and policy are discussed. Recommendations are made and suggestions for further research are outlined.

In recent years, there has been an increase in the number of practice-based studies conducted, specifically in dentistry. The present study provides important insight into restorative treatment practices and clinical decision-making of South African dentists, specifically regarding how defective dental amalgam restorations are managed by dentists in private practice.

The present study illustrated that a combination of the concepts defined by Bader and Shugar (1997) in their caries-related conceptual model and the classification of non-clinical factors by Kay and Blinkhorn (1996) gives a more comprehensive understanding of the decision-making process for the management of defective dental amalgam restorations. The findings suggest that South African dentists face similar challenges to dentists in more well-developed countries where the caries levels are lower.

7.1 SUMMARY OF KEY FINDINGS

- Dentists were more likely to replace all defective restorations.
- Dentists with more than 21 years of experience were more likely to repair defective restorations.
- Cost to patient, uncertainty in diagnosis and dental school were the most influential non-clinical factors.
- Secondary caries and the presence of a marginal gap were significant predictors for the repair of defective restorations.

Data from the treatment logs submitted indicated that the replacement of restorations does not account for a major portion of dentists' time spent in practice. This is in contrast to studies conducted in the USA, UK and Europe.

However, it is in keeping with the higher level of caries that is present in the South African population. In this study, the use of outdated concepts and knowledge, especially with regard to micro-leakage, secondary caries and the presence of a marginal gap, had a significant influence on the replacement of restorations. While the diagnosis of secondary caries and micro-leakage remains a challenge, dentists had a tendency to diagnose secondary caries and micro-leakage if they were in doubt about the quality of the restoration. This uncertainty led to many unnecessary replacements. These findings have implications for teaching and practice. Dentists are 'out of touch' with core knowledge and techniques. While this may be expected from older clinicians, younger dentists were exhibiting similar practice patterns. This means that they do not know any better or are too comfortable with their outdated techniques and too reluctant to change. Similarly, dentists reportedly replaced restorations to prevent any caries developing in the future even though it has been proved that a defective restoration does not imply that the restoration is clinically unacceptable.

This study also supports previous evidence that dental schools and their teachings not only have a tremendous influence on the initial development of clinical decision-making skills but also on the eventual treatment decisions of the professionals in dentistry (Maryniuk, 1990). The challenge is for dental curricula to be more responsive and contextually appropriate in order to affect the oral health of the population positively and to equip dentists with skills that will enable them to make evidence-based decisions. This study does not suggest that evidence-based dentistry is not taking place in South African dentistry but rather that the translation of this evidence-based dentistry to everyday clinical practice be more overt to dentists in practice and to future dentists.

The findings of this study confirmed that dentists are influenced by a number of non-clinical factors in their decision-making processes. A combination of these factors often force dentists to perform unnecessary replacement of restorations, increasing the restorative burden on the tooth and pushing patients into the 'restorative cycle'. This study also contributed to the small pool of data available in dentistry for understanding the mechanisms and the degree to which fear may affect clinical decision-making.

7.2 IMPLICATIONS FOR TEACHING AND PRACTICE

- The findings of the present study suggest that dentists are not able to use and implement evidence-based knowledge in their practices, thus adversely affecting the health outcomes of many. Specific areas include: determination of the quality of restorations; diagnosis and management of secondary caries; and marginal gap and repair techniques for defective restorations.
- The study also suggests that dentists are not equipped with the skills to search for the necessary information. Undergraduate dental curricula and continuing professional education should focus on the development of critical thinking skills.
- Although dentists in the present study were participating in continuing professional education programmes, it did not appear to translate to their clinical practice. The value of current continuing professional activities should be assessed so that dentists, and ultimately patients, may benefit from them.
- It is evident from this study that dentists' treatment patterns and clinical decision-making processes are shaped by the teaching in dental schools. Their experiences as dental students create the initial caries scripts that will later mature into their individual practice beliefs and identity as a clinician. This implies that dental students should be exposed to a greater variety of cases to develop more scripts that they may draw on during the clinical decision-making process.
- In addition, the influence of non-clinical factors on clinical decision-making should remind clinical teachers and creators of curricula that both the social aspect of patient management and the focus on patient outcomes are equally important as developing technical competences in the discipline. Comprehensive management of patient cases should be investigated in preference over the quota system that is used in South African dental schools.

7.3 IMPLICATIONS FOR POLICY

- The current health system in South Africa is a fee-for-service system. In dentistry, dentists are remunerated for treating caries with restorations. Incentives for practising preventive dentistry and minimally invasive dentistry should be instituted to allow patients to assume more responsibility for their oral health.
- Third-party funders should also evaluate the possibility of creating a fee structure for the repair and refurbishment of defective restorations as a more cost-effective measure to retain natural teeth for longer. This could ultimately improve the oral health outcomes of a population.

7.4 RECOMMENDATIONS FOR FURTHER RESEARCH

Recommendations for further research include:

- Investigating the use of evidence-based restorative treatment principles in practice.
- Evaluating the current continuing professional activities for dentists with regard to the translation of evidence-based knowledge to everyday general practice.
- Reviewing teaching on the diagnosis, management and repair of direct restorations in dental schools across South Africa as well as in continuing education programmes.

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APPENDICES

Appendix A: Summary of studies conducted on reasons for replacement of restorations

Year	First Author	Observation period	GV Black	Restorative materials	Primary or Permanent Dentition	No. of placed restorations (n)	No. of replaced restorations (n)	Study Design	Reason for replacement (% distribution)								Remarks
									Secondary caries	Bulk discolouration	discolouration	Marginal fracture/degradation	Poor anatomic form	Bulk fracture	Fracture of tooth	Lost filling	Pain/ sensitivity	
1981	Mjor	2 weeks		Amalgam Toothcoloured	Both	5487	2504 1544	Practice-based (85)	60 20		0 7	10	0 40	13	12			
1985	Boyd	5 days	surfaces	Amalgam		Only record replaced surfaces.	3662 surfaces	Practice-based (108)	19+21 +10			21	3	9	8	2		Confusing categories of recurrent caries,new caries and caries under amalgam
1985	Klausner	2		Amalgam		5392	2146	Practice-based (122)	53			13		13	11			
1986	Qvist	2 years	I II III V	Amalgam	Both		6052	Cross sectional	40 22 32 45		1 0 6 -	27	1	15	3	9		
1987	Klausner	14 days		Amalgam		5511	2996	Practice-based (191)	53			17		8	13			
1990	Elderton	1 year 3 years 5 years				5824 (tooth surfaces)	559 195	NHS	38			40						

Year	First Author	Observation period	GV Black	Restorative materials	Primary or Permanent Dentition	No. of placed restorations (n)	No. of replaced restorations (n)	Study Design	Reason for replacement (% distribution)									Remarks
									Secondary caries	Bulk discolouration	discoluration	Marginal fracture/degradation	Poor anatomic form	Bulk fracture	Fracture of tooth	Lost filling	Pain/ sensitivity	
1990	Qvist	first 30 fillings in 3 weeks	I II III V	Amalgam Composite GI SilicateCement Cast	Both	7454	1973	Practice-based (265)										Data was differentiated according to primary or secondary dentition and not material used.
1990	Qvist			Amalgam Composite		2317 1974			38			12	2	27	9	8		
1990	Drake	1 month		All		Only record replaced restorations.	284(206 amalgam)	Practice based(3 dentists)	34			42	1	42	4			Practice based study of 3 dentists. Insight into variation and choices made
1992	Mjor	2 weeks		Amalgam Composite	Permanent	2960	787	Practice based (62 dentists)	59			11		13	7		3	Composites were reported on in a different paper
1994	Friedl	1 month		Amalgam	PRT PET1 PET2		2961	cross-sectional	54 48 48			12 18 20	4 1 2	22 15 18		4 2 3		Fracture was not specified.

Year	First Author	Observation period	GV Black	Restorative materials	Primary or Permanent Dentition	No. of placed restorations (n)	No. of replaced restorations (n)	Study Design	Reason for replacement (% distribution)									Remarks
									Secondary caries	Bulk discolouration	Marginal discoluration	Marginal fracture/degradation	Poor anatomic form	Bulk fracture	Fracture of tooth	Lost filling	Pain/ sensitivity	
1994	Pink	50 amalgam restorations,50 composite restorations		Amalgam Composite	Permanent	1877 1606	-45%		25 20						8.8 4.8	4.9 5.5		Material failure:12.7% for amalgam and 16.8% composite
1997	Wilson	6 weeks		All			708	Practice based (22 dentists)	43			15		18	11			
1997	Mjor	2 weeks		Amalgam Composite GI	Permanent		1062 2431 538	Practice-based (177 dentists)	50 38 50		4 2		9 12	29 20 18	15 13 0			Marginal discrepancies are included in fracture of filling
1999	Burke	100 restorations		Amalgam Composite GI			4608	VDP(73)	46 40 40		12 7	13 9 14		12 8 7	11 6 0			60% of restorations placed were replacements.
2000	Deligeorgi	3 months: Manchester Athens		Amalgam Composite GI-related	Permanent	2620	748 (Manchester) 445 (Athens)	Student clinics in 2 dental school	67 36 17		1 22 8	4 2 0	2 5 33	11 2 8	3 7 0	2 7 17	5 3 0	
							445 Athens		25 40 x		0 5 33	15 3 0	14 14 17	23 7 17	2 1 0	6 8 33	5 0 0	

Year	First Author	Observation period	GV Black	Restorative materials	Primary or Permanent Dentition	No. of placed restorations (n)	No. of replaced restorations (n)	Study Design	Reason for replacement (% distribution)									Remarks
									Secondary caries	Bulk discolouration	Marginal discoluration	Marginal fracture/degradation	Poor anatomic form	Bulk fracture	Fracture of tooth	Lost filling	Pain/ sensitivity	
2001	Burke	1 month		Amalgam Composite GI Compomer		3196(Total)	2099(Replacements)	Practice-based dentists (15)	51 35 20 39		3	12 18 51 2	7	10 7 4 10	10 7 0 7			3=Discolouration in GI, 7= poor anatomic form in compomer
2002	Oginni	2 months		Amalgam	Permanent	488	121	cross-sectional: pts referred to dept. of restorative dentistry	30,6			12,4		47	3,3	6,6		
2005	Tyas	100 restorations		Amalgam Composite GI Compomer		767 1481 406 44	1460	Practice-based dentists (28)	32			14		19	17			Results of all replacements not only amalgam. Paper also recorded which class cavity
2013	Oloaleye	1979-1992		Amalgam	Permanent	2094	508	Records based, retrospective	11,6									Reasons for amalgam replacement were not seperated.Values include all replacements.
2013	Bahsi			Amalgam Composite	Permanent	Only replacements			30,8	9,8			15,5	17	6	8,9	8,9	Reasons for amalgam replacement were not seperated.Values include all replacements.
2014	Silvani			Amalgam Composite		306	121(total)		42,68				4,88	13		2,4		Amalgams were replaced when pts requested tooth coloured materials and all risks and benefits were evaluated.

Appendix B: Clinical studies on repair and refurbishment of restorations

Year	First Author	Observation period	GV Black	Restorative materials	Number of defective restorations	Sealing defective margins	Refurbishing	Replacement	No treatment	Number of repaired restorations (n)	Criteria	Number of patients (n)	Study Design	Results
1995	Cipriano	2yrs	I; II; V	dental amalgam						45	USPHS			7% ranked unacceptable
2006	Gordan	2yrs		dental amalgam	113	23	23	23	24	20	USPHS	45		Repair and replacemnt groups had statistically signficant diffrences in marginal daaptation and anatomic group when compared to no treatment group after 1 and 2 years
2008	Moncada	2yrs		dental amalgam; resin composite	193; 78	48	73	42	81	27	USPHS	66		The sealing of marginal defects showed significant improvements in marginal adaptation ($p<0.05$). Refurbishing of the defective restorations significantly improved anatomic form ($p<0.0001$), luster ($p<0.016$), marginal adaptation ($p<0.003$) and roughness ($p<0.0001$). The repair significantly improved anatomic form ($p<0.002$) and marginal stain ($p<0.002$). Replacement showed significant improvements for all parameters ($p<0.05$). The Untreated group showed significant deterioration on marginal adaptation ($p<0.013$).
2009	Moncada	3yrs		dental amalgam; resin composite	193; 78	48	73	42	81	27	USPHS	66		Restorations that underwent sealing of marginal defects exhibited significant improvements in marginal adaptation ($P \leq .001$). Restorations in the refurbishment group exhibited improvements in anatomical form ($P \leq .005$) and surface roughness ($P \leq .001$). Restorations in the repair group exhibited improvements with regard to anatomical form ($P = .008$). Replaced restorations exhibited improvements in all parameters ($P < .05$), while the untreated group experienced declines in all parameters ($P < .05$).
2011	Fernandez	4yrs		dental amalgam; resin composite	193; 78	36	63	28	60	21	USPHS	66		Sealed margins group showed the lowest MST while the Repair group showed the highest MST for restorations examined after 4 years of follow up. Defective amalgam and resin-based composite restorations treated by sealing of marginal gaps, refurbishment of anatomic form, luster or roughness, and repair of secondary caries lesions, had their longevity increased.

Year	First Author	Observation period	GV Black	Restorative materials	Number of defective restorations	Sealing defective margins	Refurbishing	Replacement	No treatment	Number of repaired restorations (n)	Criteria	Number of patients (n)	Study Design	Results
2011	Gordan	7yrs			113	23	23	22	25	20	USPHS	50		Repair group had a clinical failure rate of 7 percent (one downgrade and no restoration failures), which was significantly different from that of the no-treatment group (clinical failure rate of 48 percent)
2012	Opdam	Up to 24 years	class II	dental amalgam; resin composite						246			Practice-based	AFR after 4 years for amalgam retsoartions 9,3%
2013	Martin	5yrs	class I; class II	dental amalgam	160		64	21	56	19	USPHS	52	RCT	The results show that repairing and refinishing restorations with localized defects are effective and increase the MST of the restorations.
2015	Gordan	1yr		dental amalgam; direct tooth coloured; indirect tooth coloured	5687			171		74	Defined criteria		Practice-based	Multivariable logistic regression analysis indicated that additional treatment was more likely to occur if the original restoration had been repaired (7%) compared with replaced (5%).Repaired restorations were less likely to need an aggressive treatment (replacement, endodontic treatment, or extraction) than replaced restorations.
2015	Moncada	10yrs	class I; class II	dental amalgam	40			21		19	USPHS	20	RCT	Repaired and replaced amalgam restorations showed similar survival outcomes regarding marginal defects and secondary caries in patients with low and medium caries risk, and most of the restorations were considered clinically acceptable.

Appendix C: FDI criteria and gradings (Hickel *et al*., 2010)

Clinical investigation .....
ID patient / restoration .....
Date (dd /mm/yy): Baseline..... 1. Recall ..... 2. Recall..... 3. Recall..... 4. Recall..... 5. Recall.....
Photographs (n° and date) : ....
Replica (n° and date): .....

A. Esthetic properties	1. Surface lustre	2. Staining a. surface b. margin	3. Color match and translucency	4. Esthetic anatomical form
1. Clinically excellent / very good	1.1 Lustre comparable to enamel.	2a.1 No surface staining. 2b.1 No marginal staining.	3.1 Good color match, no difference in shade and/or translucency.	4.1 Form is ideal.
2. Clinically good (after polishing probably very good)	1.2.1 Slightly dull, not noticeable from speaking distance. 1.2.2 Some isolated pores.	2a.2 Minor surface staining, easily removable by polishing. 2b.2 Minor marginal staining, easily removable by polishing.	3.2 Minor deviations in shade and/or translucency	4.2 Form is only slightly deviated from the normal.
3. Clinically sufficient / satisfactory (minor shortcomings, no unacceptable effects but not adjustable w/o damage to the tooth)	1.3.1 Dull surface but acceptable if covered with film of saliva. 1.3.2 Multiple pores on more than one third of the surface.	2a.3 Moderate surface staining that may also present on other teeth, not esthetically unacceptable. 2b.3 Moderate marginal staining, not esthetically unacceptable.	3.3 Distinct deviation but acceptable. Does not affect esthetics: 3.3.1 more opaque 3.3.2 more translucent 3.3.3 darker 3.3.4 brighter	4.3 Form deviates from the normal but is esthetically acceptable.
4. Clinically unsatisfactory (but reparable)	1.4.1 Rough surface, cannot be masked by saliva film, simple polishing is not sufficient. Further intervention necessary. 1.4.2 Voids.	2a.4 Unacceptable surface staining on the restoration and major intervention necessary for improvement. 2b.4 Pronounced marginal staining, major intervention necessary for improvement.	3.4 Localized clinically deviation that can be corrected by repair. 3.4.1 too opaque. 3.4.2 too translucent. 3.4.3 too dark. 3.4.4 too bright.	4.4. Form is affected and unacceptable esthetically. Intervention/correction is necessary.
5. Clinically poor (replacement necessary)	1.5 Very rough, unacceptable plaque retentive surface.	2a.5 Severe surface staining and/or subsurface staining, generalized or localized, not accessible for intervention. 2b.5 Deep marginal staining, not accessible for intervention.	3.5 Unacceptable. Replacement necessary.	4.5 Form is unsatisfactory and/or lost. Repair not feasible / reasonable, Replacement needed.
Overall esthetic score	Acceptable esthetically (1 and 2)		Not acceptable (3, 4 and 5)	

B. Functional properties	5. Fracture of material and retention	6. Marginal adaptation	7. Occlusal contour and wear a) qualitatively b) quantitatively	8. Approximal anatomical form a. contact point b. contour	9. Radiographic examination (when applicable)	10. Patient's view
1. Clinically excellent / very good	5.1 No fractures / cracks.	6.1 Harmonious outline, no gaps, no white or discolored lines	7a.1 Physiological wear equivalent of enamel. 7b.1Wear corresponding to 80-120% of enamel.	8a.1 Normal contact point (floss or 25 µm metal blade can pass) 8b.1 Normal contour.	9.1 No pathology, harmonious transition between restoration and tooth.	10.1 Entirely satisfied with esthetics and function.
2. Clinically good	5.2 Small hairline crack.	6.2.1 Marginal gap (<150 µm), white lines. 6.2.2 Small marginal fracture removable by polishing. 6.2.3 Slight ditching, slight step/flashes, minor irregularities.	7a.2 Normal wear only slightly different from that to enamel. 7b.2 50-80% or 120-150 % wear compared to that of corresponding enamel.	8a.2. Contact slightly too strong but no disadvantage (floss or 25 µm metal blade can only pass with pressure). 8b.2 Slightly deficient contour.	9.2.1 Acceptable material excess present. 9.2.2 Positive/negative step present at margin <150 µm.	10.2 Satisfied. 10.2.1 Esthetics. 10.2.2 Function, e.g., minor roughness.
3. Clinically sufficient / satisfactory (minor shortcomings, no unacceptable effects but not adjustable w/o damage to the tooth)	5.3 Two or more or larger hairline cracks and/or material chip fracture not affecting the marginal integrity or approximal contact.	6.3.1 Gap < 250 µm not removable. 6.3.2. Several small marginal fractures. 6.3.3 Major irregularities, ditching or flash, steps.	7a.3 Different wear rate than enamel but within the biological variation. 7b.3 < 50 % or 150-300 % of corresponding enamel.	8a.3. Somewhat weak contact, no indication of damage to tooth, gingiva or periodontal structures; 50 µm metal blade can pass 8b.3 Visible deficient contour	9. 3. 1 Marginal gap < 250 µm. 9. 3. 2 Negative steps visible < 250 µm. No adverse effects noticed. 9.3.3 Poor radiopacity of filling material.	10.3 Minor criticism but no adverse clinical effects. 10.3.1 Esthetic shortcomings. 10.3.2 Some lack of chewing comfort. 10.3.3 Unpleasant treatment procedure.
4. Clinically unsatisfactory / (but reparable)	5.4.1 Material chip fractures which damage marginal quality or	6.4.1 Gap > 250 µm or dentine/base exposed. 6.4.2. Severe	7a.4 Wear considerably exceeds normal enamel wear; or	8a.4 Too weak and possible damage due to food impaction;	9.4.1 Marginal gap >250 µm. 9.4.2 Material excess accessible	10.4 Desire for improvement 10.4.1 Esthetics. 10.4.2 Function, e.g.,
	approximal contacts. 5.4.2 Bulk fractures with partial loss (less than half of the restoration).	ditching or marginal fractures. 6.4.3 Larger irregularities or steps (repair necessary)	occlusal contact points are lost. 7b.4 Restoration > 300 % of enamel wear or antagonist > 300 %.	100 µm metal blade can pass 8b.4 Inadequate contour Repair possible.	but not removable. 9.4.3 Negative steps >250µm and reparable.	tongue irritation Reshaping of anatomic form or refurbishing is possible.

5. Clinically poor (replacement necessary)	5.5 (Partial or complete) loss of restoration or multiple fractures.	6.5.1 Restoration (complete or partial) is loose but in situ. 6.5.2 Generalized major gaps or irregularities.	7a.5 Wear is excessive. 7b.5 Restoration or antagonist > 500 % of corresponding enamel.	8a.5 Too weak and/or clear damage due to food impaction and/or pain/gingivitis. 8b.4 Insufficient contour requires replacement	9.5.1 Secondary caries, large gaps, large overhangs 9.5.2 Apical pathology 9.5.3 Fracture/loss of restoration or tooth.	10.5 Completely dissatisfied and / or adverse effects, incl. pain.
	Acceptable function (n and %):			Not acceptable (n, % and reasons):		
C. Biological properties	**11. Postoperative (hyper-)sensitivity and tooth vitality**	**12. Recurrence of caries (CAR), erosion, abfraction**	**13. Tooth integrity (enamel cracks, tooth fractures)**	**14. Periodontal response (always compared to a reference tooth)**	**15. Adjacent mucosa**	**16 Oral and general health**
1. Clinically very good	11.1 No hypersensitivity, normal vitality.	12.1 No secondary or primary caries	13.1 Complete integrity.	14.1. No plaque, no inflammation, no pocket.	15.1 Healthy mucosa adjacent to restoration.	16.1 No oral or general symptoms.
2. Clinically good (after correction maybe very good) No treatment required.	11.2 Minor hypersensitivity for a limited period of time, normal vitality.	12.2 Small and localized 1. Demineralization 2. Erosion or 3. Abfraction.	13.2.1 Small marginal enamel fracture (<150 × µm). 13.2.2 Hairline crack in enamel (<150 µm).	14.2. Little plaque, no inflammation (gingivitis), no pocket development 14.2.1 without 14.2.2 with overhangs, gaps or inadequate anatomic. form	15.2 Healthy after minor removal of mechanical irritations (plaque, calculus, sharp edges etc.)	16.2 Minor transient symptoms of short duration; local or generalized.
3.Clinically sufficient / satisfactory (minor shortcomings with no adverse effects but not adjustable without damage to the tooth)	11.3.1 Moderate hypersensitivity 11.3.2 Delayed/mild sensitivity, no subjective complaints, no treatment needed.	12.3 Larger areas of 1. Demineralisation 2. Erosion or 3. Abrasion/abfraction, dentine not exposed Only preventive measures necessary ().	13.3.1 Marginal enamel defect <250µm 13.3.2 Crack <250µm; 13.3.3 Enamel chipping. 13.3.4 Multiple cracks	14.3. Difference up to one grade in severity of PBI compared to baseline and compared to control tooth. 14.3.1 without 14.3.2 with overhangs, gaps or inadequate anatomic form.	15.3 Alteration of mucosa but no suspicion of causal relationship with restorative material.	16.3. Transient symptoms, local and/or general.

4. Clinically unsatisfactory (repair for prophylactic reasons)	11.4.1 Intense hypersensitivity. 11.4.2 Delayed with minor subjective symptoms. 11.4.3 No clinical detectable sensitivity. Intervention necessary but not replacement.	12. 4.1 Caries with cavitation and suspected undermining caries 12.4.2 Erosion in dentine 12.4.3 Abrasion/ abfraction in dentine. Localized and accessible can be repaired.	13.4.1 Major marginal enamel defects; gap > 250 µm or dentine or base exposed. 13.4.2 Large cracks >250 µm, probe penetrates. 13.4.3. Large enamel chipping or wall fracture	14.4. Difference of more than one grade of PBI in comparison to control tooth or increase in pocket depth > 1mm requiring intervention. 14.4.1 without 14.4.2 with overhangs, gaps or inadequate anatomic form	15.4 Suspected mild allergic, lichenoid or toxic reaction.	16.4 Persisting local or general symptoms of oral contact stomatitis or lichen planus or allergic reactions. Intervention necessary but no replacement.
5. Clinically poor (replacement necessary)	11.5 Intense, acute pulpitis or non vital tooth. Endodontic treatment is necessary and restoration has to be replaced.	12.5 Deep caries or exposed dentine that is not accessible for repair of restoration.	13.5. Cusp or tooth fracture.	14.5 Severe / acute gingivitis or periodontitis 14.5.1 without 14.5.2 with overhangs, gaps or inadequate anatomic form	15.5 Suspected severe allergic, lichenoid or toxic reaction.	16.5. Acute / severe local and/or general symptoms.
score	**Acceptable biologically (n and %):**			**Not acceptable (n, % and reasons):**		

Appendix D: Questionnaire (with informed consent)(*Compulsory questions)

*1. You are invited to participate in an academic research study titled 'The management of defective of dental amalgam restorations ' conducted by Dr Razia Adam , at the University of the Western Cape.

The purpose of the survey is to gain a general understanding of the current practices regarding the management of defective dental amalgam restorations by dentists in South Africa.

Please note the following:

• This study involves an anonymous survey. Your name will not appear on the questionnaire and the answers you give will be treated as strictly confidential. You cannot be identified in person based on the answers you give. [Kindly note that consent can not be withdrawn once the questionnaire is submitted as there is no way to trace the particular questionnaire that has been filled in.]
• Your participation in this study is very important to us. You may, however, choose not to participate and you may also stop participating at any time without any negative consequences.
• Please answer the questions in the attached questionnaire as completely and honestly as possible. This should not take more than 8 minutes of your time.
• The results of the study will be used for academic purposes only and may be published in an academic journal. We will provide you with a summary of our findings on request.

Please feel free to contact the study leader, Prof Sue Naidoo (suenaidoo@uwc.ac.za) or the doctoral student Dr Razia Adam (rzadam@uwc.ac.a or (021) 937 3157) if you have any questions or comments regarding the study.

- ◯ I agree to participate
- ◯ I do not agree to participate.

Please select the appropriate response.

*2. I am a

- ◯ Male
- ◯ Female

3. My highest educational qualification is

- ◯ PhD or DSc
- ◯ MSc
- ◯ MChD
- ◯ Postgraduate Diploma
- ◯ BChD or BDS

4. I am in the following age group

- ◯ 20-25 years old
- ◯ 26-35 years old
- ◯ 36-45 years old
- ◯ 46-55 years old
- ◯ 56-65 years old
- ◯ 66 years and older

***6. I am currently**

- ◯ In Private Practice
- ◯ In Public Service
- ◯ A lecturer at an Academic Institution
- ◯ A student at an Academic Institution
- ◯ A Retired Dentist
- ◯ Other (please specify)

***6. My Dental Practice is situated in the**

- ◯ City
- ◯ Suburb
- ◯ Country
- ◯ Township

*7. How many years of experience do you have in private practice?

- ◯ Less than 1 year
- ◯ 1-5 years
- ◯ 6-10 years
- ◯ 11-15 years
- ◯ 16-20 years
- ◯ 21 years and more

*8. What arrangement best describes your current practice arrangement?

- ◯ Employed by another dentist
- ◯ Self-employed without partners
- ◯ Self-employed with partners
- ◯ Other (please specify)

*9. I practise dentistry

- ◯ Full-time (32 or more hours per week)
- ◯ Part-time (less than 32 hours per week)

*10. Is your practice contracted to medical aids/third party funding?

- ◯ Yes
- ◯ No

11. What percentage of your patients are on a medical aid/third party funding?

*12. Do you have a dental amalgam seperator in your practice?

- ◯ Yes
- ◯ No

*13. How do you dispose of dental amalgam waste in your practice?

14. How often in the last year have you read professional dentistry journals?

- ◯ More than once a month.
- ◯ Less than once a month.

15. In the last year, how many days in total have you spent in attendance at postgraduate meetings/courses?

- ◯ 1 day
- ◯ 2-4 days
- ◯ 5-10 days
- ◯ 11 or more days
- ◯ None

16. Please tick all that apply.
I have earned my CPD points for the last year by ...

- ☐ Answering journal questionnaires
- ☐ Attending lectures organised by dental companies
- ☐ Attending lectures organised by my profession
- ☐ Attending refresher courses
- ☐ Attending congresses
- ☐ Enrolling in a postgraduate course
- ☐ Attending small study groups
- ☐ Teaching (to others)

Other (please specify)

***17. How often do you use dental amalgam as a restorative material ?**

- ◯ Almost always
- ◯ Sometimes
- ◯ Almost never

***18. How often do you routinely discuss the choice of material with patients receiving restorations?**

- ◯ Almost always
- ◯ Sometimes
- ◯ Almost never

19. Do you REPAIR defective dental amalgam restorations?

- ◯ Yes
- ◯ No

20. I do not repair defective dental amalgam restorations because there is ....(Choose an answer)

- ☐ Lack of practicability in the technique.
- ☐ Lack of supporting scientific evidence.
- ☐ Absence of an established technique.
- ☐ No professional code and fee for the procedure.

Other (please specify)

21. Select the appropriate response/s.You may select more than one.

When I REPAIR a defective dental amalgam restoration, I do the following:

- ☐ Use a bur to create mechanical retention.
- ☐ Apply silicon coating to the amalgam prior to bonding.
- ☐ Apply silane to the amalgam prior to dentine bonding.
- ☐ Apply total etch dentine bonding system.
- ☐ Apply self-etch dentine bonding system.
- ☐ Apply a glass ionomer as a dentine bonding system.
- ☐ Place a pin-retained restoration.

Other (please specify)

22. I learnt my technique from

- [ ] Undergraduate Dental School
- [ ] Attending a Continuing Professional Education Course or lecture.
- [ ] Reading a Journal article.
- [ ] From the internet.
- [ ] A fellow colleague.
- [ ] My clinical experience.

Other (please specify)

23. Which dental restorative materials do you most often use in REPAIRING a defective dental amalgam restoration?

- [ ] Resin modified glass ionomer
- [ ] Resin-based composite
- [ ] Silorane-based composite
- [ ] Flowable composite
- [ ] Compomer
- [ ] Amalgam

Other (please specify)

24. Which restorative material would you use to REPLACE a defective dental amalgam restoration?

- [ ] Resin modified glass ionomer
- [ ] Resin-based composite
- [ ] Silorane-based composite
- [ ] Compomer
- [ ] Amalgam
- [ ] Ceramic inlay
- [ ] Ceramic onlay
- [ ] Crown

Other (please specify)

25. In deciding to manage a defective dental amalgam restoration,which 3 main factors do you consider?

1.
2.
3.

***26. Please indicate whether you agree or disgree with the following statements or if you are undecided.**

	Agree	Undecided	Disagree
There is no correlation between a marginal gap and secondary caries.	○	○	○
The size of the marginal gap between amalgam and tooth structure is directly related to the chance of secondary caries.	○	○	○
There is no relationship between the decision to replace an existing dental amalgam restoration and refurbishing an amalgam restoration.	○	○	○
I do not repair defective dental amalgam restorations because it is not an acceptable form of restorative dentistry.	○	○	○
I replace 'faulty margins' when there is no clinically or radiographically detectable caries because chances are good that there is caries below the margins that cannot be detected.	○	○	○

***27. Select the appropriate response/s.You may select more than one.**

I diagnose secondary caries by.....

- ☐ Radiographs
- ☐ Probing with a sharp explorer.
- ☐ Probing with a blunt explorer.
- ☐ Intuition or Clinical experience based on clinical appearance.
- ☐ Discoloured margins of a restoration.
- ☐ Frank or definite caries cavitation.
- ☐ Presence of soft,discoloured dentine or enamel.
- ☐ As exploratory preparation to inspect the lesion.

Repair is defined as the removal of only the defective part of the restoration and/or adjacent tooth tissue followed by placement of a new partial restoration.

Replacement is defined as the removal of an entire restoration followed by the replacement of a new restoration.

Refurbishment is defined as the refinishing and polishing of a restoration to improve the surface and appearance.

***28. Please indicate the 3 most important factors in your treatment decisions in the following examples.**

	Cost to patient	Future plans for the tooth	Caries risk of patient	Oral hygiene status of patient	Patient preference	Age of patient	Aesthetics	Pain	Visible caries	Possibility of caries	Remaining tooth structure
My decision to REPLACE a defective dental amalgam restoration.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
My decision to REPAIR a defective dental amalgam restoration.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
My decision to REMOVE a defective dental amalgam restoration.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

29. Do you think dental amalgam should be available to use in the future?

- ◯ Yes
- ◯ No
- ◯ I don't know

30. If [Q29], why?

31. Do you think dental amalgam poses an environmental risk?

- ◯ Yes
- ◯ No
- ◯ I don't know

Repair is defined as the removal of only the defective part of the restoration and/or adjacent tooth tissue followed by placement of a new partial restoration.

Replacement is defined as the removal of an entire restoration followed by the replacement of a new restoration.

Refurbishment is defined as the refinishing and polishing of a restoration to improve the surface and appearance.

*32. A 35 year old unemployed patient presents at your practice for a routine visit. The 37 has an amalgam restoration occlusally and buccally.On clinical examination, you find that there is a marginal gap on the 37 between the restoration occlusally. There is no evidence of caries radiographically or clinically. What would your treatment for the 37 entail?

Respondents: 12.5%

*32. A 35 year old unemployed patient presents at your practice for a routine visit. The 37 has an amalgam restoration occlusally and buccally.On clinical examination, you find caries on the mesial surface. The occlusal restoration has no marginal gaps.What would your treatment for the 37 entail?

Respondents: 12.5%

*32. A 35 year old unemployed patient presents at your practice for a routine visit.The 37 has an amalgam restoration occlusally and buccally. On clinical examination, you find an occlusal marginal gap between the tooth and the restoration and you detect caries occlusally.What would your treatment for the 37 entail?

Respondents: 12.5%

*32. A 35 year old unemployed patient presents at your practice for a routine visit. The 37 has an amalgam restoration occlusally and buccally.The restorations on the 37 are intact and caries free.What would your treatment for the 37 entail?

Respondents: 12.5%

*32. A 35 year old patient on medical aid presents at your practice for a routine visit. The 37 has an amalgam restoration occlusally and buccally.On clinical examination, you find that there is a marginal gap on the 37 between the restoration occlusally. There is no evidence of caries radiographically or clinically. What would your treatment for the 37 entail?

Respondents: 12.5%

*32. A 35 year old patient on medical aid presents at your practice for a routine visit.The 37 has an amalgam restoration occlusally and buccally.On clinical examination, you find caries on the mesial surface. The occlusal restoration has no marginal gaps.What would your treatment for the 37 entail?

Respondents: 12.5%

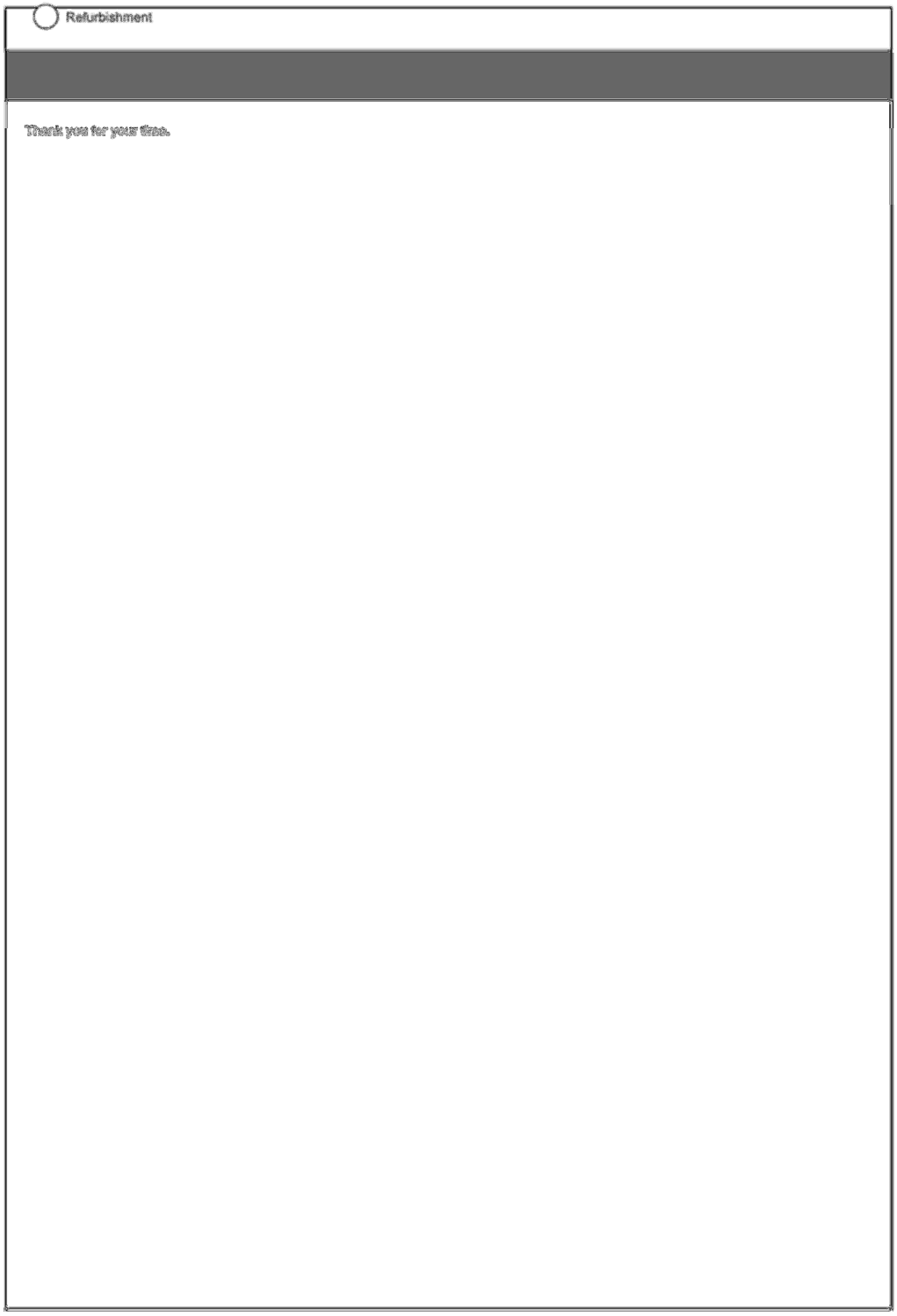
*32. A 35 year old patient on medical aid presents at your practice for a routine visit. The 37 has an amalgam restoration occlusally and buccally. On clinical examination, you find an occlusal marginal gap between the tooth and the restoration and you detect caries occlusally.What would your treatment for the 37 entail?

Respondents: 12.5%

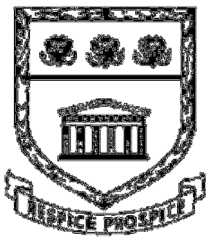
*32. A 35 year old patient on medical aid presents at your practice for a routine visit. The 37 has an amalgam restoration occlusally and buccally.The restorations on the 37 are intact and caries free.What would your treatment for the 37 entail?

Respondents: 12.5%

- Complete replacement
- Repair



Appendix E: Ethics approval



Office of the Deputy Dean
Postgraduate Studies and Research

Faculty of Dentistry and WHO Collaborating Centre for Oral Health

UNIVERSITY OF THE WESTERN CAPE

Private Bag X1, Tygerberg 7505

Cape Town

SOUTH AFRICA

Date: 04th March 2011

For Attention: Dr R Adam, Department of Restorative Dentistry

Dear Dr Adam

STUDY PROJECT: Management of defective dental amalgam restorations

PROJECT REGISTRATION NUMBER: 11/1/46

ETHICS: Approved

At a meeting of the Senate Research Committee held on Friday 4th February 2011 the above project was approved. This project is therefore now registered and you can proceed with the work. Please quote the above-mentioned project title and registration number in all further correspondence. Please carefully read the Standards and Guidance for Researchers below before carrying out your study.

Patients participating in a research project at the Tygerberg and Mitchells Plain Oral Health Centres will not be treated free of charge as the Provincial Administration of the Western Cape does not support research financially.

Due to the heavy workload auxiliary staff of the Oral Health Centres cannot offer assistance with research projects.

Yours sincerely

Professor Sudeshni Naidoo

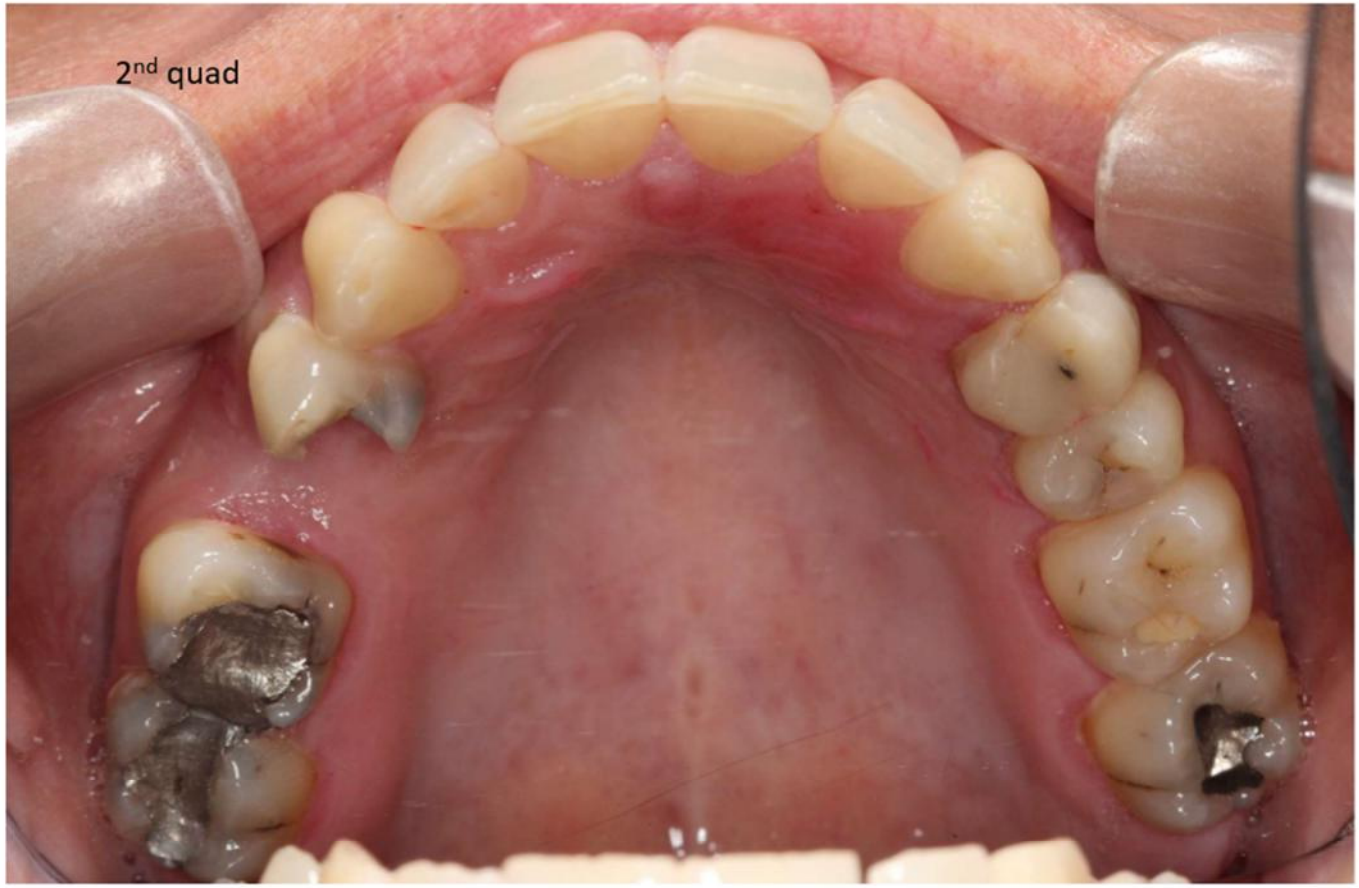
Appendix F: Case Study 1 and Case Study 2

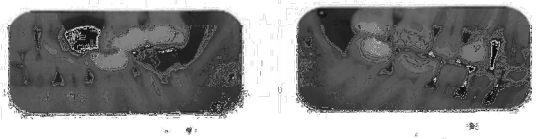
UNIVERSITY of the WESTERN CAPE

Faculty of DENTISTRY share your Smile

Case Study 1

A place of quality,
a place to grow, from hope
to action through knowledge



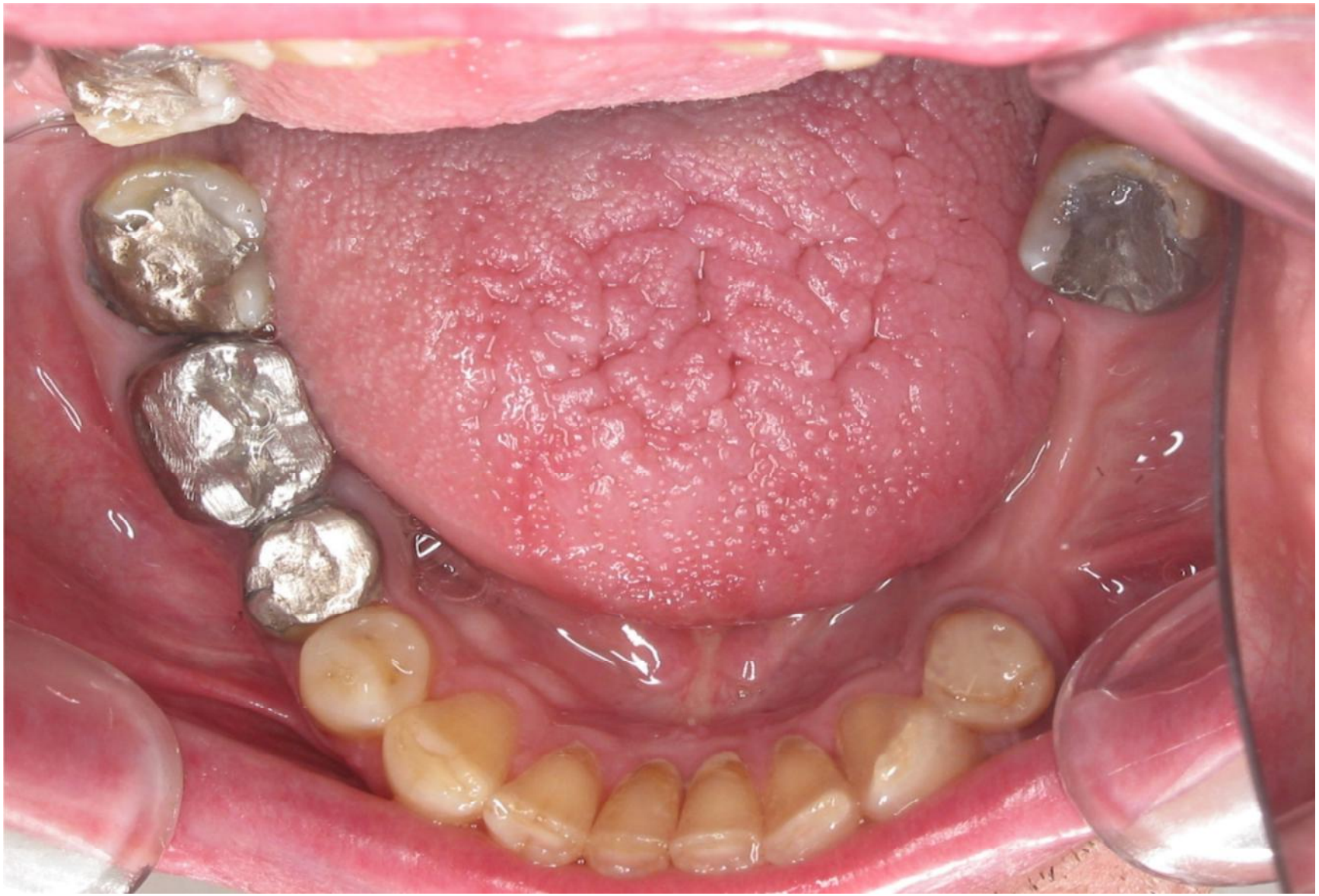


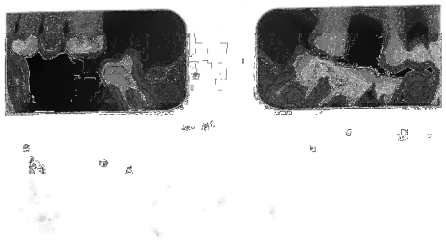
UNIVERSITY of the
WESTERN CAPE

Faculty of
DENTISTRY
share your Smile

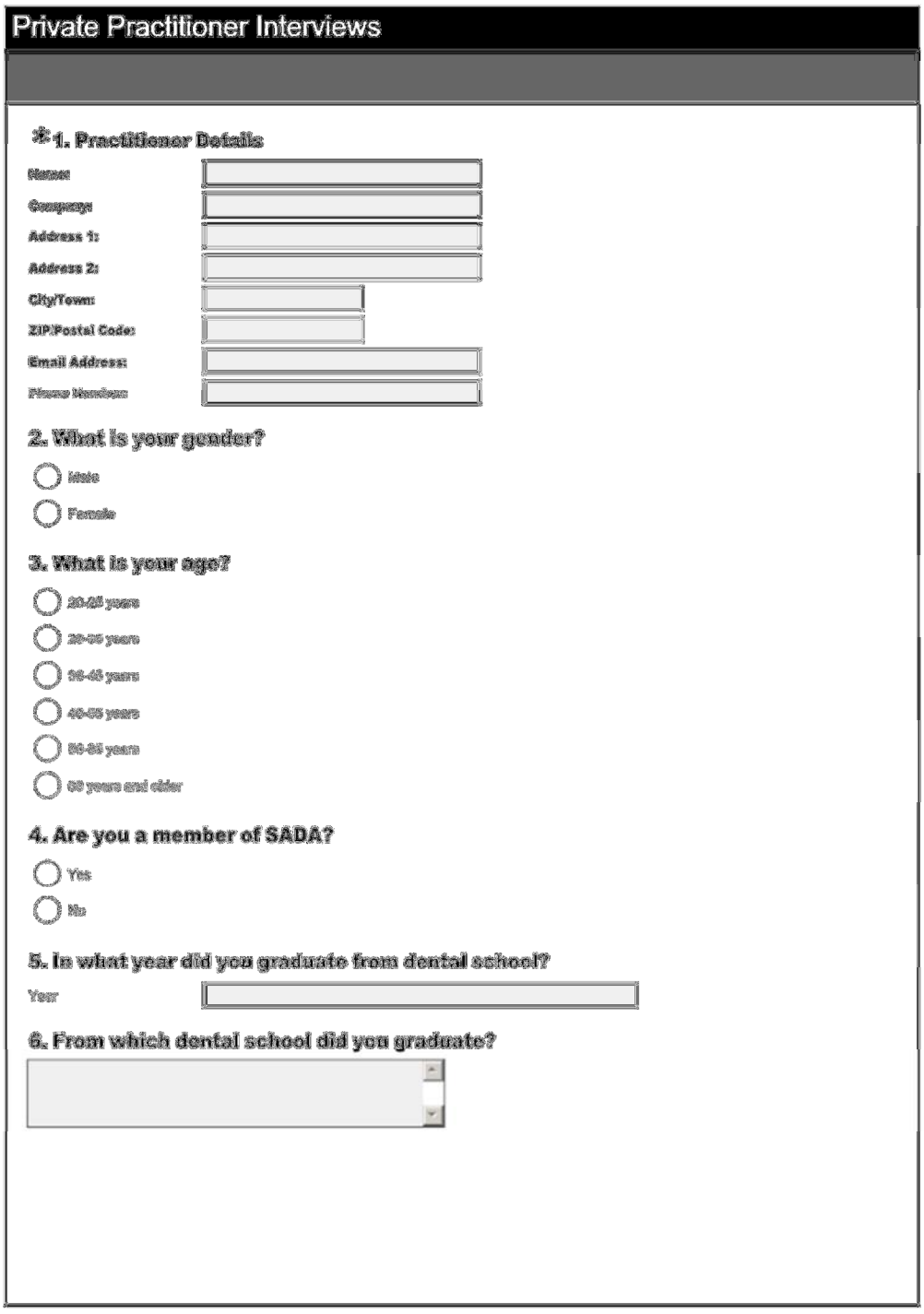
Case Study 2

A place of quality,
a place to grow, from hope
to action through knowledge





Appendix G: Self-administered questionnaire for qualitative sample (*n*=15)



Private Practitioner Interviews

*1. Practitioner Details

Name:
Company:
Address 1:
Address 2:
City/Town:
ZIP/Postal Code:
Email Address:
Phone Number:

2. What is your gender?

- Male
- Female

3. What is your age?

- 20-25 years
- 26-35 years
- 36-45 years
- 46-55 years
- 56-65 years
- 66 years and older

4. Are you a member of SADA?

- Yes
- No

5. In what year did you graduate from dental school?

Year:

6. From which dental school did you graduate?

Page 1

Private Practitioner Interviews

7. My highest educational qualification is

- PhD or DSc
- MSc
- MChD
- FCD
- BChD or BDS

8. Which one of the following BEST describes your practice arrangement?

- Employed by another dentist.
- Self-employed without partners and without sharing of income,costs,or office-space (solo practice).
- Self-employed without partners but share costs of office-space and/or assistants, etc (no income sharing).
- Self-employed as a partner in a complete partnership (both income and expenses shared).
- Other (please specify)

9. How many partners are there in the practice?

number

10. At how many dental sites,clinics or hospitals do you provide direct patient care (excluding teaching,consulting or management)at least once a week?

- One
- Two
- Three
- More than three

11. Do you practice full-time or part-time(including all sites at which you are practising)?

- Full-time(32 or more hours per week)
- Part-time (less than 32 hours per week)

12. How many patient visits do you personally have during a typical work week (including all sites)?

Number

Page 2

Private Practitioner Interviews

13. Please record what your typical fee is for a

2 surface amalgam

3 canal molar root canal

Single simple/uncomplicated extraction

Full denture

Porcelain to metal crown (anterior)

1 surface posterior composite

2 surface posterior composite

3 surface anterior composite

14. Approximately what percentage of the patients in your practice are...?

Children and Teenagers (1-18 years)

Young adults (19-44 years)

Middle-aged adults (45-64 years)

Elderly (65 or older)

15. Approximately what percentage of your patients are..?

White

Coloured

Black

Indian

Asian

16. Approximately what percentage of the patients in your practice are ..?

Covered by a private insurance programme that pays for some or all of their dental care

Not covered by any third party and pay their own bills

17. Approximately what percentage of revenues or charges are derived from different payment sources?

Dental insurance

Self-pay

Unpaid bills

Other

Private Practitioner Interviews

18. What percentage of your time in practice is spent performing?

Basic restorative procedures	
Advanced restorative procedures	
Extractions	
Surgery	
Routine periodontal treatment	
Preventative treatment	
Prosthetic treatment	
Orthodontics	

Appendix H: Treatment log

Research Project: Practice Activity Sheet: Dr

Date	Patient	Age	Gender	Tooth Number	GV Black Class	NEW restoration material *(tick applicable)*					Reasons for NEW restorations			Reasons for REPLACEMENT of restorations *(tick applicable)*							Previous restoration material *(tick applicable)*				
						Amalgam	Resin composite	Glass ionomer	Compomer	Other	Primary caries	Noncarious defects	Other	Secondary caries	Marginal discoloration	Bulk discolouration	Isthmus/ Bulk fracture	Tooth fracture	Poor anatomic form	Pain\sensitivity	Amalgam	Resin composite	Glass ionomer	Compomer	Other
14/07/2014	1	43	F			✓						✓													

Appendix I: Research participant consent form

Title of Project: Clinical Decision-making REC Ref No: Project Registration: 11/1/46).

Name of Researcher: Dr Razia Adam

(tick the appropriate box)

➢ I confirm that I have read and understood the information sheet for the above study and what my contribution will be	Yes	No	Not applicable
➢ I have been given the opportunity to ask questions (face to face, via telephone and email)	Yes	No	Not applicable
➢ I agree to take part in the interview	Yes	No	Not applicable
➢ I agree to being voice recorded	Yes	No	Not applicable
➢ I agree to take digital images during the research exercises	Yes	No	Not applicable
➢ I agree to keep a log of replaced/repaired/refurbished amalgam restorations for a period of 14 working days	Yes	No	Not applicable
➢ I agree to the researcher disseminating the information collected in the following formats: thesis, conference presentations, published articles(journals and electronically)	Yes	No	Not applicable
➢ I understand that my participation is voluntary and that I can withdraw from the research at any time without giving any reason and without penalty	Yes	No	Not applicable
➢ I agree to take part in the above study	Yes	No	Not applicable

Name of participant: _____

Signature: _____

Date: _____

Name of researcher taking consent: _____

Researcher's email address: rzadam@uwc.ac.za

Appendix J: Origin of technique used

Friedman result for outcome y with id and item variables: Pairs significantly different: Adjusted $p<0.05$

Obs.	Effect	Item	Item	Estimate	Std Err.	DF	t-value	Probt.	Adjustment	Adjp.
item	1	2	0.6985	0.1058	1305	6.60	<.0001	Tukey	<.0001	
item	1	3	0.9618	0.1058	1305	9.09	<.0001	Tukey	<.0001	
item	1	4	1.4198	0.1058	1305	13.43	<.0001	Tukey	<.0001	
item	1	5	0.9847	0.1058	1305	9.31	<.0001	Tukey	<.0001	
item	1	6	-0.5267	0.1058	1305	-4.98	<.0001	Tukey	<.0001	
item	2	4	0.7214	0.1058	1305	6.82	<.0001	Tukey	<.0001	
item	2	6	-1.2252	0.1058	1305	-11.59	<.0001	Tukey	<.0001	
item	3	4	0.4580	0.1058	1305	4.33	<.0001	Tukey	0.0002	
item	3	6	-1.4885	0.1058	1305	-14.08	<.0001	Tukey	<.0001	
item	4	5	-0.4351	0.1058	1305	-4.11	<.0001	Tukey	0.0006	
item	4	6	-1.9466	0.1058	1305	-18.41	<.0001	Tukey	<.0001	
item	5	6	-1.5115	0.1058	1305	-14.29	<.0001	Tukey	<.0001	

KEY

1= Undergraduate Dental School

2= Attending a CPD course or lecture

3= Reading a journal article

4= From the Internet

5= From a fellow colleague

6= From my clinical experience

Appendix K: Restorative material of choice for repairing a defective dental amalgam restoration

Pairs significantly different: Adjusted $p<0.05$

Item	_Item			Estimate	Std Err.	DF	t-value	Probt.	Adjustment	Adjp.
1	item	1	2	-0.7560	0.1109	1245	-6.81	<.0001	Tukey	<.0001
2	item	1	3	1.0080	0.1109	1245	9.09	<.0001	Tukey	<.0001
3	item	1	4	0.4080	0.1109	1245	3.68	0.0002	Tukey	0.0033
4	item	1	5	0.8280	0.1109	1245	7.46	<.0001	Tukey	<.0001
6	item	2	3	1.7640	0.1109	1245	15.90	<.0001	Tukey	<.0001
7	item	2	4	1.1640	0.1109	1245	10.49	<.0001	Tukey	<.0001
8	item	2	5	1.5840	0.1109	1245	14.28	<.0001	Tukey	<.0001
9	item	2	6	0.9600	0.1109	1245	8.65	<.0001	Tukey	<.0001
10	item	3	4	-0.6000	0.1109	1245	-5.41	<.0001	Tukey	<.0001
12	item	3	6	-0.8040	0.1109	1245	-7.25	<.0001	Tukey	<.0001
13	item	4	5	0.4200	0.1109	1245	3.79	0.0002	Tukey	0.0022
15	item	5	6	-0.6240	0.1109	1245	-5.62	<.0001	Tukey	<.0001

KEY

1= Resin-modified glass ionomer

2= Resin-based composite

3= Silorane-based composite

4= Flowable composite

5= Compomer

6= Amalgam

Pairs NOT significantly different: Adjusted *p*>=0.05

Obs.	Effect	Item	_Item	Estimate	Std Err.	DF	t-value	Probt.	Adjustment	Adjp.
5	item	1	6	0.2040	0.1109	1245	1.84	0.0662	Tukey	0.4411
11	item	3	5	-0.1800	0.1109	1245	-1.62	0.1050	Tukey	0.5837
14	item	4	6	-0.2040	0.1109	1245	-1.84	0.0662	Tukey	0.4411

Appendix L: Diagnosis of secondary caries (*n*=285)

Pairs significantly different: Adjusted $p<0.05$

Obs.	Effect	Item	_Item	Estimate	Std Err.	DF	t-value	Probt.	Adjustment	Adjp.
item	1	2	0.6035	0.1249	1988	4.83	<.0001	Tukey	<.0001	
item	1	3	3.5228	0.1249	1988	28.21	<.0001	Tukey	<.0001	
item	1	4	1.4596	0.1249	1988	11.69	<.0001	Tukey	<.0001	
item	1	5	1.4175	0.1249	1988	11.35	<.0001	Tukey	<.0001	
item	1	6	1.0807	0.1249	1988	8.65	<.0001	Tukey	<.0001	
item	1	7	0.4772	0.1249	1988	3.82	0.0001	Tukey	0.0034	
item	1	8	3.0737	0.1249	1988	24.61	<.0001	Tukey	<.0001	
item	2	3	2.9193	0.1249	1988	23.38	<.0001	Tukey	<.0001	
item	2	4	0.8561	0.1249	1988	6.86	<.0001	Tukey	<.0001	
item	2	5	0.8140	0.1249	1988	6.52	<.0001	Tukey	<.0001	
item	2	6	0.4772	0.1249	1988	3.82	0.0001	Tukey	0.0034	
item	2	8	2.4702	0.1249	1988	19.78	<.0001	Tukey	<.0001	
item	3	4	-2.0632	0.1249	1988	-16.52	<.0001	Tukey	<.0001	
item	3	5	-2.1053	0.1249	1988	-16.86	<.0001	Tukey	<.0001	
item	3	6	-2.4421	0.1249	1988	-19.56	<.0001	Tukey	<.0001	

KEY

1= Radiographs

2= Probing with a sharp explorer

3=Probing with a blunt explorer

4= Clinical experience or intuition based on clinical experience

5= Discoloured margins of a restoration

6= Frank or definite caries cavitation

7= Presence of soft, discoloured dentine or enamel

8= An exploratory preparation to inspect the lesion

item	3	7	-3.0456	0.1249	1988	-24.39	<.0001	Tukey	<.0001
item	3	8	-0.4491	0.1249	1988	-3.60	0.0003	Tukey	0.0079
item	4	6	-0.3789	0.1249	1988	-3.03	0.0024	Tukey	0.0499
item	4	7	-0.9825	0.1249	1988	-7.87	<.0001	Tukey	<.0001
item	4	8	1.6140	0.1249	1988	12.92	<.0001	Tukey	<.0001
item	5	7	-0.9404	0.1249	1988	-7.53	<.0001	Tukey	<.0001
item	5	8	1.6561	0.1249	1988	13.26	<.0001	Tukey	<.0001
item	6	7	-0.6035	0.1249	1988	-4.83	<.0001	Tukey	<.0001
item	6	8	1.9930	0.1249	1988	15.96	<.0001	Tukey	<.0001
item	7	8	2.5965	0.1249	1988	20.79	<.0001	Tukey	<.0001

Pairs NOT significantly different: Adjusted *p*>=0.05

Obs.	Effect	Item	_Item	Estimate	Std Err.	DF	t-value	Probt.	Adjustment	Adjp.
item	2	7	-0.1263	0.1249	1988	-1.01	0.3119	Tukey		0.9728
item	4	5	-0.04211	0.1249	1988	-0.34	0.7360	Tukey		1.0000
item	5	6	-0.3368	0.1249	1988	-2.70	0.0070	Tukey		0.1239

Appendix M: Relationships between demographic variables, use of amalgam, future use of dental amalgam, repairing defective dental amalgam restorations and replacing defective dental amalgam restorations

Categorical with Chi-square test (*significant: $p<0.005$)

Obs.	Table	DF	Value	Prob.
1	Gender * Repair or not	1	5.4413	0.0197
8	Practice arrangement * Repair or not	3	2.5954	0.4583
14	Practice location * Repair or not	3	3.9947	0.2620
27	Contracted to third-party funding * Repair or not	1	9.2106	0.0024*
34	Gender * q29	2	1.0234	0.5995
40	Practice arrangement * q29	6	3.2993	0.7705
46	Practice location * q29	6	12.1938	0.0578
52	Repair or not * q29	2	19.5325	<.0001*
58	Contracted to third-party funding * q29	2	8.1020	0.0174
64	Gender * amalgam 23	1	4.6053	0.0319
71	Practice arrangement * amalgam 23	3	1.0815	0.7816
77	Practice location * amalgam 23	3	4.1819	0.2425
83	Repair or not * amalgam 23	1	8.6737	0.0032*
90	Contracted to third-party funding * amalgam 23	1	3.3144	0.0687
97	Gender * amalgam 24	1	0.0006	0.9811
104	Practice arrangement * amalgam 24	3	2.7246	0.4361
110	Practice location * amalgam 24	3	1.9870	0.5751
116	Repair or not * amalgam 24	1	7.4179	0.0065
123	Contracted to third-party funding * amalgam 24	1	7.9154	0.0049*
130	Gender * tcr24	1	0.0021	0.9634
137	Practice arrangement * tcr24	3	3.2290	0.3576

143	Practice location * tcr24	3	0.6097	0.8942
149	Repair or not * tcr24	1	0.1934	0.6601
156	Contracted to third-party funding * tcr24	1	0.6177	0.4319
163	Gender * crb24	1	1.2668	0.2604
170	Practice arrangement * crb24	3	7.1555	0.0671
176	Practice location * crb24	3	8.8965	0.0307
182	Repair or not * crb24	1	6.6853	0.0097
189	Contracted to third-party funding * crb24	1	4.7798	0.0288

Ordinal predictor with categorical outcome (*significant: $p<0.005$)

Obs.	Table	Statistic	Alt Hypothesis	DF	Value	Prob.
2	Table Repair or not * q4	2	Row Mean Scores Differ	1	5.2715	0.0217
5	Table q29 * q4	2	Row Mean Scores Differ	2	2.7712	0.2502
8	Table amalgam 23 * q4	2	Row Mean Scores Differ	1	14.8119	0.0001
11	Table amalgam 24 * q4	2	Row Mean Scores Differ	1	7.5227	0.0061
14	Table tcr24 * q4	2	Row Mean Scores Differ	1	3.5380	0.0600
17	Table crb24 * q4	2	Row Mean Scores Differ	1	1.5945	0.2067
20	Table q19 * q7	2	Row Mean Scores Differ	1	1.9779	0.1596
23	Table q29 * q7	2	Row Mean Scores Differ	2	2.0247	0.3634
26	Table amalgam 23 * q7	2	Row Mean Scores Differ	1	9.0126	0.0027
29	Table amalgam 24 * q7	2	Row Mean Scores Differ	1	4.2222	0.0399
32	Table tcr24 * q7	2	Row Mean Scores Differ	1	1.0214	0.3122
35	Table crb24 * q7	2	Row Mean Scores Differ	1	1.2909	0.2559
38	Table q19 * q15	2	Row Mean Scores Differ	1	2.4106	0.1205
41	Table q29 * q15	2	Row Mean Scores Differ	2	0.6782	0.7124

44	Table amalgam 23 * q15	2	Row Mean Scores Differ	1	0.2645	0.6071
47	Table amalgam 24 * q15	2	Row Mean Scores Differ	1	1.0716	0.3006
50	Table tcr24 * q15	2	Row Mean Scores Differ	1	2.1727	0.1405
53	Table crb24 * q15	2	Row Mean Scores Differ	1	2.3656	0.1240
56	Table q19 * q17	2	Row Mean Scores Differ	1	16.0141	<.0001
59	Table q29 * q17	2	Row Mean Scores Differ	2	100.3082	<.0001
62	Table amalgam 23 * q17	2	Row Mean Scores Differ	1	96.8283	<.0001
65	Table amalgam 24 * q17	2	Row Mean Scores Differ	1	134.8118	<.0001
68	Table tcr24 * q17	2	Row Mean Scores Differ	1	41.3328	<.0001
71	Table crb24 * q17	2	Row Mean Scores Differ	1	0.3070	0.5795
74	Table q19 * q18	2	Row Mean Scores Differ	1	2.6989	0.1004
77	Table q29 * q18	2	Row Mean Scores Differ	2	20.6717	<.0001
80	Table amalgam 23 * q18	2	Row Mean Scores Differ	1	16.2631	<.0001
83	Table amalgam 24 * q18	2	Row Mean Scores Differ	1	23.3813	<.0001
86	Table tcr24 * q18	2	Row Mean Scores Differ	1	12.3979	0.0004
89	Table crb24 * q18	2	Row Mean Scores Differ	1	0.6063	0.4362

KEY

q19 = repair or not

q29 = future use of amalgam

amalgam 23= choice of material to repair

amalgam 24 = choice of material to replace

q7= years of experience

tcr24 = use of amalgam to repair

q4= age

crb24= choice of composite to repair

q15= cpd activity

q17= use of amalgam

q18= discuss material choice with patient

Ordinal predictor with ordinal outcome (*significant: $p<0.005$)

Obs.	Table	Statistic	Alt Hypothesis	DF	Value	Prob.
1	Table q4 * q17	1	Non-zero Correlation	1	7.0490	0.0079
4	Table q7 * q17	1	Non-zero Correlation	1	3.1547	0.0757
7	Table q15 * q17	1	Non-zero Correlation	1	0.1935	0.6600
10	Table q18 * q17	1	Non-zero Correlation	1	38.8717	<.0001*

Appendix N: Summary of proposed treatment for clinical vignettes

Treatment plan recommendation	No. of participants (*n=15*)	
	(Case Study 1) Tooth 26	(Case Study 2) Tooth 26
Crown and bridge	2	2
Repair of restoration	1	0
Replacement of restoration	5	1
Re-examine tooth at next recall visit	4	1
No treatment indicated	3	12

Appendix O: Summary table of all treatment logs

APPENDIX N: Summary Table of All Treatment Logs							NEW restoration material *(tick applicable)*					Reasons for NEW restorations			Reasons for REPLACEMENT of restorations*(tick applicable)*							Previous restoration material *(tick applicable)*				
Dentist	No. of patients treated	Mean Age	No. of Females	% Females	No. of Males	%Males	Amalgam	Resin composite	Glass ionomer	Compomer	Other	Primary caries	Noncarious defects	Other	Secondary caries	Marginal discoloration	Bulk discolouration	Isthmus' Bulk fracture	Tooth fracture	Poor anatomic form	Pain\sensitivity	Amalgam	Resin composite	Glass ionomer	Compomer	Other
RI	22	38,4	14	63	8	36	0	20	5	1	2	7	16	1	6	0	0	5	6	1	0	11	7	1	0	0
S	52	34,5	29	56	23	44	0	69	15	21	0	73	11	1	5	0	0	1	1	0	0	1	3	0	0	0
LI	39	30,6	26	66	13	33	0	56	0	3	0	37	5	0	10	0	1	0	1	0	4	0	0	0	1	0
K	31	31	16	55	13	45	2	28	17	0	1	44	3	0	10	0	0	0	3	0	2	5	10	0	0	0
F	30	30,6	16	53	14	47	7	28	0	0	0	19	0	1	16	0	0	0	0	0	0	17	1	0	0	15
J	22	33	9	40	13	59	0	26	0	0	1	19	4	1	4	0	1	2	1	0	0	2	3	0	0	0
LA	34	34	18	53	16	47	0	59	0	0	0	30	4	10	5	2	0	3	3	0	3	7	8	0	0	0
A	18	28	12	67	6	33	0	17	1	0	0	13	3	0	2	0	1	0	0	0	1	0	0	0	0	0
M	52	30	27	52	25	48	2	64	12	0	0	52	8	9	3	0	1	3	2	0	9	6	10	0	0	1