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

By

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KEYWORDS
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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:
People 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, 1995b; 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 specialties 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)
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; McCleery 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)

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

<table>
<thead>
<tr>
<th>Year</th>
<th>First author</th>
<th>Observation period (yrs.)</th>
<th>GV/Black</th>
<th>Restorative materials</th>
<th>Number of restorations (n)</th>
<th>Number of patients (n)</th>
<th>Study design</th>
<th>Survival Rate (%)</th>
<th>Annual failure rate (%)</th>
<th>Median Survival Time (yrs.)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1969</td>
<td>Allan</td>
<td>10</td>
<td>I II</td>
<td>Amalgam (alloys not specified, gamma-2 alloys)</td>
<td>78</td>
<td>92</td>
<td>Cross-sectional</td>
<td>54</td>
<td>4.6</td>
<td>6.1</td>
<td>Slightly better performance in class I cavities</td>
</tr>
<tr>
<td>1971</td>
<td>Robinson</td>
<td>20</td>
<td>I II</td>
<td>Amalgam (alloys not specified, gamma-2 alloys)</td>
<td>145</td>
<td>22,8</td>
<td>Cross-sectional</td>
<td>22</td>
<td>3,9</td>
<td>10</td>
<td>75% of the amalgam restorations lasted &gt;5 years</td>
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<td>1976</td>
<td>Lavelle</td>
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<td>6000</td>
<td>4,8</td>
<td>Cross-sectional</td>
<td>4.0</td>
<td>8</td>
<td></td>
<td>Main failure reasons: secondary caries, fracture</td>
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<td>1976</td>
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<td>Amalgam (alloys not specified, gamma-2 alloys)</td>
<td>400</td>
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<td>Longitudinal</td>
<td>7</td>
<td>&lt;10</td>
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<td>1977</td>
<td>Allan</td>
<td>20</td>
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<td>Amalgam (alloys not specified, gamma-2 alloys)</td>
<td>148</td>
<td>7</td>
<td>Cross-sectional</td>
<td>14</td>
<td>4.3</td>
<td>8</td>
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<tr>
<td>1981</td>
<td>Crabb</td>
<td>10</td>
<td>I II</td>
<td>Amalgam (alloys not specified, gamma-2 alloys)</td>
<td>269</td>
<td>59.5</td>
<td>Cross-sectional</td>
<td>59.5</td>
<td>4.1</td>
<td>&gt;10</td>
<td>Slightly better performance in class I cavities</td>
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<tr>
<td>1984</td>
<td>Paterson</td>
<td>15</td>
<td>I II</td>
<td>Solila</td>
<td>854</td>
<td>8</td>
<td>Cross-sectional</td>
<td>854</td>
<td>8</td>
<td>7</td>
<td>No difference between class I and class II amalgams</td>
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http://etd.uwc.ac.za
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<thead>
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<th>Year</th>
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<th>Observation period (yrs.)</th>
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<th>Number of patients (n)</th>
<th>Study design</th>
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<th>Annual failure rate (%)</th>
<th>Median Survival Time (yrs.)</th>
<th>Remarks</th>
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<td>1984</td>
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<td>15</td>
<td>I II</td>
<td>Solila</td>
<td>854</td>
<td>1490</td>
<td>Cross-sectional</td>
<td>8, 7</td>
<td>No difference between class I and class II amalgams</td>
<td></td>
<td></td>
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<td>1989</td>
<td>Letzel</td>
<td>5-7</td>
<td>I II</td>
<td>Conventional and high copper alloy</td>
<td>2341</td>
<td>Longitudinal</td>
<td>88–91</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>1989</td>
<td>Moffa</td>
<td>5</td>
<td>I II</td>
<td>Amalgam (alloys not specified)</td>
<td>314</td>
<td>90</td>
<td>75</td>
<td>2</td>
<td></td>
<td>5</td>
<td></td>
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<tr>
<td>1990</td>
<td>Qvist</td>
<td>3</td>
<td>I II</td>
<td>Amalgam (alloys not specified)</td>
<td>13</td>
<td>Longitudinal</td>
<td>100</td>
<td>0</td>
<td>Small restorations</td>
<td></td>
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<tr>
<td>1990</td>
<td>Smales</td>
<td>5</td>
<td>I</td>
<td>Dispersalloy</td>
<td>150</td>
<td>103</td>
<td>Longitudinal</td>
<td>92, 7</td>
<td>All amalgams failed due to recurrent caries</td>
<td></td>
<td></td>
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<tr>
<td>1991</td>
<td>Jokstad</td>
<td>7-10</td>
<td>II</td>
<td>4 non-gamma-2 alloys; 1 conventional alloy</td>
<td>256</td>
<td>141</td>
<td>73, 5</td>
<td>2.7–3.8</td>
<td>Main failure reasons: secondary caries and bulk fracture; no significant difference between gamma-2 and non-gamma-2 alloys</td>
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Table 2: Longevity of dental restorations (continued)

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<th>Number of patients (n)</th>
<th>Study design</th>
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<th>Annual failure rate (%)</th>
<th>Median Survival Time (yrs.)</th>
<th>Remarks</th>
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<tbody>
<tr>
<td>1991</td>
<td>Osborne</td>
<td>14</td>
<td>I</td>
<td>II</td>
<td>5 gamma-2-alloys and 7 non-gamma-2 alloys</td>
<td>367</td>
<td>40</td>
<td>Longitudinal</td>
<td>87.2</td>
<td>0, 9</td>
<td>Gamma-2 amalgams had 84% success rate, non-gamma-2 alloys had 91.6%</td>
</tr>
<tr>
<td>1991</td>
<td>Pieper</td>
<td>9-11</td>
<td>I</td>
<td>II</td>
<td>Amalgam (alloys not specified)</td>
<td>129</td>
<td>413</td>
<td>Cross-sectional</td>
<td>85.3</td>
<td>1.3–1.6</td>
<td></td>
</tr>
<tr>
<td>1991</td>
<td>Smales</td>
<td>Nov 18</td>
<td>I</td>
<td>II</td>
<td>New True Dentalloy, Dispersalloy, Shofu Spherical</td>
<td>1680</td>
<td></td>
<td>Cross-sectional</td>
<td>1.0–1.7, 6.3</td>
<td></td>
<td>Shofu Spherical showed an annual failure rate of 6.3% while the other alloys failed 1–1.7% a year</td>
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<tr>
<td>1991</td>
<td>Smales</td>
<td>15</td>
<td>II</td>
<td></td>
<td>Amalgam (alloys not specified)</td>
<td>768</td>
<td></td>
<td></td>
<td>72</td>
<td>1.9</td>
<td>No difference in survival time between cusp-covered class II amalgam and restorations without cusp-coverage.</td>
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<td>1992</td>
<td>Mjor</td>
<td></td>
<td></td>
<td></td>
<td>Amalgam (alloys not specified)</td>
<td>360</td>
<td></td>
<td>Cross-sectional</td>
<td>4.7</td>
<td></td>
<td></td>
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<tr>
<td>Year</td>
<td>First author</td>
<td>Observation period (yrs.)</td>
<td>GV Black</td>
<td>Restorative materials</td>
<td>Number of restorations (n)</td>
<td>Number of patients (n)</td>
<td>Study design</td>
<td>Survival Rate (%)</td>
<td>Annual failure rate (%)</td>
<td>Median Survival Time (yrs.)</td>
<td>Remarks</td>
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<td>------------------------</td>
<td>--------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>1993</td>
<td>Mjor</td>
<td>5</td>
<td>II</td>
<td>Disperalloy</td>
<td>88</td>
<td></td>
<td>Longitudinal</td>
<td>95</td>
<td>1</td>
<td></td>
<td>Estimated survival function, Small class II cavities</td>
</tr>
<tr>
<td>1994</td>
<td>Jokstad</td>
<td>&gt;10</td>
<td>I II</td>
<td>Amalgam (alloys not specified)</td>
<td>803 &gt;3000</td>
<td></td>
<td>Cross-sectional</td>
<td></td>
<td>14, 7-11</td>
<td></td>
<td>Increasing number of affected surfaces of class II restorations results in a lower median longevity</td>
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<tr>
<td>1994</td>
<td>Mahmood</td>
<td>&gt;14</td>
<td>I II</td>
<td>Amalgam (alloys not specified)</td>
<td>245(P) 455(A)</td>
<td></td>
<td>Cross-sectional</td>
<td>7.9</td>
<td>9</td>
<td></td>
<td>Study conducted in Pakistan(P) and Australia (A)</td>
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<tr>
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<td>Smales</td>
<td>15</td>
<td>II</td>
<td>Amalgam (alloys not specified)</td>
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<td></td>
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<td>47,8</td>
<td>3,5</td>
<td></td>
<td>Cusp-covered amalgam restorations</td>
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<td>1996</td>
<td>Wilson</td>
<td>5</td>
<td>I II</td>
<td>High copper alloys (Sybralloy, Disperalloy, Tytin)</td>
<td>172</td>
<td></td>
<td>Longitudinal</td>
<td>94, 8</td>
<td>1</td>
<td></td>
<td>Deterioration was greater in molars and large-sized restorations</td>
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<td>1997</td>
<td>Hawthorne</td>
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<td>Amalgam (alloys not specified)</td>
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<td></td>
<td>22, 5</td>
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<td>Life-table method.</td>
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<td>Number of patients (n)</td>
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<td>Survival Rate (%)</td>
<td>Annual failure rate (%)</td>
<td>Median Survival Time (yrs.)</td>
<td>Remarks</td>
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<tr>
<td>1997</td>
<td>Letzel</td>
<td>13</td>
<td>I II</td>
<td>Conventional zinc-free, conventional zinc containing, high copper zinc-free, high copper zinc-containing</td>
<td>3119</td>
<td>25</td>
<td>II</td>
<td>70 70</td>
<td>2.3 2.3</td>
<td>85</td>
<td>5.8</td>
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<tr>
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<td>Mjor</td>
<td>&gt;25</td>
<td>I II</td>
<td>Amalgam (alloys not specified)</td>
<td>282</td>
<td>87, 5</td>
<td>Cross-sectional</td>
<td>2, 1</td>
<td>1</td>
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<td>9</td>
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<td>1997</td>
<td>Roulet</td>
<td>6</td>
<td>I II</td>
<td></td>
<td>163</td>
<td>87, 5</td>
<td>Cross-sectional</td>
<td>43 5 1</td>
<td></td>
<td>2, 1</td>
<td>Kaplan-Meier method. Main reasons for replacement: fracture</td>
</tr>
<tr>
<td>Year</td>
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<td>Observation period (yrs.)</td>
<td>GV Black</td>
<td>Restorative materials</td>
<td>Number of restorations (n)</td>
<td>Number of patients (n)</td>
<td>Study design</td>
<td>Survival Rate (%)</td>
<td>Annual failure rate (%)</td>
<td>Median Survival Time (yrs.)</td>
<td>Remarks</td>
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<td>II</td>
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<td>77.6</td>
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<td>3.3</td>
<td>14, 6</td>
<td>Extensive amalgam restorations with cusp replacement</td>
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<td>Kreulen</td>
<td>15</td>
<td>II</td>
<td>New True Dentalloy, Tytin, Cavex</td>
<td>1117</td>
<td>Longitudinal</td>
<td>83</td>
<td>1</td>
<td>1, 1</td>
<td>Replacement risk for MOD is significantly higher than for MO/OD replacement</td>
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<td>1998</td>
<td>Mair</td>
<td>10</td>
<td>II</td>
<td>New True Dentalloy, Solila Nova</td>
<td>35</td>
<td>Longitudinal</td>
<td>94.3</td>
<td>0.6</td>
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<td>Plasmans</td>
<td>8</td>
<td>II</td>
<td>Cavex (non-gamma-2)</td>
<td>266</td>
<td>Longitudinal</td>
<td>88</td>
<td>1.5</td>
<td></td>
<td>Large amalgam restorations in molars with cusp replacement</td>
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<td>1999</td>
<td>Burke</td>
<td>I</td>
<td>II</td>
<td></td>
<td>268</td>
<td>Cross-sectional</td>
<td>7.4</td>
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Table 2: Longevity of dental restorations (continued)

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<thead>
<tr>
<th>Year</th>
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<th>Observation period (yrs.)</th>
<th>GV Black</th>
<th>Restorative materials</th>
<th>Number of restorations (n)</th>
<th>Number of patients (n)</th>
<th>Study design</th>
<th>Survival Rate (%)</th>
<th>Annual failure rate (%)</th>
<th>Median Survival Time (yrs.)</th>
<th>Remarks</th>
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<td>1999</td>
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<td>62</td>
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<td>80</td>
<td>2.5</td>
<td>3.4</td>
<td>3.6</td>
</tr>
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<td>1999</td>
<td>Kamann</td>
<td>6</td>
<td>I, II</td>
<td>Amalgam</td>
<td>620</td>
<td>62</td>
<td>Longitudinal</td>
<td>83.9</td>
<td>2.7</td>
<td>5.6</td>
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<td>2007</td>
<td>Soncini</td>
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<td>I, II</td>
<td>Amalgam</td>
<td>509</td>
<td>534</td>
<td>Longitudinal</td>
<td>15, 9</td>
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<td>2007</td>
<td>Opdam</td>
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<td>I, II</td>
<td>Amalgam Dispersed phase</td>
<td>912</td>
<td>621</td>
<td>Longitudinal</td>
<td>89.6</td>
<td>2.5</td>
<td>3.4</td>
<td>3.6</td>
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<tr>
<td>2007</td>
<td>Bernado</td>
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<td>I, 2, 3</td>
<td>Amalgam Dispersed phase</td>
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<td>19892</td>
<td>Retrospective</td>
<td>0,8, 2</td>
<td>0.8, 2</td>
<td>0.8, 2</td>
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<td>2009</td>
<td>Kakilehto</td>
<td>20</td>
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<td>Retrospective</td>
<td>19892</td>
<td>19892</td>
<td>Retrospective</td>
<td>0,8, 2</td>
<td>0.8, 2</td>
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## Table 2: Longevity of dental restorations (continued)

<table>
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<tr>
<th>Year</th>
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<th>GV Black</th>
<th>Restorative materials</th>
<th>Study design</th>
<th>Survival Rate (%)</th>
<th>Annual failure rate (%)</th>
<th>Median Survival Time (yrs.)</th>
<th>Remarks</th>
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<tr>
<td>2010</td>
<td>Opdam</td>
<td>5</td>
<td>II</td>
<td>Dispersalloy</td>
<td>Retrospective</td>
<td>1202</td>
<td>8</td>
<td>0.9</td>
<td>Practice-based research of 1 dentist</td>
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<td>2012</td>
<td>Kopperud</td>
<td>4</td>
<td>II</td>
<td>Amalgam, compomer, resin composite, glass ionomer</td>
<td>Practice based</td>
<td>4030</td>
<td>1873</td>
<td>93 % (Hg), 88% (Au)</td>
<td>Practice-based research of 27 dentists</td>
</tr>
<tr>
<td>2015</td>
<td>Laske</td>
<td>15</td>
<td></td>
<td>Composite, amalgam, compomer, glass Ionomer</td>
<td>Longitudinal descriptive</td>
<td>432044</td>
<td>76071</td>
<td>4.5, 5.1, 7.1, 10.7</td>
<td>Practice-based research of 67 dentists</td>
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</table>
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)

<table>
<thead>
<tr>
<th>Patient</th>
<th>Dentist</th>
<th>Material</th>
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</thead>
<tbody>
<tr>
<td>Oral hygiene</td>
<td>Correct indication</td>
<td>Strength (fractures)</td>
</tr>
<tr>
<td>Preventive measures</td>
<td>Cavity preparation (size, type, finishing)</td>
<td>Fatigue/degradation</td>
</tr>
<tr>
<td>Compliance in recall</td>
<td>Handling and application (e.g. incremental vs. bulk placement)</td>
<td>Wear resistance (occlusal contact areas, contact-free areas)</td>
</tr>
<tr>
<td>Oral environment (quality of tooth structure, saliva, etc.)</td>
<td>Curing mode (device, time, light intensity)</td>
<td>Bond strength</td>
</tr>
<tr>
<td>Size, shape, location of the lesion and tooth (number of surfaces, vital vs. non-vital, premolar vs. molar)</td>
<td>Mode of finishing and polishing the restoration</td>
<td>Chemical compatibility of restorative systems (DBA, composite)</td>
</tr>
<tr>
<td>Cooperation during treatment</td>
<td>Correct occlusion</td>
<td>Technique sensitivity</td>
</tr>
<tr>
<td>Bruxism/habits</td>
<td>Experience (with material)</td>
<td>Caries-inhibiting effects (release of substances)</td>
</tr>
</tbody>
</table>
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, Mjör *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% (Mjör, 1981; Klausner and Charbeneau, 1985; Klausner *et al.*, 1987; Mjör and Toffenetti, 1992; Friedl *et al.*, 1994; Mjör, 1997; Mjör *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 World 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)

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

<table>
<thead>
<tr>
<th>POSSIBLE OBJECTIVE INFLUENCES</th>
<th>Subjective factors</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>General patient factors</strong></td>
<td></td>
</tr>
<tr>
<td>Exposure to fluoride</td>
<td>Incentives</td>
</tr>
<tr>
<td>Caries status</td>
<td>Clinical setting</td>
</tr>
<tr>
<td>General health</td>
<td>Country</td>
</tr>
<tr>
<td>Parafuntion</td>
<td>Clinician’s diagnostic, treatment and maintenance philosophy</td>
</tr>
<tr>
<td>Age</td>
<td></td>
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</tbody>
</table>

**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

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 to 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)

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Analytical framework</strong></td>
<td>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.</td>
</tr>
<tr>
<td><strong>Analytic memo</strong></td>
<td>A written investigation of a particular concept, theme or problem, reflecting on emerging issues in the data that captures the analytic process.</td>
</tr>
<tr>
<td><strong>Categories</strong></td>
<td>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).</td>
</tr>
<tr>
<td><strong>Charting</strong></td>
<td>Entering summarized data into the Framework Method matrix.</td>
</tr>
<tr>
<td><strong>Code</strong></td>
<td>A descriptive or conceptual label that is assigned to excerpts of raw data in a process called ‘coding’.</td>
</tr>
<tr>
<td><strong>Data</strong></td>
<td>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.</td>
</tr>
<tr>
<td><strong>Indexing</strong></td>
<td>The systematic application of codes from the agreed analytical framework to the whole dataset.</td>
</tr>
<tr>
<td><strong>Matrix</strong></td>
<td>A spreadsheet contains numerous cells into which summarized data are entered by codes (columns) and cases (rows).</td>
</tr>
<tr>
<td><strong>Themes</strong></td>
<td>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.</td>
</tr>
<tr>
<td><strong>Transcript</strong></td>
<td>A written verbatim (word-for-word) account of a verbal interaction, such as</td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>Dentist</th>
<th>Gender</th>
<th>Age group (years)</th>
<th>Graduation year</th>
<th>Highest qualification</th>
<th>Practice arrangement</th>
<th>Full or part-time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr J</td>
<td>M</td>
<td>36-45</td>
<td>2001</td>
<td>BChD</td>
<td>Self-employed as a partner in a complete partnership</td>
<td>Full time</td>
</tr>
<tr>
<td>Dr S</td>
<td>F</td>
<td>36-45</td>
<td>2000</td>
<td>BChD</td>
<td>Self-employed without partners (solo practice)</td>
<td>Part-time</td>
</tr>
<tr>
<td>Dr A</td>
<td>M</td>
<td>56-65</td>
<td>1991</td>
<td>BChD</td>
<td>Self-employed without partners (solo practice)</td>
<td>Full time</td>
</tr>
<tr>
<td>Dr LD</td>
<td>M</td>
<td>36-45</td>
<td>2000</td>
<td>BChD</td>
<td>Self-employed without partners but share costs</td>
<td>Full time</td>
</tr>
<tr>
<td>Dr M</td>
<td>F</td>
<td>20-25</td>
<td>2012</td>
<td>BChD</td>
<td>Employed by Group</td>
<td>Full time</td>
</tr>
<tr>
<td>Dr LA</td>
<td>F</td>
<td>36-45</td>
<td>2001</td>
<td>PDD</td>
<td>Other (please specify)</td>
<td>Full time</td>
</tr>
<tr>
<td>Dr LE</td>
<td>F</td>
<td>26-35</td>
<td>2006</td>
<td>BChD</td>
<td>Employed by another dentist</td>
<td>Full time</td>
</tr>
<tr>
<td>Dr K</td>
<td>F</td>
<td>36-45</td>
<td>1993</td>
<td>BChD</td>
<td>Employed by another dentist</td>
<td>Full time</td>
</tr>
<tr>
<td>Dr F</td>
<td>M</td>
<td>&gt;66</td>
<td>1980</td>
<td>BChD</td>
<td>Self-employed as a partner in a complete partnership</td>
<td>Full time</td>
</tr>
<tr>
<td>Dentist</td>
<td>Gender</td>
<td>Age group (years)</td>
<td>Graduation year</td>
<td>Highest qualification</td>
<td>Practice arrangement</td>
<td>Full or part-time</td>
</tr>
<tr>
<td>---------</td>
<td>--------</td>
<td>------------------</td>
<td>----------------</td>
<td>----------------------</td>
<td>---------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Dr LI</td>
<td>M</td>
<td>26-35</td>
<td>2009</td>
<td>BChD</td>
<td>Other (please specify)</td>
<td>Full time</td>
</tr>
<tr>
<td>Dr RI</td>
<td>F</td>
<td>26-35</td>
<td>2005</td>
<td>BChD</td>
<td>Other (please specify)</td>
<td>Full time</td>
</tr>
<tr>
<td>Dr RA</td>
<td>M</td>
<td>46-55</td>
<td>1991</td>
<td>BChD</td>
<td>Self-employed without partners (solo practice)</td>
<td>Full time</td>
</tr>
<tr>
<td>Dr N</td>
<td>F</td>
<td>36-45</td>
<td>1997</td>
<td>PDD</td>
<td>Employed by another dentist</td>
<td>Part-time</td>
</tr>
<tr>
<td>Dr Y</td>
<td>M</td>
<td>36-45</td>
<td>1993</td>
<td>BChD</td>
<td>Self-employed without partners (solo practice)</td>
<td>Full time</td>
</tr>
</tbody>
</table>
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 \((n=322)\)

<table>
<thead>
<tr>
<th>Highest qualification</th>
<th>Frequency ((n))</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>PhD/DSc</td>
<td>2</td>
<td>0.62</td>
</tr>
<tr>
<td>MSc</td>
<td>16</td>
<td>4.97</td>
</tr>
<tr>
<td>PG Dip</td>
<td>86</td>
<td>26.71</td>
</tr>
<tr>
<td>BChD/BDS</td>
<td>218</td>
<td>67.70</td>
</tr>
</tbody>
</table>

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)

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

*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

<table>
<thead>
<tr>
<th>Reasons</th>
<th>Frequency</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of predictability in the technique</td>
<td>58</td>
<td>72</td>
</tr>
<tr>
<td>Lack of supporting evidence</td>
<td>16</td>
<td>20</td>
</tr>
<tr>
<td>Absence of an established technique</td>
<td>21</td>
<td>26</td>
</tr>
<tr>
<td>No professional code and fee for the procedure</td>
<td>7</td>
<td>8.6</td>
</tr>
</tbody>
</table>

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 \((n=246)\)

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

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)

<table>
<thead>
<tr>
<th>Activities</th>
<th>Frequency</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undergraduate dental school</td>
<td>131</td>
<td>50</td>
</tr>
<tr>
<td>CPD course or lecture</td>
<td>70</td>
<td>27</td>
</tr>
<tr>
<td>Reading journal</td>
<td>47</td>
<td>18</td>
</tr>
<tr>
<td>Internet</td>
<td>7</td>
<td>12.6</td>
</tr>
<tr>
<td>Fellow colleague</td>
<td>45</td>
<td>17</td>
</tr>
<tr>
<td>My clinical experience</td>
<td>177</td>
<td>68</td>
</tr>
</tbody>
</table>

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)

<table>
<thead>
<tr>
<th>Restorative Material</th>
<th>Frequency</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resin-modified glass ionomer</td>
<td>91</td>
<td>36</td>
</tr>
<tr>
<td>Resin-based composite</td>
<td>154</td>
<td>62</td>
</tr>
<tr>
<td>Silorane-based composite</td>
<td>7</td>
<td>2.8</td>
</tr>
<tr>
<td>Flowable composite</td>
<td>57</td>
<td>22.8</td>
</tr>
<tr>
<td>Compomer</td>
<td>22</td>
<td>8.8</td>
</tr>
<tr>
<td>Amalgam</td>
<td>74</td>
<td>30</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Restorative Material</th>
<th>Frequency</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resin-modified glass ionomer</td>
<td>68</td>
<td>24</td>
</tr>
<tr>
<td>Resin-based composite</td>
<td>219</td>
<td>78</td>
</tr>
<tr>
<td>Silorane-based composite</td>
<td>14</td>
<td>5</td>
</tr>
<tr>
<td>Compomer</td>
<td>27</td>
<td>9.6</td>
</tr>
<tr>
<td>Amalgam</td>
<td>71</td>
<td>25</td>
</tr>
<tr>
<td>Ceramic inlay</td>
<td>75</td>
<td>27</td>
</tr>
<tr>
<td>Ceramic onlay</td>
<td>68</td>
<td>24</td>
</tr>
<tr>
<td>Crown</td>
<td>164</td>
<td>58</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Category</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient factors</td>
<td>Occlusion, finances, presence of pain</td>
</tr>
<tr>
<td>Tooth factors</td>
<td>Remaining tooth structure, size of restoration, depth of restoration, presence of caries, etc.</td>
</tr>
<tr>
<td>Clinician factors</td>
<td>Experience, available time</td>
</tr>
<tr>
<td>Material factors</td>
<td>Longevity of restorative material, condition of existing restoration</td>
</tr>
<tr>
<td>Do not repair</td>
<td>defecte dental amalgam restorations</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>First Position</th>
<th>%</th>
<th>Second Position</th>
<th>%</th>
<th>Third Position</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tooth factors</td>
<td>85</td>
<td>Tooth factors</td>
<td>70</td>
<td>Patient factors</td>
<td>47</td>
</tr>
<tr>
<td>Patient factors</td>
<td>10</td>
<td>Patient factors</td>
<td>22</td>
<td>Tooth factors</td>
<td>43</td>
</tr>
<tr>
<td>Do not repair restorations</td>
<td>2</td>
<td>Material factors</td>
<td>7</td>
<td>Material factors</td>
<td>8</td>
</tr>
<tr>
<td>Material factors</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Statements</th>
<th>Agree</th>
<th>Undecided</th>
<th>Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>There is no correlation between a marginal gap and secondary caries</td>
<td>8</td>
<td>9</td>
<td>83</td>
</tr>
<tr>
<td>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</td>
<td>44</td>
<td>16</td>
<td>40</td>
</tr>
<tr>
<td>The size of the marginal gap between amalgam and tooth structure is directly related to the chance of secondary caries</td>
<td>60</td>
<td>19</td>
<td>21</td>
</tr>
<tr>
<td>There is no relationship between the decision to replace an existing restoration and refurbishing an amalgam restoration</td>
<td>18</td>
<td>44</td>
<td>38</td>
</tr>
<tr>
<td>I do not repair defective dental amalgam restoration because it is not an acceptable form of restorative dentistry</td>
<td>21</td>
<td>14</td>
<td>65</td>
</tr>
<tr>
<td>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</td>
<td>39</td>
<td>19</td>
<td>41</td>
</tr>
</tbody>
</table>
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)

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

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

<table>
<thead>
<tr>
<th></th>
<th>Cost to patient</th>
<th>Future plans for tooth</th>
<th>Caries risk</th>
<th>OH</th>
<th>Pt. preference</th>
<th>Age of patient</th>
<th>Aesthetics</th>
<th>Pain</th>
<th>Visible caries</th>
<th>Possibility of caries</th>
<th>Remaining tooth structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>My decision to REPLACE a defective dental amalgam restoration</td>
<td>22</td>
<td>20</td>
<td>22</td>
<td>12</td>
<td>16</td>
<td>5.2</td>
<td>19</td>
<td>42</td>
<td>60</td>
<td>17</td>
<td>48</td>
</tr>
<tr>
<td>My decision to REPAIR a defective dental amalgam restoration</td>
<td>64</td>
<td>27</td>
<td>17</td>
<td>9.5</td>
<td>25</td>
<td>17</td>
<td>4</td>
<td>14</td>
<td>24</td>
<td>15</td>
<td>50</td>
</tr>
<tr>
<td>My decision to REFURBISH a defective dental amalgam restoration</td>
<td>59</td>
<td>23</td>
<td>26</td>
<td>24</td>
<td>30</td>
<td>17</td>
<td>23</td>
<td>5.5</td>
<td>5.5</td>
<td>17</td>
<td>25</td>
</tr>
</tbody>
</table>
Table 20: Factors affecting treatment decisions: Ranking of factors

<table>
<thead>
<tr>
<th>Decision to Replace a Defective Dental Amalgam Restoration</th>
<th>1st %</th>
<th>2nd %</th>
<th>3rd %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visible Caries</td>
<td>60</td>
<td>Remaining Tooth Structure</td>
<td>48</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Decision to Repair a Defective Dental Amalgam Restoration</th>
<th>1st %</th>
<th>2nd %</th>
<th>3rd %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost to Patient</td>
<td>64</td>
<td>Remaining Tooth Structure</td>
<td>50</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Decision to Refurbish a Defective Dental Amalgam Restoration</th>
<th>1st %</th>
<th>2nd %</th>
<th>3rd %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost to Patient</td>
<td>59</td>
<td>Patient Preference</td>
<td>30</td>
</tr>
</tbody>
</table>

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>
<thead>
<tr>
<th>Dentists’ Individual Characteristics</th>
<th>Practice Profile</th>
<th>Biases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>Practice arrangement</td>
<td>Use of repair as a treatment option</td>
</tr>
<tr>
<td>Gender</td>
<td>Practice location</td>
<td>Choice of material to repair</td>
</tr>
<tr>
<td>Years of experience</td>
<td>Contracted to third-party funders</td>
<td>Future use of amalgam</td>
</tr>
<tr>
<td>CPD activities</td>
<td></td>
<td>Choice of material to replace amalgam</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Treatment option chosen in vignette</td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>Repair amalgams</th>
<th>Future use of amalgam</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
<td>No</td>
<td>Do not know</td>
<td>Total</td>
<td></td>
</tr>
<tr>
<td>Frequency ($n$)</td>
<td>118</td>
<td>43</td>
<td>12</td>
<td>173</td>
<td></td>
</tr>
<tr>
<td>%</td>
<td>68.21</td>
<td>24.86</td>
<td>6.94</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>Frequency ($n$)</td>
<td>43</td>
<td>50</td>
<td>11</td>
<td>104</td>
</tr>
<tr>
<td>%</td>
<td>41.35</td>
<td>48.08</td>
<td>10.58</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>161</td>
<td>93</td>
<td>23</td>
<td>277</td>
<td></td>
</tr>
</tbody>
</table>

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.

\[ \text{but I would prefer to remove the entire restoration and then clean out under the restoration in case of secondary caries (Dr J).} \]

\[ \text{I think the gap is always a problem for caries (Dr N).} \]

\[ \text{Every dentist experiences secondary caries. Even under the fillings I placed. Secondary caries will develop if the initial caries was not removed 100\% (Dr RA).} \]

\[ \text{Secondary caries can develop under any restoration, and it's something we can’t guarantee (Dr RA).} \]
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)

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Secondary Caries absent SC=0</th>
<th>Secondary Caries present SC=1</th>
<th>Marginal Gap absent MG=0</th>
<th>Marginal Gap present MG=1</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replacement</td>
<td>37</td>
<td>121</td>
<td>50</td>
<td>108</td>
<td>158</td>
</tr>
<tr>
<td></td>
<td>62.71%</td>
<td>78.57%</td>
<td>68.49</td>
<td>77.14</td>
<td></td>
</tr>
<tr>
<td>Repair</td>
<td>22</td>
<td>33</td>
<td>23</td>
<td>32</td>
<td>55</td>
</tr>
<tr>
<td></td>
<td>37.29%</td>
<td>21.43%</td>
<td>31.51</td>
<td>22.86</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>59</td>
<td>154</td>
<td>73</td>
<td>140</td>
<td>213</td>
</tr>
</tbody>
</table>

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).

The 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

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

\( Missing = 50 \)

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 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

<table>
<thead>
<tr>
<th>Effect</th>
<th>DF</th>
<th>Wald Chi-square</th>
<th>Pr&gt;Chi-square</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marginal Gap</td>
<td>2</td>
<td>27.1587</td>
<td>&lt;0.0001*</td>
</tr>
<tr>
<td>Secondary Caries</td>
<td>2</td>
<td>41.2585</td>
<td>&lt;0.0001*</td>
</tr>
</tbody>
</table>

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 (Dr RA).

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 happen is 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

<table>
<thead>
<tr>
<th></th>
<th>Number of patients per week</th>
<th>% patients with private insurance</th>
<th>% patients without private insurance</th>
<th>% patients 1–18 years</th>
<th>% patients 19–44 years</th>
<th>% patients 45–64 years</th>
<th>% patients 65 years and older</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr J</td>
<td>60</td>
<td>65</td>
<td>35</td>
<td>30</td>
<td>30</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Dr S</td>
<td>50</td>
<td>90</td>
<td>10</td>
<td>60</td>
<td>15</td>
<td>20</td>
<td>5</td>
</tr>
<tr>
<td>Dr A</td>
<td>80</td>
<td>70</td>
<td>30</td>
<td>10</td>
<td>60</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>Dr LD</td>
<td>50</td>
<td>70</td>
<td>30</td>
<td>10</td>
<td>50</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Dr M</td>
<td>70</td>
<td>85</td>
<td>15</td>
<td>25</td>
<td>25</td>
<td>40</td>
<td>10</td>
</tr>
<tr>
<td>Dr LA</td>
<td>80</td>
<td>80</td>
<td>20</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Dr LE</td>
<td>60</td>
<td>70</td>
<td>30</td>
<td>25</td>
<td>63</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>Dr K</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>20</td>
<td>40</td>
<td>30</td>
<td>10</td>
</tr>
<tr>
<td>Doctor</td>
<td>Number of patients per week</td>
<td>% patients with private insurance</td>
<td>% patients without private insurance</td>
<td>% patients 1–18 years</td>
<td>% patients 19–44 years</td>
<td>% patients 45–64 years</td>
<td>% patients 65 years and older</td>
</tr>
<tr>
<td>--------</td>
<td>-----------------------------</td>
<td>-----------------------------------</td>
<td>-------------------------------------</td>
<td>----------------------</td>
<td>-----------------------</td>
<td>-----------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>Dr F</td>
<td>50</td>
<td>50</td>
<td>100</td>
<td>30</td>
<td>25</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Dr LI</td>
<td>50</td>
<td>0</td>
<td>100</td>
<td>20</td>
<td>60</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Dr RI</td>
<td>40</td>
<td>70</td>
<td>100</td>
<td>20</td>
<td>70</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Dr RA</td>
<td>100</td>
<td>70</td>
<td>100</td>
<td>30</td>
<td>50</td>
<td>15</td>
<td>5</td>
</tr>
<tr>
<td>Dr MA</td>
<td>100</td>
<td>85</td>
<td>15</td>
<td>20</td>
<td>10</td>
<td>20</td>
<td>50</td>
</tr>
<tr>
<td>Dr N</td>
<td>25</td>
<td>60</td>
<td>10</td>
<td>30</td>
<td>50</td>
<td>30</td>
<td>10</td>
</tr>
<tr>
<td>Dr Y</td>
<td>75</td>
<td>75</td>
<td>25</td>
<td>30</td>
<td>30</td>
<td>25</td>
<td>15</td>
</tr>
</tbody>
</table>
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’

<table>
<thead>
<tr>
<th>Material</th>
<th>Frequency</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amalgam</td>
<td>11</td>
<td>2.4</td>
</tr>
<tr>
<td>Resin composite</td>
<td>357</td>
<td>78</td>
</tr>
<tr>
<td>Glass Ionomer</td>
<td>41</td>
<td>9</td>
</tr>
<tr>
<td>Compomer</td>
<td>24</td>
<td>5.2</td>
</tr>
<tr>
<td>Other</td>
<td>4</td>
<td>0.8</td>
</tr>
<tr>
<td>Not answered</td>
<td>21</td>
<td>4.6</td>
</tr>
</tbody>
</table>

*Missing = 10*
Table 28: Reasons for a ‘new restoration’

<table>
<thead>
<tr>
<th>Reason</th>
<th>Frequency</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary caries</td>
<td>294</td>
<td>63</td>
</tr>
<tr>
<td>Non-carious defects</td>
<td>54</td>
<td>11</td>
</tr>
<tr>
<td>Other</td>
<td>23</td>
<td>5</td>
</tr>
<tr>
<td>Not answered</td>
<td>97</td>
<td>21</td>
</tr>
</tbody>
</table>

Table 29: Reason for replacement of a restoration

<table>
<thead>
<tr>
<th>Reason</th>
<th>Frequency</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Secondary caries</td>
<td>56</td>
<td>12</td>
</tr>
<tr>
<td>Marginal discoloration</td>
<td>2</td>
<td>0.43</td>
</tr>
<tr>
<td>Bulk discolouration</td>
<td>2</td>
<td>0.43</td>
</tr>
<tr>
<td>Isthmus/ Bulk fracture</td>
<td>12</td>
<td>2.6</td>
</tr>
<tr>
<td>Tooth fracture</td>
<td>17</td>
<td>4</td>
</tr>
<tr>
<td>Poor anatomic form</td>
<td>1</td>
<td>0.2</td>
</tr>
<tr>
<td>Pain/sensitivity</td>
<td>18</td>
<td>3.9</td>
</tr>
<tr>
<td>Not answered</td>
<td>355</td>
<td>77</td>
</tr>
</tbody>
</table>
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 microleakage 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 “\textit{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 \textit{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 “\textit{patchwork}” and “\textit{not the right thing to do}” (DR LE). This supports the findings of Sharif \textit{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.
REFERENCES


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http://etd.uwc.ac.za


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

<table>
<thead>
<tr>
<th>Year</th>
<th>First/Author</th>
<th>Observation period</th>
<th>GV/Black</th>
<th>Restorative materials</th>
<th>Primary or Permanent Detonation</th>
<th>No. of placed restorations (n)</th>
<th>No. of replaced restorations (n)</th>
<th>Study Design</th>
<th>Reason for replacement (Co-distribution)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1981</td>
<td>Mjor</td>
<td>2 weeks</td>
<td>Amalgam</td>
<td>Toothcoloured</td>
<td>Both</td>
<td>5487</td>
<td>2504/1544</td>
<td>Practice-based</td>
<td>Secondary caries 60% / Fracture 20% / Discoloration 10%</td>
<td>Confusing categories of recurrent caries, new caries and caries under amalgam</td>
</tr>
<tr>
<td>1982</td>
<td>Boyd</td>
<td>3 days surfaces</td>
<td>Amalgam</td>
<td>Only record replaced surfaces</td>
<td>Only record replaced surfaces</td>
<td>3862 surfaces</td>
<td>Practice-based (108)</td>
<td>Fracture of tooth 21% / Sensitivity 13%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1983</td>
<td>Klausner</td>
<td>2</td>
<td>Amalgam</td>
<td></td>
<td>Both</td>
<td>3392</td>
<td>2146</td>
<td>Practice-based (122)</td>
<td>Fracture of tooth 33%</td>
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</tr>
<tr>
<td>1986</td>
<td>Qvist</td>
<td>2 years I II III V</td>
<td>Amalgam</td>
<td>Both</td>
<td>Both</td>
<td>6052</td>
<td>Cross sectional</td>
<td>Cross sectional</td>
<td>Fracture of tooth 40% / Sensitivity 3%</td>
<td></td>
</tr>
<tr>
<td>1987</td>
<td>Klausner</td>
<td>14 days</td>
<td>Amalgam</td>
<td></td>
<td>Amalgam</td>
<td>5511</td>
<td>2996</td>
<td>Practice-based (191)</td>
<td>Fracture of tooth 53%</td>
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</tr>
<tr>
<td>1990</td>
<td>Elderton</td>
<td>1 year 3 years 5 years</td>
<td>Amalgam</td>
<td>5824 (tooth surfaces)</td>
<td>5824 (tooth surfaces)</td>
<td>559</td>
<td>195</td>
<td>NHS</td>
<td>Fracture of tooth 40%</td>
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<tr>
<td>Year</td>
<td>First Author</td>
<td>Observation period</td>
<td>GV Black</td>
<td>Restorative materials</td>
<td>Primary or permanent Dentition</td>
<td>No. of replaced restorations (a)</td>
<td>No. of replaced restorations (b)</td>
<td>Study Design</td>
<td>Reason for replacement (distribution)</td>
<td>Secondary caries</td>
</tr>
<tr>
<td>------</td>
<td>--------------</td>
<td>--------------------</td>
<td>----------</td>
<td>----------------------</td>
<td>-------------------------------</td>
<td>--------------------------------</td>
<td>--------------------------------</td>
<td>--------------</td>
<td>--------------------------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>1990</td>
<td>Qvist</td>
<td>first 30 fillings in 3 weeks</td>
<td>I II III IV V</td>
<td>Amalgam Composite GI Silicate Cement Cast</td>
<td>Both</td>
<td>7454</td>
<td>1973</td>
<td>Practice-based (265)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1990</td>
<td>Qvist</td>
<td>Amalgam Composite</td>
<td>2317 1974</td>
<td>Only record replaced restorations</td>
<td>284 (206 amalgam)</td>
<td>Practice based (3 dentists)</td>
<td>34</td>
<td>12</td>
<td>2</td>
<td>27</td>
</tr>
<tr>
<td>1990</td>
<td>Drake</td>
<td>1 month</td>
<td>All</td>
<td>284 (206 amalgam)</td>
<td>Practice based (3 dentists)</td>
<td>34</td>
<td>42</td>
<td>1</td>
<td>42</td>
<td>4</td>
</tr>
<tr>
<td>1992</td>
<td>Mjor</td>
<td>2 weeks</td>
<td>Amalgam Composite</td>
<td>Permanent</td>
<td>Practice based (62 dentists)</td>
<td>59</td>
<td>11</td>
<td>13</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>1994</td>
<td>Friedl</td>
<td>1 month</td>
<td>Amalgam</td>
<td>PR T PET T1 PET T2</td>
<td>cross-sectional</td>
<td>2961</td>
<td></td>
<td></td>
<td></td>
<td>12</td>
</tr>
<tr>
<td>Year</td>
<td>First Author</td>
<td>Observation period</td>
<td>GV Black</td>
<td>Restorative materials</td>
<td>Primary or Permanent Teeth</td>
<td>No. of placed restorations (A)</td>
<td>No. of replaced restorations (B)</td>
<td>Study Design</td>
<td>Reason for replacement (Distribution)</td>
<td>Secondary curvatures</td>
</tr>
<tr>
<td>------</td>
<td>--------------</td>
<td>--------------------</td>
<td>----------</td>
<td>----------------------</td>
<td>---------------------------</td>
<td>-----------------------------</td>
<td>--------------------------------</td>
<td>-------------</td>
<td>--------------------------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>1991</td>
<td>Pink</td>
<td>50 amalgam restorations, 50 composite restorations</td>
<td>Amalgam Composite</td>
<td>Permanent</td>
<td>1077 1606</td>
<td>-45%</td>
<td>25</td>
<td>20</td>
<td>Practice based (22 dentists)</td>
<td>8.8 4.9</td>
</tr>
<tr>
<td>1997</td>
<td>Wilson</td>
<td>6 weeks</td>
<td>All</td>
<td>Permanent</td>
<td>708</td>
<td>Practice based (22 dentists)</td>
<td>43</td>
<td>15</td>
<td>18 11</td>
<td>Marginal discrepancies are included in fracture of filling</td>
</tr>
<tr>
<td>1997</td>
<td>Mjor</td>
<td>2 weeks</td>
<td>Amalgam Composite GI</td>
<td>Permanent</td>
<td>1062 2131 538</td>
<td>Practice-based (177 dentists)</td>
<td>50</td>
<td>4</td>
<td>2 9 29 15</td>
<td>Marginal discrepancies are included in fracture of filling</td>
</tr>
<tr>
<td>1999</td>
<td>Burke</td>
<td>100 restorations</td>
<td>Amalgam Composite GI</td>
<td>Permanent</td>
<td>4608</td>
<td>VDP(73)</td>
<td>46</td>
<td>12</td>
<td>13 12 11</td>
<td>Marginal discrepancies are included in fracture of filling</td>
</tr>
<tr>
<td>2000</td>
<td>Deligiorgi</td>
<td>3 months: Manchester Athens</td>
<td>Amalgam Composite GI related</td>
<td>Permanent</td>
<td>748 (Manchester) 415 (Athens)</td>
<td>Student clinics in 2 dental school</td>
<td>67</td>
<td>1 4</td>
<td>2 11 3 2 5</td>
<td>Marginal discrepancies are included in fracture of filling</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Permanent</td>
<td>40 445 Athens</td>
<td>25</td>
<td>0</td>
<td>15 14 23 2</td>
<td>Marginal discrepancies are included in fracture of filling</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Permanent</td>
<td>17 445 Athens</td>
<td>40</td>
<td>0</td>
<td>3 14 7 1 8 0</td>
<td>Marginal discrepancies are included in fracture of filling</td>
<td></td>
</tr>
<tr>
<td>Year</td>
<td>First Author</td>
<td>Observation period</td>
<td>GV Black</td>
<td>Restorative materials</td>
<td>Primary or Permanent tooth</td>
<td>No. replaced restoration(s)</td>
<td>No. of replaced restoration(s)</td>
<td>Study Design</td>
<td>Reason for replacement (%)</td>
<td>Distribution</td>
</tr>
<tr>
<td>------</td>
<td>--------------</td>
<td>------------------</td>
<td>----------</td>
<td>----------------------</td>
<td>---------------------------</td>
<td>----------------------------</td>
<td>----------------------------</td>
<td>-------------</td>
<td>---------------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>2001</td>
<td>Burke</td>
<td>1 month</td>
<td>Amalgam Composite GI Composers</td>
<td>3196 (Total)</td>
<td>2099 (Replacement)</td>
<td>Practice-based dentists (15)</td>
<td>51</td>
<td>3</td>
<td>12</td>
<td>7</td>
</tr>
<tr>
<td>2002</td>
<td>Ogianni</td>
<td>2 months</td>
<td>Amalgam</td>
<td>Permanent</td>
<td>488</td>
<td>121</td>
<td>Cross-sectional: pts referred to dept. of restorative dentistry</td>
<td>30.6</td>
<td>12.4</td>
<td>47</td>
</tr>
<tr>
<td>2005</td>
<td>Tya</td>
<td>100 restorations</td>
<td>Amalgam Composite GI Composers</td>
<td>767 1481 406 44</td>
<td>1460</td>
<td>Practice-based dentists (38)</td>
<td>32</td>
<td>14</td>
<td>19</td>
<td>17</td>
</tr>
<tr>
<td>2013</td>
<td>Otosamey</td>
<td>1979-1992</td>
<td>Amalgam</td>
<td>Permanent</td>
<td>2094</td>
<td>508</td>
<td>Records based, retrospective</td>
<td>11.6</td>
<td>Reasons for amalgam replacement were not separated. Values include all replacements</td>
<td></td>
</tr>
<tr>
<td>2013</td>
<td>Bahsi</td>
<td></td>
<td>Amalgam Composite</td>
<td>Permanent Only replacements</td>
<td>2094 508</td>
<td>Records based, retrospective</td>
<td>30.8 9.8</td>
<td>15.5 17</td>
<td>6 8.9</td>
<td>8.9</td>
</tr>
<tr>
<td>2014</td>
<td>Silvani</td>
<td></td>
<td>Amalgam Composite</td>
<td>306 121 (total)</td>
<td>42.68</td>
<td>4.88</td>
<td>13</td>
<td>2.4</td>
<td>Amaligams were replaced when pts requested tooth coloured materials and all risks and benefits were evaluated</td>
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### Appendix B: Clinical studies on repair and refurbishment of restorations

<table>
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<tr>
<th>Year</th>
<th>First Author</th>
<th>Observation period</th>
<th>GV Blue</th>
<th>Restorative material</th>
<th>Number of defective restorations</th>
<th>Sealing defective margin</th>
<th>Refurbishing</th>
<th>Replacement</th>
<th>No treatment</th>
<th>Number of repaired restorations (n)</th>
<th>Criteria</th>
<th>Number of patients (n)</th>
<th>Study Design</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993</td>
<td>Cipriano</td>
<td>2yrs</td>
<td>I; II; V</td>
<td>dental amalgam</td>
<td>113</td>
<td>23</td>
<td>23</td>
<td>23</td>
<td>24</td>
<td>45</td>
<td>USPHS</td>
<td>45</td>
<td></td>
<td>7% rated unacceptable</td>
</tr>
<tr>
<td>2006</td>
<td>Gordon</td>
<td>2yrs</td>
<td></td>
<td>dental amalgam</td>
<td>193; 193</td>
<td>48</td>
<td>73</td>
<td>42</td>
<td>81</td>
<td>27</td>
<td>USPHS</td>
<td>66</td>
<td></td>
<td>Repair and replacement groups had statistically significant differences in marginal adaptation and anatomic group when compared to no treatment group after 1 and 2 years</td>
</tr>
<tr>
<td>2008</td>
<td>Moncada</td>
<td>2yrs</td>
<td></td>
<td>dental amalgam; resin composite</td>
<td>193; 78</td>
<td>48</td>
<td>73</td>
<td>42</td>
<td>81</td>
<td>27</td>
<td>USPHS</td>
<td>66</td>
<td></td>
<td>The sealing of marginal defects showed significant improvements in marginal adaptation (p&lt;0.05). Refurbishing of the defective restorations significantly improved anatomic form (p&lt;0.001), luster (p&lt;0.016), marginal adaptation (p&lt;0.003) and roughness (p&lt;0.001). The repair significantly improved anatomic form (p&lt;0.002) and marginal stain (p&lt;0.002). Replacement showed significant improvements for all parameters (p&lt;0.05). The untreated group showed significant deterioration on marginal adaptation (p&lt;0.013).</td>
</tr>
<tr>
<td>2009</td>
<td>Moncada</td>
<td>3yrs</td>
<td></td>
<td>dental amalgam; resin composite</td>
<td>193; 78</td>
<td>48</td>
<td>73</td>
<td>42</td>
<td>81</td>
<td>27</td>
<td>USPHS</td>
<td>66</td>
<td></td>
<td>Restorations that underwent sealing of marginal defects exhibited significant improvements in marginal adaptation (p&lt;.001). Restorations in the refurbishment group exhibited improvements in anatomical form (p&lt;.005) and surface roughness (p&lt;.001). Restorations in the repair group exhibited improvements with regard to anatomical form (p=.008). Replaced restorations exhibited improvements in all parameters (p&lt;.05), while the untreated group experienced declines in all parameters (p&lt;.05).</td>
</tr>
<tr>
<td>2011</td>
<td>Fernandez</td>
<td>4yrs</td>
<td></td>
<td>dental amalgam; resin composite</td>
<td>193; 78</td>
<td>36</td>
<td>61</td>
<td>28</td>
<td>60</td>
<td>21</td>
<td>USPHS</td>
<td>66</td>
<td></td>
<td>Sealed margins group showed the lowest MII while the Repair group showed the highest MII 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.</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Year</th>
<th>FirstAuthor</th>
<th>Observation period</th>
<th>GV/Black</th>
<th>Restorative material</th>
<th>Number of defective restorations</th>
<th>Sealing defective margin</th>
<th>Refinishing</th>
<th>Replacement</th>
<th>No treatment</th>
<th>Number of repaired restorations (n)</th>
<th>Criteria</th>
<th>Number of patients (n)</th>
<th>Study Design</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>Gordon</td>
<td>7yrs</td>
<td></td>
<td></td>
<td>113</td>
<td>23</td>
<td>23</td>
<td>22</td>
<td>25</td>
<td>20</td>
<td>USPHS</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>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 68 percent)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2012</td>
<td>Opdam</td>
<td>Up to 24 years</td>
<td>class II</td>
<td>dental amalgam; resin composite</td>
<td>246</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Practice-based</td>
<td>AFR after 4 years for amalgam restorations 9.3%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2013</td>
<td>Martin</td>
<td>5yrs</td>
<td>class I; class II</td>
<td>dental amalgam</td>
<td>160</td>
<td>64</td>
<td>21</td>
<td>56</td>
<td>19</td>
<td>USPHS</td>
<td>52</td>
<td>RCT</td>
<td>Practice-based</td>
<td>The results show that repairing and refinishing restorations with localized defects are effective and increase the MST of the restorations.</td>
</tr>
<tr>
<td>2015</td>
<td>Gordon</td>
<td>1yr</td>
<td></td>
<td>dental amalgam; direct tooth coloured; indirect tooth coloured</td>
<td>5687</td>
<td>171</td>
<td></td>
<td></td>
<td></td>
<td>Defined criteria</td>
<td>Practice-based</td>
<td>RCT</td>
<td>Repair 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.</td>
<td></td>
</tr>
<tr>
<td>2015</td>
<td>Moncada</td>
<td>10yrs</td>
<td>class I; class II</td>
<td>dental amalgam</td>
<td>40</td>
<td>21</td>
<td>21</td>
<td>19</td>
<td></td>
<td>USPHS</td>
<td>20</td>
<td>RCT</td>
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Appendix C: FDI criteria and gradings (Hickel et al., 2010)

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<tr>
<td>Replica (n° and date)</td>
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</tr>
</tbody>
</table>

### A. Esthetic properties

#### 1. Clinically excellent / very good

1.1 Lustrous, comparable to enamels.

#### 2. Clinically good

2.1 Slightly dull, not noticeable from speaking distance.

#### 3. Clinically sufficient / satisfactory

3.1 Null surface but acceptable if covered with film of saliva.

#### 4. Clinically unsatisfactory (but repairable)

4.1 Rough surface, cannot be masked by saliva film, simple polishing is not sufficient. Further intervention necessary.

#### 5. Clinically poor (replacement necessary)

5.1 Very rough, unacceptable plaque retentive surface.

### 1. Surface luster

1. Surface luster b. margin

2a.1 No surface staining.

2b.1 No marginal staining.

3.1 Good color match, no difference in shade and/or translucency.

### 2. Staining

2a.2 Minor surface staining, easily removable by polishing.

2b.2 Minor marginal staining, easily removable by polishing.

### 3. Color match and translucency

3.2 Minor deviations in shade and/or esthetics.

### 4. Esthetic anatomical form

4.1 Form is ideal.

4.2 Form is only slightly deviated from the normal.

4.3 Form deviates from the normal but is esthetically acceptable.

4.4 Form is affected and unacceptable esthetically. Intervention/correction is necessary.

4.5 Form is unsatisfactory and/ or lost. Repair not feasible / reasonable, Replacement needed.
<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Clinically excellent / very good</td>
<td>5.1 No fractures / cracks.</td>
<td>6.1 Harmonious outline, no gaps, no white or discolored lines</td>
<td>7.1 Physiological wear equivalent to enamel. 7b.1 Wear corresponding to 90-120% of enamel.</td>
<td>8a.1 Normal contact point (fossa or 25 μm metal blade can pass) 8b.1 Normal contour.</td>
<td>9.1 No pathology, harmonious transition between restoration and tooth.</td>
<td>10.1 Esthetics, aesthetics and function.</td>
</tr>
<tr>
<td>2. Clinically good</td>
<td>5.2 Small hairline crack.</td>
<td>6.2.1 Marginal gap (&lt;150 μm), white lines. 6.2.2 Small marginal fracture, removable by polishing, slight ditching, slight step/flaw, minor irregularities.</td>
<td>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.</td>
<td>8a.2. Contact slightly too strong but no disadvantage (fossa or 25 μm metal blade can only pass with pressure). 8b.2 Slightly deficient contour.</td>
<td>9.2.1 Acceptable material excess present. 9.2.2 Positive/negative step present at margin &lt;150 μm.</td>
<td>10.2 Satisfied. 10.2.1 Esthetics. 10.2.2 Function, e.g., minor roughness.</td>
</tr>
<tr>
<td>3. Clinically satisfactory (minor shortcomings, no unacceptable effects but not adjustable within damage to the tooth)</td>
<td>5.3 Two or more larger hairline cracks and/or material chip fracture not affecting the marginal integrity or approximal contact.</td>
<td>6.3.1 Gap &lt; 250 μm not removable. 6.3.2. Several small marginal fractures. 6.3.3 Major irregularities, ditching or flaw, step.</td>
<td>7a.3 Different wear rates than enamel but within the biological variation. 7b.3 &lt; 50% or 150-300% of corresponding enamel.</td>
<td>8a.3. Somewhat weak contact, no indication of damage to tooth, gingiva or pericoronal structures; 50 μm metal blade can pass. 8b.3 Visible deficient contour.</td>
<td>9.3.1 Marginal gap &lt; 250 μm. 9.3.2 Negative steps visible &lt; 250 μm. No adverse effects noticed. 9.3.3 Poor radiopacity of filling material.</td>
<td>10.3 Minor criticism but no relevant clinical effects. 10.3.1 Esthetics shortcomings. 10.3.2 Some lack of chewing comfort. 10.3.3 Unilateral treatment procedure.</td>
</tr>
<tr>
<td>4. Clinically unsatisfactory (but repairable)</td>
<td>6.4.1 Material chip fractures which damage marginal quality or</td>
<td>6.4.1 Gap &gt; 250 μm or dentine/base exposed. 6.4.2. Severe.</td>
<td>7a.4 Wear considerably exceeds normal enamel wear; or</td>
<td>8a.4 Too weak and possible damage due to food impaction.</td>
<td>6.4.1 Marginal gap &gt;250 μm. 6.4.2 Material excessive excess.</td>
<td>10.4 Desire for improvement. 10.4.1 Esthetics. 10.4.2 Function, e.g.,</td>
</tr>
<tr>
<td></td>
<td>approximal contacts, 5.4.2 Bulk fractures with partial loss (less than half of the restoration), ditching or marginal fracture. 5.4.3 Larger (neighboring) or steps (repair necessary)</td>
<td>occlusal contact points are lost. 7b.4 Restoration &gt; 300% of original wear or antagonist &gt; 300%.</td>
<td>100 μm metal blade can pass. 8b.4 Inadequate contour Repair possible.</td>
<td>but not removable. 8a.4.3 Negative steps &gt;250μm and repairable.</td>
<td>&amp;</td>
<td></td>
</tr>
</tbody>
</table>

http://etd.uwc.ac.za
| 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 > 50% of corresponding enamel, 8a.5 Too weak and/or clear damage due to food implanation 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): |


| 1. Clinically very good | 11.1 No hyper-/sensitivity, normal vitality, 13.1 Complete integrity, 14.1 No plaque, no inflammation, no pocket |

| 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. Abrasion, 13.2.1 Small marginal enamel fractures (<150 μm), 13.2.2 Half-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 esthetic form, 15.2 Healthy after minor removal of mechanical irritations (plaque, calculus, sharp edges etc.), 16.2 Minor transient symptoms of short duration; focal or generalized. |

| 3. Clinically sufficient / satisfactory (minor shortcomings with no adverse effects) | 11.3.1 Moderate hypersensitivity, 11.3.2 Delayed/mild sensitivity, no subjective complaints, no treatment needed, 12.3 Larger areas of 1. Demineralization 2. Erosion or 3. Abrasion/abfractio, 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 esthetic form, 15.3 Alteration of mucoea but no apparent causation of causal relationship with restoration material, 16.3. Transient symptoms, local and/or general. |

http://etd.uwc.ac.za
| 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 undermined caries 12.4.2 Erosion in dentine 12.4.3 Abrasion/abrasion in dentine. Localized and accessible can be repaired. 13.4.1 Major marginal enamel defect; 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 > 1 mm 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. | Score | Acceptable biologically (ni and %): Not acceptable (ni, % and reasons): |}

http://etd.uwc.ac.za
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 cannot 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 (rztadam@uwc.ac.za or (021) 937 3157) if you have any questions or comments regarding the study.

☐ I agree to participate
☐ I do not agree to participate.

*2. I am a

☐ Male
☐ Female
3. My highest educational qualification is
- PhD or DSc
- MSc
- BScHED
- Postgraduate Diploma
- BComH or BEd

4. I am in the following age group
- 30-39 years old
- 40-49 years old
- 50-59 years old
- 60-69 years old
- 70-79 years old
- 80 years and older

5. I am currently
- In Private Practice
- In Public Service
- A Teacher 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 (52 or more hours per week)
- Part-time (less than 52 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 separator 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...

- Attending journal quizzes quizzes
- Attending lectures organized by dental companies
- Attending lectures organized by my practices
- Attending out-of-hospital courses
- Attending congresses
- Sterilizing 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 predictability in the technique.

☐ Lack of supporting scientific evidence.

☐ Absence of an established technique.

☐ No professional code and fees 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 followings

☐ Use a bur to create retention for restorations.

☐ Apply etch primer to the amalgam prior to bonding.

☐ Apply silane to the amalgam prior to etch bonding.

☐ Apply etch primer to etch the amalgam bonding.

☐ Apply all-enamel etch bonding system.

☐ Apply self-etch etch bonding system.

☐ Apply a glass ionomer as a dentin bonding system.

☐ Place a provisional restoration.

Other (please specify)
22. I learnt my technique from
☐ Undergraduate Dental School
☐ Attending a Continuing Professional Education Course or lectures.
☐ 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
☐ Glass-based composite
☐ Flowable composite
☐ Composite
☐ 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
☐ Glass-based composite
☐ Composite
☐ Amalgam
☐ Ceramic
☐ Glass-ionomer
☐ 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 disagree with the following statements or if you are undecided.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Agree</th>
<th>Undecided</th>
<th>Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>There is no correlation between a marginal gap and secondary caries.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>The size of the marginal gap between amalgam and tooth structure is directly related to the chance of secondary caries.</td>
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<tr>
<td>There is no relationship between the status of existing dental intra/extrusion and undetecting amalgam restoration.</td>
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<tr>
<td>I do not repair defective dental amalgam restorations because it is not an acceptable form of restorative dentistry.</td>
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<tr>
<td>I replace “faulty margins” when there is radiologically or radiographically detectable caries because margins are questionable is not below the margin that cannot be detected.</td>
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</table>

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.
- Intelligence or clinical experience based on clinical appearance.
- Decoloured areas of a restoration.
- Frank or definite carious excitation.
- Presence of soft, decoloured dentine or enamel.
- An 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 restaining and polishing of a restoration to improve the surface and appearance.
23. Please indicate the 3 most important factors in your treatment decisions in the following examples.

<table>
<thead>
<tr>
<th>Cost to patient</th>
<th>Future plans for the tooth</th>
<th>Caries risk of patient</th>
<th>Oral hygiene status of patient</th>
<th>Patient preference</th>
<th>Age of patient</th>
<th>Aesthetics</th>
<th>Pain</th>
<th>Visible edges</th>
<th>Possibility of erosion</th>
<th>Remaining tooth structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>My decision to REPLACE a nongolden-dental-amalgam restoration.</td>
<td></td>
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<tr>
<td>My decision to REPAIR a nongolden-dental-amalgam restoration.</td>
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<tr>
<td>My decision to REPAIR a nongolden-dental-amalgam restoration.</td>
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</tbody>
</table>

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

- [ ] Yes
- [ ] No
- [ ] I don't know

30. If [Q25], 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 placement of a new restoration.

Refinishing 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 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

[Signature]

Professor Sudeshni Naidoo
Appendix F: Case Study 1 and Case Study 2
Case Study 1
Appendix G: Self-administered questionnaire for qualitative sample (n=15)
Private Practitioner Interviews

7. My highest educational qualification is
   ○ PhD or DPhil
   ○ MPhil
   ○ MSciD
   ○ PGD
   ○ BChD or BDent

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 (sole 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? ____________________________________________

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 (at least 8h a month per week)
    ○ Part-time (less than 8h a month 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**

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Fee 1</th>
<th>Fee 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 surface amalgam</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 cavity root canal</td>
<td></td>
<td></td>
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<tr>
<td>Single simple/uncomplicated root extraction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full denture</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Porcelain to metal crown (terior)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 surface posterior composite</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 surface posterior composite</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 surface anterior composite</td>
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<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Percentage 1</th>
<th>Percentage 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children and Teenagers (1-18 years)</td>
<td></td>
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<tr>
<td>Young adults (19-44 years)</td>
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<tr>
<td>Middle-aged adults (45-64 years)</td>
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</tr>
<tr>
<td>Elderly (65 or older)</td>
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</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Race</th>
<th>Percentage 1</th>
<th>Percentage 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td></td>
<td></td>
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<tr>
<td>Coloured</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indian</td>
<td></td>
<td></td>
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<tr>
<td>Asian</td>
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</table>

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

<table>
<thead>
<tr>
<th>Insurance Coverage</th>
<th>Percentage 1</th>
<th>Percentage 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covered by a private insurance program that pays for most or all of their dental care</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not covered by any third-party and pay their own MBs</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Payment Source</th>
<th>Percentage 1</th>
<th>Percentage 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dental insurance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Self-pay</td>
<td></td>
<td></td>
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<tr>
<td>Unpaid bills</td>
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<tr>
<td>Other</td>
<td></td>
<td></td>
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<tr>
<td>Private Practitioner Interviews</td>
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<tr>
<td>--------------------------------</td>
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<tr>
<td><strong>18. What percentage of your time in practice is spent performing?</strong></td>
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<tr>
<td>Basic restorative procedures</td>
<td></td>
<td></td>
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<tr>
<td>Advanced restorative procedures</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Endodontics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surgery</td>
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<tr>
<td>Routine periodontal treatment</td>
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<tr>
<td>Preventative treatment</td>
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<tr>
<td>Prophylaxis treatment</td>
<td></td>
<td></td>
</tr>
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Appendix H: Treatment log

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http://etd.uwc.ac.za
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 \( p < 0.05 \)

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**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 $p<0.05$

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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 $p>=0.05$

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

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

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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: \( p<0.005 \))

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

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**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
Appendix N: Summary of proposed treatment for clinical vignettes

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<tr>
<td>Replacement of restoration</td>
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### Appendix O: Summary table of all treatment logs

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<th>No. of Females</th>
<th>% Females</th>
<th>No. of Males</th>
<th>% Males</th>
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<th>Reasons for NEW restorations</th>
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The table provides a comprehensive summary of treatment logs, including demographics, restoration materials used, and reasons for both new and replacement restorations.