Factors influencing accuracy of caries risk assessment among South Australian children

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Abbreviations

ADJCI	Adjusted caries increment
AIHW	Australian Institute of Health and Welfare
ANOVA	Analysis of variance
ARCPOH	Australian Research Centre for Population Oral Health
AUC	Area Under Curve
CART	Classification and regression tree analysis
CCI	Crude caries increment
CRA	Caries Risk Assessment
dmfs	Decayed, missing, filled deciduous surfaces
DMFS	Decayed, missing, filled permanent surfaces
dmft	Decayed, missing, filled deciduous teeth
DMFT	Decayed, missing, filled permanent teeth
DT	Dental therapist
EXACT	Electronic clinical record data management system
F	Factor
FDA	Food and Drug Administration
GLM	Generalised Linear Regression Model
h^2	Communality
ID	Incidence density
IDR	Incidence density ratio
KMO	Kaiser-Meyer-Olkin
LRA	Logistic regression analysis
LDA	Linear discriminant analysis
Max	Maximum
Min	Minimum
n	Sample size
NA	Not available
NC	Not calculated
NCI	Net caries increment
NHMRC	National Health and Medical Research Council
NIDR	National Institute of Dental Research

NS	Not significant
P	p-value
PDC	Personalised Dental Care
PHR	Percentage high risk patients
R^2	Per cent variance explained
Ref	Reference category
ROC	Receiver Operating Curve
SDS	School Dental Service
SA	South Australia
SA SDS	South Australian School Dental Service
SADS	South Australian Dental Service
SD	Standard deviation
Se	Sensitivity
Se+Sp	Sensitivity + Specificity
SES	Socioeconomic status
Sp	Specificity
WHO	World Health Organization
99%CI	99% Confidence Interval

Abstract

This thesis examined factors associated with the accuracy of caries risk assessment by South Australian Dental Service (SADS) staff for children enrolled in the school dental service. Understanding those factors can help to address variation in accuracy of assessment and ultimately caries risk among children. The aims of this thesis were to examine the relationship between clinician's assessment of caries risk at a baseline examination and subsequent caries development and to explore the association between accuracy in caries risk assessment and clinician- and patient-related factors.

This study consisted of four sub-studies which addressed a set of specific objectives. Two data sources were used in the analysis. The first dataset was obtained from the South Australian component of the Child Dental Health Survey, an ongoing national surveillance survey of the oral health status of Australian children attending school dental services in all states and territories. Data on caries experience were extracted from electronic examination records collected during the period 2002–2005. These data included caries experience (decayed, missing and filled tooth surfaces) of the deciduous (dmfs) and permanent dentition (DMFS). The level of risk status assigned by clinicians at the baseline examination as well as socio-demographic factors of those children, were obtained. This first dataset was used for sub-study no. 1 and sub-study no. 2. Sub-study no. 3 and sub-study no. 4 used additional information from the second dataset, which contained responses to a self-completed clinician questionnaire. This questionnaire collected data on clinicians' personal characteristics, routine caries risk assessment practices and their perception of factors that were important in caries risk assessment and their confidence in their routine clinical activities.

Sub-study no. 1 described caries experience and increment and their associations with clinicians' caries risk assessment. Children who had at least two recorded examinations with an interval of more than six months between them were included. Caries experience in both permanent and deciduous dentitions at baseline examination was described by assigned risk status. Net caries increment and caries incidence density between examinations were computed. Caries incidence density was contrasted according to children' risk status at the baseline examination. Children who were classified as high-risk at baseline had a significantly higher rate of new dental caries regardless of their caries experience status at

baseline. This result supported the conclusion that clinicians' judgement was a valid predictor of future caries development.

Clinicians who examined more than 20 children during the study period were selected for study no. 2. This study aimed to evaluate clinician accuracy in predicting caries risk for South Australian children. Computed caries rate between the two examinations (caries incidence density) was used as the gold standard and compared with clinicians' classification of children' risk status at the baseline examination. Sensitivity (Se) and specificity (Sp) were calculated as measures of clinician accuracy. Accuracy in predicting caries development was moderate, although there was large variation between clinicians. This finding suggested that a number of clinician-related characteristics influenced caries risk assessment accuracy.

In sub-study no. 3, a survey was conducted among all SADS school dental service clinicians using a self-completed questionnaire. The aim of this sub-study was to identify clinician-related factors that associated with caries risk assessment. Factor analysis was used for a group of items collected in the questionnaire. The factor analysis revealed three main constructs belonging to reported clinician routine caries risk assessment practices: clinical procedure during the first examination; child behaviour; and child's stressful life events and family circumstances. Further eight constructs were derived by factor analysis from data items on clinician perception of caries risk assessment including: Ecology; Plaque; Current caries; Past caries; Diet; Socioeconomic status; Fluoride exposure; and Dental behaviour.

Clinician accuracy (Se, Sp and Se+Sp) was used as the dependent variables in sub-study no. 4. The independent variables were clinician characteristics, clinician-related factors which were derived from sub-study no. 3 and children's characteristics which were obtained from the Child Dental Health Survey. Evaluating a child's stressful life events and family circumstance was associated with clinicians' accuracy in both bivariate and multivariate analysis. Clinicians who evaluated a child's stressful life events and family circumstance more frequently had a higher sensitivity and combined sensitivity and specificity than their colleagues. Clinician accuracy was also strongly influenced by the child's caries experience at the baseline examination. Caries risk assessment performed among children with higher level of caries experience was significantly more accurate compared with that observed among children with no level of caries experience at baseline.

In conclusion, the accuracy of caries risk assessment performed by clinicians in routine practice in SADS was comparable to that reported in other studies. Further staff

development in improving clinicians' understanding of a child's stressful life events and family circumstance can potentially improve the accuracy of caries risk assessment. However, the accuracy of caries risk assessment depended largely on the child's level of past caries experience. This finding indicated that among children with no caries experience, the current caries risk assessment is not adequate in predicting caries development. The study also revealed even if risk is correctly identified, and if more preventive treatment is allocated to high risk children, those children still developed significant amount of caries. The focus of future research should be on identifying approaches to limit that disappointing outcome.

Declaration

This thesis contains no material that has been accepted for the award of any other degree or diploma in any university. To the best of the candidate's knowledge and belief, the thesis contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

I give my consent to the thesis being made available for photocopying and loan if accepted for the award of the degree.

Signed:.....

Date:.....

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Chapter 1. Introduction

1.1 Background

Despite effective population oral health preventive programs in many Western countries, dental caries among children remains a major public health issue. Certain groups of children develop high levels of the disease that compromises their quality of life and places further burden on the healthcare system. It is prudent that those children be identified and appropriately targeted to prevent caries. This identification process – the caries risk assessment process – may act like a 'precision-guided' measure for those at-risk groups under coverage of other population preventive programs to further reduce the caries experience level in the population.

The caries risk assessment process is the identification of individuals who are at higher risk of developing future caries. Historically, efforts to predict caries susceptibility have always been in parallel with the development of modern dentistry (1988). However, caries was on almost a universal disease for most of the last century. Therefore, caries risk assessment received little attention. The recent dramatic reduction in caries experience in children as a result of population preventive programs including water fluoridation and its mimic fluoridated toothpaste has resulted in a dramatic shift in the population distribution of caries experience with increasing skewness of the disease, signalling the potential relevance of caries risk assessment.

Stamm and co-workers at the University of North Carolina summarised the epidemiological evidence that had been accumulated in the late 1970s and early 1980s which showed that the pattern of caries activity was not universally distributed but was concentrated in a relatively small subset of the general population (Stamm et al. 1988). The majority of the burden of caries experience occurred in 20–30% of the population and the remainder had low levels of caries activity (Spencer 1997). This observation suggested that individual-based preventive activities could be a useful complement to the existing broader population-based strategies such as water fluoridation and use of fluoride toothpaste. In terms of dental care delivery, preventive measures could be more effectively applied to high-risk individuals if they could be accurately identified.

A caries risk assessment strategy also attempts to address efficiency in resource allocation. This includes provision of more extensive preventive measures for individuals who are considered to be at higher risk of developing caries, as well as reducing unnecessary care for

children who are considered to be at low risk of developing caries. The basic concept is firstly to preserve resources and secondly to avoid over-treatments as discussed by Elderton (Elderton 1993). This is even more important in a modern society where dental programs are expensive and unnecessary over-treatment may be both unethical and wasteful of scarce public resources.

Since the 1980s, investigations in the area of caries risk assessment have focused on developing a tool that would be relatively simple to apply in identifying individuals at high-risk of future clinical caries activity. Formal caries risk assessment has been described as a four step process (Beck et al. 1988). The first two steps involve identification of risk factors and development of a multifactorial assessment tool or model that uses risk factors in a way that weighs them according to their level of influence. The third step is the assessment process, which entails application of a relevant caries risk model to individuals to identify their risk status. The fourth step is a targeting a tailoring the application of disease prevention regimens or treatment that matches the risk profile of each individual.

Accuracy of the Caries Risk Assessment (CRA) model is defined as the ability of that model to accurately predict caries for each individual. The accuracy of the model is measured by sensitivity and specificity or combined sensitivity and specificity.

To date, the first two aspects of CRA have received the most attention. A wide range of risk factors have been identified and numerous multivariate caries risk assessment models have been developed so as to assign a risk profile to individuals. For example, Caries Risk Assessment Tool has been proposed by Academy of Pediatric Dentistry (AAPD, 2010) or The California Dental Association advocated for the Caries Management by Risk Assessment program (Featherstone, 2003) However, these CRA models have not been as accurate as desired. Although substantial effort has been spent exploring the inclusion of new factors, observed accuracy of those models remained modest. Also Moss and Zero (Moss and Zero 1995) stated that the accuracy of the CRA systems has varied greatly depending on clinicians' characteristics, experience and their perception of caries risk assessment. However, to what extent factors have influenced the accuracy of the risk assessment remains under-researched.

Several studies have reported the clinicians' ability in dental programs to accurately identify risk for chronic dental diseases such as caries and periodontal disease (Alanen et al. 1994; Bader et al. 1999). These studies reported a reasonable level of validity, which was measured by combined sensitivity and specificity. They also reported a wide variation in clinician accuracy. These studies were conducted under special circumstances where examiners were dentists specially trained in using risk assessment criteria. Those circumstances may provide

a “proof of principle” for the validity of caries risk assessment practice. However, there is little information available about accuracy in routine practice by clinicians who are not specially trained in CRA. This information is important, as the accuracy of CRA in routine practice will have implications for oral health outcomes and cost of dental care.

The University of North Carolina’s well-designed caries risk assessment study emphasised that examiner judgement was one of the most useful factors in caries risk assessment (Disney et al. 1992). Moss and Zero also indicated that the clinician was the key component in the assessment of caries risk (Moss and Zero 1995). Clinicians are known to vary in their accuracy of caries risk assessment (Bader et al. 1999). However, clinician-related factors associated with CRA accuracy have not been intensively studied. It was suggested that variation in accuracy might be due to clinicians’ individual characteristics. These characteristics may affect their assessment of patients and subsequently, risk assessment and risk management (Moss and Zero 1995). These characteristics may include sex, age, training, experience, physical health or working environment. Another study of dental screening and referral of young children by paediatric primary care providers found that the confidence in screening abilities was significantly associated with referral (dela Cruz et al. 2004). The process by which clinicians used available risk information needs to be further understood (Moss and Zero 1995). Relevant information about this process would improve clinical outcomes of dental care. Therefore, clinician related factors that influence the accuracy of caries risk assessment need to be further assessed.

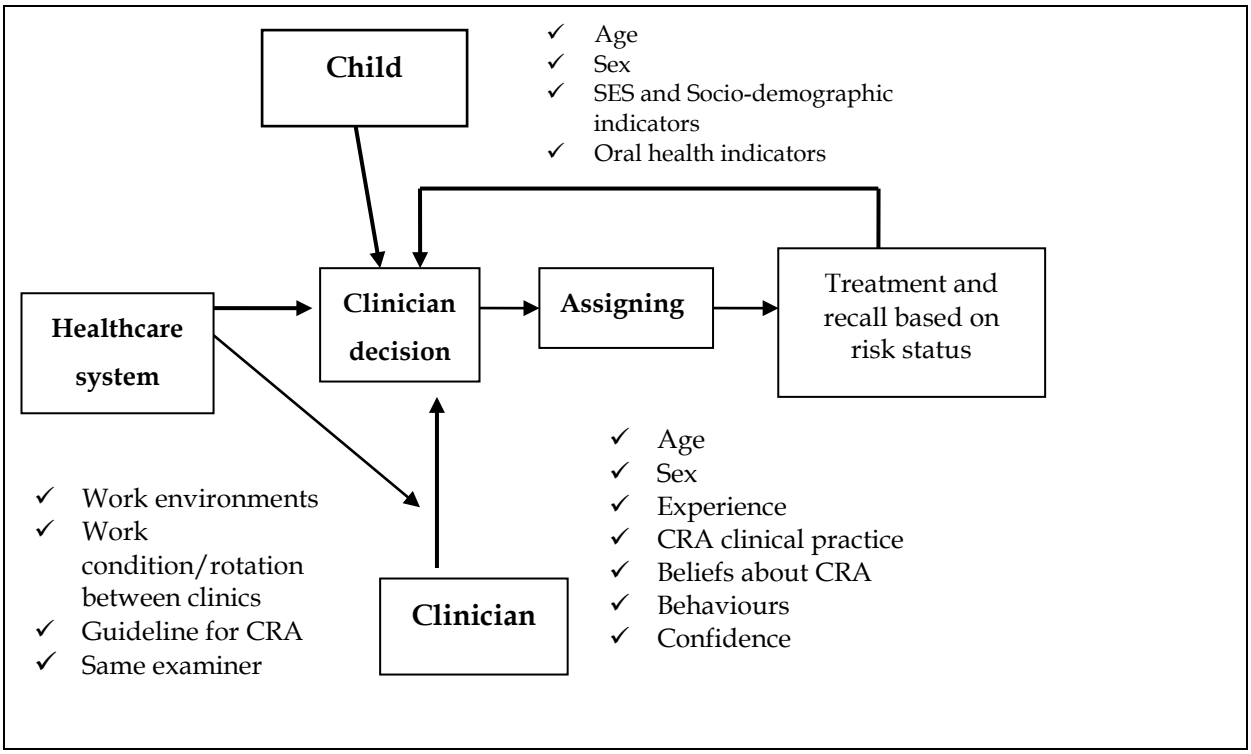


Figure 1.1: Schematic diagram of the risk assessment process and possible factors affecting the accuracy of this process

The process in which a clinician evaluates and assigns a risk status to a patient is schematically described in Figure 1.1. This process involves different but related information gathering aspects. The healthcare system provides physical availability of services to the patient. The system also provides facilities, training and regulation for practise by the clinician. Patients may vary in terms of socio-demographic and socioeconomic characteristics, attitude and values about oral health and indicators of oral health. Clinician may vary in terms of age and sex. They may also differ in practice beliefs, especially knowledge of and attitudes toward the caries assessment process. Clinicians' experience may also play a role in the process. In the context of physical availability of services, the clinician is expected to apply his/her best knowledge and experience to gather appropriate information from the patient. That information is then evaluated by the clinician who subsequently makes a decision based on both the patient information and practice guidelines. A risk status is then assigned for the patient. A treatment plan would then be developed tailored to the assigned level of risk. The patient would later be evaluated for the outcomes of the dental care provided.

In the early 1990s, the South Australian Dental Service (SADS) adopted the risk assessment strategy and implemented it as the Personalised Dental Care (PDC) programme (Chartier 1997). The risk classification (low-, medium- or high-risk of developing caries) is made for each child based on available individual and clinical factors. This classification of each child is dependent on the judgement of the dentists or dental therapists (combined as clinicians) who provide care for the child.

The Caries Risk Assessment strategy in the South Australian School Dental Service (SA SDS) entails designation of children as low-, medium- or high-caries risk, and provision of preventive and therapeutic services that are tailored for each level of risk and management of recall and maintenance care that is tailored for each level of risk with periodic re-assessment of risk-group designation. The risk classification made for each child was based on current and past caries experience, dietary habits, oral hygiene habits, fluoride exposure and social history. Children are routinely examined for their oral health and assigned to one of the three risk levels. Children receive restorative and preventive services depending on their risk status. Furthermore, children are recalled at different time interval based on their assigned risk. For example, low risk children are recalled at 18–24 month intervals while high-risk children are recalled after 6-10 months. Certain preventive services such as fissure sealants are more routinely provided to high-risk children as compared with low-risk children (Polster 2003). Available evidence for South Australian children has reported that clinicians based their caries risk judgement to a large extent on past caries experience. High

risk children have developed a greater amount of disease compared with low/medium risk children. Prevention treatment, oral hygiene instructions and oral health education were provided twice as often as to high risk compared with low/medium risk children (Polster A 2003). However, the accuracy of the South Australian school dental service CRA system in general and the accuracy of performance of individual clinicians in their attempts to predict caries have not been examined. In addition, knowing an individual clinician's accuracy would help to further explore factors that might influence the accuracy of the CRA. The understanding of such information would help to assess the effectiveness of a risk-based prevention strategy at a program level and further help to deliver the best dental care to children in South Australia.

1.2 Objectives

The main aim of this study was to evaluate the accuracy of caries risk assessment practised by individual School Dental Service clinicians by examining the relationship between caries risk at a baseline examination and subsequent caries development. Another aim of the study was to determine factors influencing the caries risk assessment process at a program level. The findings of the study could assist in developing a more appropriate caries risk assessment system, with the longer term goal of delivering more effective dental care to children.

Within the broad aims of the research, the specific objectives of the study were:

1. To compare caries experience and incidence of South Australian children assigned to different risk categories. *It was hypothesised that caries experience and incidence of caries was strongly associated with assigned risk status at baseline.*
2. To quantify the accuracy of clinicians' assessment of risk for dental caries in South Australian children. *It was hypothesised that the observed level of accuracy of caries risk assessment by South Australian School Dental Service clinicians in real life clinical conditions was comparable to that of specially trained clinicians reported by other related studies.*
3. To describe the caries risk assessment activities and perceptions among South Australian Dental Service staff. *It was hypothesised that caries risk assessment activities and perceptions varied among South Australian School Dental Service staff.*
4. To assess the association between clinician-related and child-related factors and the accuracy of caries risk assessment. *It was hypothesised that clinician-related and child-related factors had independent effects on the observed accuracy of caries risk assessment.*

1.3 Rationale of the study

The distribution of caries experience has been shown to be skewed with a small number of children experiencing the majority of caries in the population. Those children need to have more intensive care to reduce their risk of developing new disease. Other children are at low risk of developing caries, do not need such intensive care, and in fact. A caries risk assessment system that would effectively distinguish the levels of risk would be required to deliver appropriate care to children. The available caries risk assessment models are often confined to specific research conditions. Such conditions may limit generalisation of those models to the routine clinical dental practice. This study aimed to provide evidence of caries risk assessment in real life clinical conditions.

1.4 Structure of this thesis

This thesis consists of four sub-studies presented in four chapters: caries experience and incidence of South Australian children attending school dental services; the accuracy of caries risk assessment observed in the South Australian School Dental Service (SA SDS); a comprehensive survey of caries risk assessment practice among SADS clinicians; and a combined analysis to explore factors influencing the accuracy of SA SDS's caries risk assessment. Chapter 2 presents a summary of the current scientific literature relevant to the caries risk assessment process. Chapter 3 uses clinical data on some 72,000 children aged 5 to 15 years to report caries prevalence and experience and caries incidence and increment observed in the SA SDS child population. The distribution of caries among the three different risk categories is reported. Factors associated with caries experience and caries rate are explored. Chapter 4 uses the dataset from Chapter 3, to examine the accuracy of the SA SDS caries risk assessment by quantifying three measurements: sensitivity, specificity and combined sensitivity + specificity. This chapter also evaluates methodological issues associated with accuracy of caries risk assessment. Chapter 5 uses data from a survey of caries risk assessment practice among SA SDS clinicians to explore clinician-level factors influencing the caries risk assessment process. Chapter 6 combines both child and clinician datasets to examine the effect of clinician-related and child-related factors on accuracy. It first analyses unadjusted effects of individual child and clinician-related factors on the accuracy of caries risk assessment. It then considers the joint effects of child-related factors and clinician-related factors in multivariate analyses. The multivariate models were generated from both the child-based analyses and clinician-based analyses in Chapter 6. Each of the four chapters presenting the sub-studies (3, 4, 5 and 6) has separate sections presenting methods, results and a summary of the findings. Overall discussion and conclusions are presented in chapter 7. The Appendices contain copies of survey instruments and SA SDS caries risk assessment guidelines.

Chapter 2. Literature review

2.1 Conceptual model of caries and caries risk assessment

There has been a remarkable reduction of dental caries experience in Australia over the last half century. Children with no experience of having dental caries are no longer unusual. The use of fluoride in public water supplies, dentifrices and professional products, improvement of oral hygiene practices as well as increased access to dental care have played a major role in this dramatic improvement (Spencer 1997). However, dental caries still remains as one of the most prevalent chronic diseases in children (AIHW 2000). Dental caries is a multifactorial disease creating a need for a more comprehensive understanding of factors influencing children's experience of caries and more generally oral health (Fisher-Owens et al. 2007).

Population health research during the last few decades has been focusing on identifying medical and non-medical determinants of health. A growing parallel body of research has been focusing on identifying the dental and non-dental determinants of child and adult oral health. This field of research offers a basis on which to develop a conceptual model of the determinants of children's oral health, especially caries experience. This model provides a structure to identify genetic and biological factors, social and physical environment, health behaviours, and dental and general healthcare that influence child caries experience. Those factors may also be classified as individual-, family-, and community-related factors.

Internationally, recognition of the importance of the wider determinants of health has increased over the last 10 years. Consequently, models have been developed to identify the range of determinants and their influence on health. One such model, frequently used in international and national policy documents, is Dahlgren's policy rainbow, which describes the layers of influence on an individual's potential for health (Figure 2). It presents a social model for health, including fixed factors such as age, gender and genetic characteristics, and a set of potentially modifiable factors, both within and outside the individual's control. Whitehead (1995) describes these layers of influence in the context of action required by policy-makers to tackle health inequalities. The model prompts questions about how much the factors in each layer influence health, what is the feasibility of changing specific factors and what action would be required for the factors in one layer to influence those to which they are linked in others. From a research perspective, the model provides a useful framework for building analytical strategies to test existing theories on the health and health behaviour of young people and to support the development of new ones. The model

reinforces the need to build these strategies at the individual, environmental (including social interaction) and societal levels.

NOTE:
This figure is included on page 11 of the print copy of the thesis held in the University of Adelaide Library.

Figure 2: Social Model of Health – Dahlgren & Whitehead, 1991

Table 2.1: Domains of determinants of oral health according to level of influence

NOTE:
This table is included on page 12 of the print copy of the thesis held in the University of Adelaide Library.

Adapted from Fisher-Owens, (Fisher-Owens et al. 2007)

Similar to the Dahlgren and Whitehead model (**Error! Reference source not found.**), the conceptual model of the multi-level nature of oral health determinants has been recently discussed (Fisher-Owens et al. 2007). The previously dominant individually based models of assessment are now having additional levels of family and community factors. Individual children live within families; families are embedded in communities, which in turn are affected by the lower level structures. The community-level factors are upstream determinants of oral health. Factors such as dental healthcare system characteristics and health-related policies determine the level, availability, accessibility and quality of service available to individuals. Those factors must be accounted for in evaluating caries experience in the population.

Studies have shown that general health is correlated with oral health. Because the mouth is part of the body, a child's risk of oral disease cannot be separated from his/her risk of overall illness. Likewise, a child's risk of general illness and dental disease in particular cannot be isolated from family and community disease risk. Hence, any realistic model of children's oral health outcomes must incorporate a multi-factorial perspective (Fisher-Owens et al. 2007).

Recently, there is growing evidence to indicate that individual-level factors alone are insufficient in explaining the variation in caries experience among the population. The evidence suggests that oral health providers must look beyond the mouth of an individual in order to correctly identify factors that determine the oral health of the individual. The caries risk assessment process, as an extended screening/diagnostic process, is even more complex. Therefore, the caries risk assessment process must also be based on a multifactorial conceptual model of caries. Furthermore, evaluation of the caries risk assessment process must take into account individual- and family-based as well as healthcare-related factors such as service regulations and clinicians' characteristics. A considerable number of dental epidemiological studies in different countries have included various family-based characteristics in caries risk prediction models. However, the accuracy is still modest.

2.2 Overview of caries risk assessment models

Good caries prediction models have long been the target of dental researchers and practitioners alike as they strive to establish more efficient dental care delivery systems. As a consequence of the skewed distribution of dental caries, the usefulness of risk assessment, both for individuals and for groups of subjects, became evident. At the individual level, early identification of subjects with different levels of risk for caries can allow for planning appropriate preventive measures for individual needs. An equally important role of caries

risk assessment can be found at population level where risk assessment may help to increase the efficiency and to reduce the costs of dental care programmes.

Early prediction models usually explored the association of a single variable with caries development. More recently, multiple factors are frequently included in the models. This approach is sensible as caries is a multifactorial disease involving host, agent, and substrate factors. However, the search for risk factors for caries, which could be used in developing subsequent caries prediction models, has focused primarily on dental factors such as previous caries experience, or dietary pattern, or biological factors such as level of *Streptococcus mutans* or *Lactobacilli* in the plaque or saliva. Such an approach can be resource intensive while its accuracy in predicting caries development has been found to be limited ((Bowden 1997; Pinelli et al. 2001); Hausen 1997; Petti 2000). A considerable number of dental epidemiological studies in different countries have shown that various sociodemographic characteristics and some dental risk behaviours were also found to be associated with a higher risk of caries (Litt et al. 1995). Hence, there is also a need to explore the role of those factors in caries prediction models.

Nearly 20 years ago a risk assessment conference was held at the University of North Carolina. The Dental Caries Working Group concluded the following:

- clinical variables were stronger predictors than non-clinical variables
- past caries experience was among the most significant predictors
- other important variables were: socioeconomic status, fluoride exposure, tooth morphology and microbial agents (Newbrun 1990).

Another significant finding was that the clinician's judgement had the most significant role in predicting caries. However, clinicians involved in that study were specially trained for the research study. Therefore, they might be different from clinicians in everyday practice.

Over the last two decades numerous caries risk prediction models have been developed for different populations. The accuracy of these prediction models has been measured by their sensitivity and specificity scores. These scores will be introduced in detail in Chapter 4. Summaries of available studies in the literature are presented in Table 2.2.

Table 2.2: Summary of caries prediction models in children

Authors & publication years	Sample size	Age (years)	Follow-up time	Outcome	Multivariate modelling method	No. of variables studied	Significant variables			Se	Sp	Se+Sp
							Caries experience	Microflora	Host factors			
Grindefjord et al. (1996)	786	1	2.5 years	≥ 1 carious lesion	LRA (Stepwise)	31	NA	Mutans streptococci	Immigrant's background, mother's education, sugared beverages, candy	87	83	170
Li et al. (2002)	362	3–4	8 years	DMFT at follow up	LRA		Maxillary incisors			61.2	47.0	101.2
	362	3–4	8 years	DMFT at follow up	LRA		Maxillary molars			83.7	39.5	123.2
	362	3–4	8 years	DMFT at follow up	LRA		Mandibular molars			89.8	31.2	121
Holgerson et al. (2009)	55	2	5 years	any new enamel or dentine lesion	LRA		Baseline caries experience, clinician predicted caries	streptococci, Lactobacilli	Diet, oral hygiene, fluoride exposure,	46	88	134
Gao et al. (2010)	1782	3-6	1 year	Caries increment (Δ dmft>0)	LRA (Stepwise)		Baseline caries experience	Mutans streptococci, Lactobacilli	Age, father's education, using fluoride, dental visit	90	90	180
Demers et al. (1992)	302	5.8	1 year	≥ 1ds	LRA	9	Caries experience	Lactobacilli		78.3–81.8	77.4	155–159
Disney et al. (1992)	1099	6	3 years	≥ 4 DMFS	LRA (Stepwise)	38-43	DMFS, dmfs, predicted caries		Morphology	59	83	146
	1086	6	3 years	≥ 2 DMFS	LRA (Stepwise)	38-43	Predicted caries, examiner		Morphology	59	84	147
Beck et al. (1992)	1099	6	3 years	≥1 DMFS	LRA	38-43	dmfs, DMFS, predicted caries	Mutans streptococci	Race, morphology, brushing, dental visits	80	61	141
	1086	6	3 years	≥1 DMFS	LRA	38-43	Predicted caries, examiner	Lactobacilli	Parent education, fluoride tablet	66	78	144

Authors & Publication years	Sample size	Age (years)	Follow-up time	Outcome	Multivariate modelling method	No of variables studied	Significant variables			Se	Sp	Se+Sp
							Caries experience	Microflora	Host factors			
Steward & Stamm (1991)	914	6	2 years	≥2 DMFS	CART	38-43	dmfs, DMFS, permanent fissured sound surfaces		Morphology	64	86	150
	1024	6			LDA		dmfs (primary molar only) Predicted caries			62	67	129
Leverett et al. (1993)	319	6	1.5 years	≥ 1DS	LDA	8	Not applicable	Streptococci mutans lactobacilli	Salivary phosphate	83	82	165
Vanobbergen et al. (2001)	3,002	7–8	3 years	≥ 2DMFS	LRA	16	dmfs	Plaque index	Socio-demographic, brushing, diet, fluoride supplement use	59–66	65–72	124–138
Disney et al. (1992)	877	10	3 years	≥5 DMFS	LRA	38-43	DMFS, white spot lesions, sound permanent surfaces, referral caries, examiner	Mean plaque, Lactobacilli	Morphology	62	81	143
	912	10	3 years	≥3 DMFS	LRA		DMFS, white spot lesions, sound permanent surfaces, referral caries, examiner	Mean plaque, Lactobacilli		62	84	146
Beck et al. (1992)	967	10	3 years	≥1 DMFS	LRA		DMFS, white spot lesions, sound permanent surfaces, referral caries, examiner	Lactobacilli	Parents' education, fluoride tablets	84	54	138
	965	10	3 years				DMFS, white spot lesions, sound permanent surfaces, referral caries, examiner	Lactobacilli	Brushing, dental visits	76	71	147

NA: Not applicable
LRA: Logistic regression analysis; LDA: Linear discriminant analysis; CART: Classification and regression tree analysis;
Se: sensitivity; Sp: specificity

The prediction models were developed for different purposes. A model developed by Grindefjord and co-workers (Grindefjord et al. 1996) for very young children (aged 1 year) reported a high combined sensitivity and specificity score (170) when bacterial levels, dietary factors and socio-demographic factors were included in the model. Powel (Powell 1998) stated that "It is interesting to note that in these very young children socio-demographics factors were as successful in predicting caries development as clinical variables". The latter variables were the dominant factors in the models for older children. This statement is proved by a recent study among preschool children (aged 3 to 6 year-old) in Singapore by Gao el al. (Gao et al. 2010). Gao and others reported that screening /diagnostic examination models without biological tests achieved a sensitivity and specificity of 82% and 73% (respectively); with biological tests, models achieved the sensitivity and specificity of 90% and 90% (respectively). However, in a report by Holgerson et al. (Holgerson et al. 2009), the validity of the CRA model was unsatisfactory in preschool children with a sensitivity and specificity of 46% and 88% (respectively).

The model proposed by Demers and co-workers (Demers et al. 1992) was designed for the purpose of developing an economically feasible caries screening /diagnostic examination for young children with a mean age of 5.7 years. Their final model, which included caries experience (dmfs) and *lactobacilli* counts, resulted in a combined sensitivity and specificity score of 159 when predicting for children who would develop at least one new carious surface. More than 80% of caries susceptible children were identified with this model. Socio-demographic variables were not significant to this model.

The investigation of prediction models for older children and adolescents was more extensive. Researchers from the University of North Carolina conducted an "exhaustive exploration of predictor variables and statistical methods"(Powell 1998). Several reports were published from data collected from two groups of more than 4000 children. These studies identified dmfs and DMFS as the strongest predictor variables. However, the accuracy of these models in predicting caries prone children was only moderate with combined sensitivity and specificity ranging from 140–160. Predicted caries by clinician was also shown to be the one best single predictor for future caries. These studies were landmarks for investigation into the configuration of outcome variables and statistical methods (Stewart and Stamm 1991; Beck et al. 1992; Disney et al. 1992).

Two other notable studies involved children in the mixed dentition stage (Steiner et al. 1992; Leverett et al. 1993). Leverett and co-workers focused more on the predictive ability of bacterial factors and host factors. The outcome of interest was the development of new carious lesions. *Mutans streptococci, lactobacilli*, and salivary phosphate were excellent short term predictors of caries development (sensitivity + specificity = 165) (Leverett et al. 1993).

Recently a study was done among Flemish 7 year old children in order to establish a reliable screening /diagnostic examination method for caries prediction and to identify risk factors that could be used to predict future caries development in the permanent first molar at the age of 10 years. The risk status which was assigned by examiners, oral health status at baseline, oral hygiene level, oral health behaviours and socio-demographic factors, were included in the models. Vanobbergen and co-workers (2001) found brushing less than once a day, dmfs, buccal and occlusal plaque indices and daily use of sugar containing drinks between meals were highly significant in predicting caries increment in permanent first molars at the age of 10 years. The logistic regression analysis provided a sensitivity of 59–66% and specificity of 66–72%. The authors also stated that none of the socio-demographic variables had enough predictive power at a community level to be useful for identifying caries susceptible children (Vanobbergen et al. 2001).

There might be an argument that most caries risk prediction models had been developed in low caries prevalence countries and that might be a reason for a relatively low sensitivity score. Recently, an eight-year longitudinal cohort study of caries risk prediction was conducted in China, where caries prevalence ranged from 67% to 86% among pre-school children, which aimed to predict caries in permanent teeth from caries in primary teeth (Li and Wang 2002). The study found a statistically significant association between caries prevalence in primary dentition and permanent dentition. Children having caries in primary teeth were three times more likely to develop caries in their permanent teeth. The authors suggested that the caries status of primary teeth could be used to predict caries in permanent teeth. A model with caries on primary molars provided very high sensitivity (89.8%). However, the combined sensitivity and specificity of models with deciduous caries experience alone range from 104% to 124% and were far lower than the suggested desirable combined score (160%).

It is also noted that there is a distinction between assessing population risk for targeted public health programmes (which should take into account how accurately the CRA model can perform) and the approach to individual patient management in the clinical setting (Tickle 2002).

2.3 Potential factors influencing the caries risk assessment process

This section focuses on exploring potential factors influencing the caries risk assessment process. This involves consideration of factors in two main areas: clinician characteristics and children's characteristics.

2.3.1 Clinician characteristics

Clinicians are known to vary in their practice of dentistry. This variation has been reported in the literature in a wide variety of aspects. For example, female dentists are more likely than male dentists to work in a Community Dental Service. Women are also more likely to work part-time and specialise in orthodontics or paediatric dentistry. More women than men take career breaks and the reasons for taking career breaks differ between male and females. Women take longer career breaks on average (Newton et al. 2000). This phenomenon suggests that clinicians might also vary in their caries risk assessment as well.

There have been numerous studies reporting the range of dental practices associated with clinician characteristics. The provision of a number of services were found to be lower for female compared to male dentists (Spencer AJ 2003), and this has been linked to child rearing and part-time work patterns (Brennan et al. 1992). A study of the nature of self-reported changes in general dental practice in a sample of English general dental practitioners could not find any trend related to the sex of the dentist. However, younger dentists have been found to have high reported levels of change in educational activities, staff development and communication with patients (Watt et al. 2004). A study of treatment recommendations for proximal surfaces of primary molars found that dentists aged 60+ years were more likely to recommend treatment for smaller lesions. Composite resins were recommended infrequently. However, dentists in the 60+ dentist category were somewhat more likely to recommend composite resins than younger dentists.

Dentists in the 40–49 age range were the most likely to recommend stainless steel crowns (Hanes et al. 1992).

In the United Kingdom, regional variations in dental care have been associated with the supply of services, with extraction of teeth associated with fewer dentists per capita (Ashford 1978). In Australia, the availability of dentists is considerably lower in regional areas compared with major urban locations. It was reported that patients from urban locations received more cleaning and scaling services than those from rural or remote locations. Those from remote locations received more extractions and fewer fillings than those from urban locations (Brennan and Spencer 2002). However, there is little information reported on the association between clinician characteristics and caries risk assessment practices, perceptions and beliefs.

Clinician judgement of caries risk assessment:

Clinician judgement (or assigned risk) of caries was reported as the strongest predictive factor contributing to caries risk assessment models (Disney et al. 1992; Vanobbergen et al. 2001). Saemundsson et al (1997) found that clinicians' judgement was strongly associated with caries experience such as proximal DMFS/dmfs in predicting caries risk for South Australian children. A study in children and adolescents at public dental clinics in Sweden reported that dentists in Uppsala County (Sweden) mainly base their caries risk assessment on past caries experience (Sarmadi et al. 2009). Other factors significantly associated with the risk assignment were: exposure to professionally applied fluoride and sealants, country of birth, frequency of tooth brushing and exposure to fluoridated water (Saemundsson et al. 1997). Other than these reports, the question of what reasons underpin the clinicians' judgements is little researched. What single factor or combination of risk factors is used by a clinician to form their judgement needs to be researched further. There might be an association between clinicians' caries risk assessment and their characteristics, practices, perception or beliefs on caries risk assessment. These potential associations require further research.

2.3.2 Children's characteristics

Children's characteristics are fundamental sources of influence on the accuracy of the caries risk assessment process. Caries is a multi-factorial disease. There are many risk indicators or risk factors that have been found to be associated to caries development. Factors can be assigned to groups such as:

- ✓ socio-demographic, socioeconomic and behavioural factors
- ✓ microbiological and salivary factors and
- ✓ physical and environmental factors.

These groups of factors were described at the Workshop of Caries Risk Assessment in 1990 (Newbrun 1990).

Factors from each of these groups were associated with dental caries and their interrelation is highly complex. These groups of caries risk indicators or factors will be discussed in detail.

2.3.2.1 Socio-demographic and socioeconomic risk factors for dental caries

Dental epidemiological surveys in Australia have investigated the relationship between dental caries and socio-behavioural or cultural characteristics. Two demographic variables commonly used have been sex and Indigenous identity. Typically, schoolgirls have a slightly higher caries experience than boys (Armfield et al. 2004). The difference in the sex-specific caries experience is small and it can be attributed to the early eruption of permanent teeth among girls putting teeth at risk for caries for longer period of time. The association between Indigenous and non-Indigenous children and caries appears clearly in some studies. Indigenous children in Australia aged 4–10 years were more than twice as likely to have caries in their deciduous dentition as non-Indigenous children of the same age. Similarly, 6 to 14 year old Indigenous children were more than one and a half times more likely to have decay in their permanent dentition than their non-Indigenous counterparts (Jamieson et al. 2007).

Children's socioeconomic status (SES) is another variable associated with caries. SES is a complex construct that has been operationally defined many different ways. Most dental studies use, as a measure of SES, ordinal indexes of social class, frequently expressed as low, middle or high. Recent data showed the relationship between increased caries and lower social class. In general, there is an inverse association between caries and SES levels. In other words, caries experience is higher among children of low social class both for primary teeth and for permanent teeth (Burt 2005; Slade et al. 2006).

There have been relatively few studies that have considered either psychological or sociological characteristics as risk factors for caries in children. Most social epidemiological studies of caries in children have included a few psychological, sociological or SES variables (Tang et al. 2005). Some of these variables have been used in a multivariate analysis such as the education of the child's mother or father, family type and size (Mattila et al. 2000). However, success of using these variables in caries risk assessment has been considered as limited.

Locker (Locker 2000) concludes that there is a difficulty in measuring socio-economic factors. These differences arise because there is no commonly accepted definition of deprivation and no theoretical framework to guide the selection of appropriate indicators. As a result, indicators of deprivation are sometimes direct and sometimes indirect. They may incorporate variables representing conditions or states and/or the types of individuals subject to those conditions or states and it might be the major hinderer of using socioeconomic variables in caries risk assessment. The conventional measures of socioeconomic status used in these studies, such as social class and household income, have a number of weaknesses. However, those area-based deprivation indices are sensitive to variations in oral health and oral health behaviours and can be used at an area level to identify small areas with high levels of need for dental treatment and oral health promotion services.

2.3.2.2 Dietary risk factors for dental caries

A major behavioural factor studied in the attempt to assess risk of dental caries is the consumption of potentially cariogenic foods, especially sugars. Sreebny (Sreebny 1982) concluded that sugar (total consumption as well as the frequency of intake) contributes to dental caries. The relationship between sugar consumption and caries in developed countries has long been viewed as linear: the more sugar the population consumed and the greater the frequency of that consumption the greater the severity of caries. However, in more recent years, this linear relationship has become unclear (Burt et al. 1988). Most studies have found only a moderate or weak relationship between sugar consumption and caries. Burt concluded in his review paper that persons with high sugar consumption usually have higher counts of cariogenic bacteria than people who have low consumption. However, the relationship is not linear and high bacteria counts do not necessarily lead to an outcome of clinical caries (Burt and Pai 2001). Sugar

consumption is likely to be a more powerful indicator for risk of caries in persons who do not have regular exposure to fluoride. However, measures of sugar consumption have been included in multivariate caries prediction models for children with limited success in increasing predictive ability (Petti and Hausen 2000). The problem of finding a clear link between caries and dietary factors could be a consequence of difficulties in measurement.

Recently, a longitudinal study in Iowa found that higher sugared beverage consumption such as soda pop and powdered beverage concentrates made with sugar were associated with progression of dental caries (Levy et al. 2003; Warren et al. 2009).

2.3.2.3 Oral hygiene and dental caries

One of the major behavioural factors commonly studied in assessing the risk of caries is the oral hygiene status of individuals. It is speculated that poor oral hygiene will lead to higher caries experience. The available evidence does not demonstrate a clear and consistent relationship between oral hygiene level and dental caries prevalence (Newbrun 1990). In some studies, brushing frequency with fluoridated toothpaste was one of the important factors for the development of caries in school children (Mattila et al. 2001; Vanobbergen et al. 2001). However, the association with tooth brushing frequency was more likely due to use of fluoridated toothpaste. This phenomenon was first described by Ainamo & Parviainen in 1979. Ainamo & Parviainen studied the occurrence of plaque, gingivitis and caries as related to self-reported frequency of tooth brushing in fluoridated areas in Finland and concluded that water fluoridation effectively reduces caries whereas regular tooth brushing, as performed by the general public, is of value for general oral hygiene and the prevention of periodontal disease, but seems to have no restricting effect whatsoever on the progression of dental caries (Ainamo and Parviainen 1979).

2.3.2.4 Previous caries experience

The most consistent factor observed in caries risk assessment studies has been past individual caries experience. The association between past and future caries experience has been found to be strong for groups in a population, but past caries experience has weak predictive power for individuals. It was reported that adolescents and children who develop lesions early in life or who have several lesions, tended to develop more

lesions later in life (Helfenstein et al. 1991; Powell 1998; Zero et al. 2001; Li and Wang 2002).

Caries experience in the primary dentition was among the strongest predictors of caries increment in the permanent dentition in many studies (Steiner et al. 1992; Mattiasson-Robertson and Twetman 1993; Grindefjord et al. 1995; Grindefjord et al. 1996; Vanobbergen et al. 2001; Li and Wang 2002; Skeie et al. 2006; Tagliaferro et al. 2006). Primary teeth emerge early in childhood, therefore their caries experience might show a predicted future picture in permanent teeth. The use of deciduous caries experience as an indicator to predict the risk of future caries development has an obvious advantage in that an individual is identified before decay is apparent in permanent teeth (Skeie et al. 2006).

However, in the situation of an already high background of caries experience, past caries experience might not have a high power in predicting future caries. Those children may have a reduced caries increment because most of their teeth have already been affected and few teeth are left at further risk of caries attack (Graves 1990). Therefore, it is important to control for the number of surfaces or teeth at risk for new caries in caries risk assessment research. On the other hand, in a situation of low background caries experience such as in Australia, using caries experience as the main predictor in predicting future caries might miss the amount of caries which will develop among those in the initial no caries experience sub-population (Batchelor and Sheiham 2006).

Milsom et al. (2008), studying the incidence of dental caries in the primary molar teeth of children aged 3 to 6 years attending general dental practices, reported 5 to 6 times difference in the incidence of new cavities between caries-free children and children with caries. With children who were initially caries-free but who developed caries during the study period, their risk of developing new caries was similar to those who had caries experience at the first examination. It was concluded that once children contract the disease, it progresses at a similar rate. This study also suggested that children with or without caries experience should be considered as two different populations as it has implications for care strategies applied to each population (Milsom et al. 2008).

2.3.2.5 Protective factors

2.3.2.5.1 Fluoride

A series of classical epidemiological studies by Black and Dean established the relationship between brown stained teeth, fluoride levels in natural water supplies and the caries experience of population groups. The finding that around 1.0mg/L of fluoride in water resulted in a much lower caries prevalence without unsightly fluorotic enamel led to the fluoridation of community water supplies (Dean 1942; Burt 2005) Currently fluoridated water is available to nearly three quarters of the Australian population (Armfield 2006). Water fluoridation is available in many other countries. In general, the caries prevalence in fluoridated communities is much lower than had been observed prior to fluoridation. Data in the Australian state of Queensland showed that caries rates were significantly lower among children in Townsville where the water has been fluoridated since 1965 than in Brisbane, both in the deciduous dentition (32 to 55 per cent fewer tooth surfaces affected) and permanent dentition (20 to 65 per cent fewer tooth surfaces affected) (Slade et al. 1996). Living in a fluoridated area was associated with a lower level of caries experience. The protective effect of water fluoridation has been documented in major systematic reviews (NHMRC 1991; CDC 2001; MRC 2002; NHMRC 2007).

Fluoridated toothpaste has been widely used for over 3 decades and remains a benchmark intervention for the prevention of dental caries. A Cochrane sytematic review concluded that the effect of fluoride toothpaste increased with higher baseline levels of D(M)FS, higher fluoride concentration, higher frequency of use, and supervised brushing, but was not influenced by exposure to water fluoridation. There is little information concerning the deciduous dentition and the adverse effects (fluorosis) (Marinho et al. 2003).

2.3.2.5.2 Fissure sealants

Extensive research has shown a caries protective benefit from fissure sealants (Ahovuo-Saloranta et al. 2004). In the South Australian School Dental Service, fissure sealants are a protective method of choice in the clinic for high-risk children. Children who receive fissure sealants may be protected from new caries increments. It was likely that children who were correctly assigned as high-risk at baseline would not develop as much new caries after receiving extensive prevention and being recalled at a shorter time interval. This situation may confound the accuracy of the caries risk assessment. It is not possible to quantify the amount of new caries that has been prevented by fissure sealants. Nevertheless, it is important to assess this confounding effect as presented in Chapter 4.

2.3.2.6 Microbiological and salivary factors

2.3.2.6.1 Microbiological factors in dental caries:

Caries is a bacterial disease. Bacteria are a necessary condition for caries occurrence. *Streptococcus Mutans* and *Lactobacilli,* the main bacteria that are involved in the caries process, are normal constituents of the flora in most mouths. Caries is considered as a bacterial ecologic imbalance rather than as an exogenous infection (Burt 2005).

At a population (group) level, total bacterial count has been related to caries experience (Kohler et al. 1995), but this relationship was not strong. At an individual level, bacterial count is a poor predictor of future caries (Hausen 1997; Petti and Hausen 2000).

2.3.2.6.2 Salivary factors

No variation in a single salivary component in a healthy population has been shown to be a significant predictive factor. Nevertheless, decreased salivary function, as manifested by extreme xerostomia, is a consistent predictor of high caries risk (Newbrun 1990).

2.4 Measurements of caries increment in longitudinal research

A number of different approaches to describing dental caries incidence and increment can be used. The advantages and limitations of each individual index are summarised by Broadbent (Broadbent and Thomson 2005) below.

2.4.1 DMF increment

Each subject's increment is calculated by subtracting their caries experience score (such as DMFT or DMFS) observed at baseline from their corresponding score observed at follow-up. This index is quick and simple to calculate. However, it does not allow for reversals or recurrent caries.

Equation 1: $$\text{DMF increment} = \frac{\sum_{i=1}^{n} (DMF_{t1} - DMF_{t0})}{n}$$

2.4.2 Crude caries increment (CCI)

Beck and co-workers (Beck et al. 1995) described crude caries increment using surface-by-surface comparison of baseline and follow-up data. This method is more accurate than caries increment as it includes the change in status for each surface. This index counts the change from unerupted; sound; and fissure sealed tooth at the baseline examination to decay or filled or missing tooth in the follow-up examination. The disadvantages of the CCI are that it is more difficult and time-consuming to compute and it does not allow adjustment for reversals.

Equation 2: $$CCI = \frac{\sum_{i=1}^{n} (\text{Events where surface sound at time 0 but decayed or filled at time 1})}{n}$$

2.4.3 Net caries increment (NCI)

Most recent longitudinal studies of dental caries have reported net caries increment (NCI). The calculation is similar to that for crude caries increment. However, with net caries increment, reversals are included so they can be subtracted from the crude increment. This is based on the assumption that examiners made an equal number of false positive and false negative errors (Slade and Caplan 1999). This method assumes that time between baseline and follow-up examination is the same for all subjects. Therefore, in a study that uses clinical data when time interval between baseline and

follow-up examination is different for each subject, this index may not be relevant. More details on the calculation of NCI are available in Chapter 3.

2.4.4 Adjusted caries increment (ADJCI)

Beck and co-workers (1995) described a method to calculate adjusted caries increment (ADJCI). This ADJCI calculation is built upon the premise that 'examiner' reversals are more common than 'true' reversals, and may be regarded as a pragmatic compromise between the NCI and CCI. It is calculated as the crude increment multiplied by the number of surfaces with caries experience at both examinations, divided by the total number of surfaces with reversals or caries.

Equation 3: $$ADJCI_i = Y_{2i} \times \frac{y_{4i}}{y_{3i} + y_{4i}}$$

Where: $ADJCI_i$= adjusted caries increment for the i^{th} subject

Y_2: number of surfaces with new caries (crude increment) for the i^{th} subject

Y_3: number of surfaces with caries reversal for the i^{th} subject

Y_4: number of surfaces with caries experience at both examinations for the i^{th} subject

The ADJCI has been previously used in epidemiological investigations of caries in older people (Beck et al. 1995; Thomson et al. 2002; Chalmers et al. 2003). It has been suggested that the ADJCI should not be used when the number of reversals is <10% of the number of positive caries increments, because, if the percentage of reversals is small, the reversals might well be the result of random recording errors. In such cases, the use of the NCI is recommended (Beck et al. 1995).This method does not mention the difference in time between the two examinations. Furthermore, the ADJCI is analytically complex (Broadbent and Thomson 2005).

2.4.5 Incidence

The incidence of caries over a period may be computed simply as follows:

Equation 4: $$\text{Incidence} = \frac{\text{Number of participants experiencing a caries event between two assessments}}{\text{Total number of participants}} \times 100$$

This measure is simple to understand, particularly for lay people. However, this measure only gives a somewhat broad view of caries rate, as it does not distinguish

between individuals who experience only one event and those who experience a high number of events during the same period (Broadbent and Thomson 2005).

2.4.6 Incidence density (ID)

It has been stated that incidence density is a measure of the 'force of morbidity' of a disease, or a person-time incidence rate (Broadbent and Thomson 2005). Where a disease event (or loss from/entry into the study) occurs, it is assumed that this occurred at the halfway point between assessments. This is relevant for the calculation of the number of years of exposure (Broadbent and Thomson 2005).

Incidence density (ID) is commonly calculated at the group level as follows:

Equation 5:
$$\text{Incidence Density} = \frac{\text{Total number of new cases of disease during the study period}}{\text{Total number of person years of participation in the study}}$$

In dental research, incidence density can be calculated at both the individual level and the participants' group level. For the individual 'ith' participant, incidence density is calculated as follows. This equation below calculates the incidence density of caries at surface level.

Equation 6:
$$\text{Incidence Density}_{\text{mouth i}} = \frac{\text{Total number of new events of disease during the study period}_{\text{i}}}{\text{Total number of surface years of participation in the study}_{\text{i}}}$$

For the group level, incidence density of caries at surface level (ratio in population) is calculated as follows:

Equation 7:
$$\text{Incidence Density}_{\text{(population)}} = \frac{\text{Total number of new events during the study period among the group}}{\text{Total number of surface years of participation in the study of the whole group}}$$

A crucial assumption required when calculating incidence density in studying dental caries is that any event (such as loss or eruption of a tooth or new lesion) is assumed to have occurred at the half-way point between assessments. Despite the assumptions required, incidence density is perhaps the most accurate technique of measuring the rate at which new events occur, as it accounts for caries increments relative to the number of

surfaces present, and the time that these surfaces are at risk of caries (Broadbent and Thomson 2005).

2.4.7 The use of incidence density in dental health research

The two different indexes of caries development measurement (net caries increment and incidence density) used to evaluate caries preventive measures have been compared (Kallestal and Stenlund 2003). The authors reported that the differences between the two analytical methods were small. However, when incidence density was used as the outcome variable in logistic regression models, the analysis was more sensitive, yielding more significant association (Kallestal and Stenlund 2003).

Unlike other areas of health research, incidence density is rarely used in dental epidemiological studies (Broadbent and Thomson 2005). This method has been used in a small number of studies (Lawrence et al. 1996; Caplan et al. 1999; Slade and Caplan 2000; Kallestal and Stenlund 2003). It has been suggested that great value could be gained from the more frequent use of incidence density in analyses involving dental caries (Broadbent and Thomson 2005). This study aimed to explore the use of incidence density as the main measurement of caries development.

2.5 Indicators of risk prediction models accuracy

2.5.1 Sensitivity and specificity

Test	Disease	
	Yes	**No**
Positive	a (true-positive)	b (false-positive)
Negative	c (false-negative)	d (true-negative)

Sensitivity and specificity calculation

$$\text{Sensitivity} = \frac{a}{a+c}$$

$$\text{Specificity} = \frac{d}{b+d}$$

Several formal definitions describe a test's performance in terms of the relationship between test results and the presence or absence of actual disease. Four mutually exclusive categories arise:

1. A test is considered as true-positive when it correctly identifies subjects who actually have the disease as positive (cell a).

2. A test is considered as true-negative when it correctly identifies subjects who actually have no disease as negative (cell b).

3. A test is considered as false-negative when it incorrectly identifies subjects who actually have the disease as negative (cell c).

4. A test is considered as false-positive when it incorrectly identifies subjects who actually have no disease as positive (cell d).

The accuracy of a test is usually stated in terms of sensitivity and specificity. Sensitivity refers to the proportion of all individuals with the disease correctly identified by the test. In other words, it gives the probability of correctly identifying a diseased individual. Specificity is the proportion of individuals without the condition whom the test will

correctly identify as not having the condition. It is the probability of correctly identifying a non-diseased individual.

Consequently, a sensitivity of 100% indicates that the test will correctly identify all those individuals with the condition in question and a specificity of 100% indicates that all individuals without the disease will test negative.

Sensitivity and specificity are used widely in medical as well as dental research to evaluate accuracy of screening/diagnostic tests. The predictive power of any predicted model can also be measured by sensitivity and specificity. Alanen and co-workers reported a sensitivity of 44% and specificity of 90% in predicting future caries development within 1 year for Finnish children (Alanen et al. 1994).

More details on the calculation of sensitivity and specificity are documented in Chapter 4.

2.5.2 Receiver Operating Characteristic curve (ROC curve.)

A ROC curve is a plot of the true positive rate against the false positive rate for the different possible cut points where above which we consider the test to be abnormal and below which we consider the test to be normal of a test.

A ROC curve demonstrates several things:

- It shows the trade-off between sensitivity and specificity (any increase in sensitivity will be accompanied by a decrease in specificity).
- The closer the curve follows the left-hand border and then the top border of the ROC space, the more accurate the test.
- The closer the curve comes to the 45-degree diagonal of the ROC space, the less accurate the test.
- The area under the curve is a measure of test accuracy.

Figure 2.3 shows three ROC curves representing excellent, good, and worthless tests plotted on the same graph. The accuracy of the test depends on how well the test separates the group being tested into those with and without the disease in question. Accuracy is measured by the area under the ROC curve (AUC). An area of 1 represents a

perfect test; an area of 0.5 represents a worthless test. A rough guide for classifying the accuracy of a screening/diagnostic test is the traditional point system.

AUC: 0.90–1.00 = excellent

AUC: 0.80–0.90 = good

AUC: 0.70–0.80 = fair

AUC: 0.60–0.70 = poor

AUC: 0.50–0.60 = fail

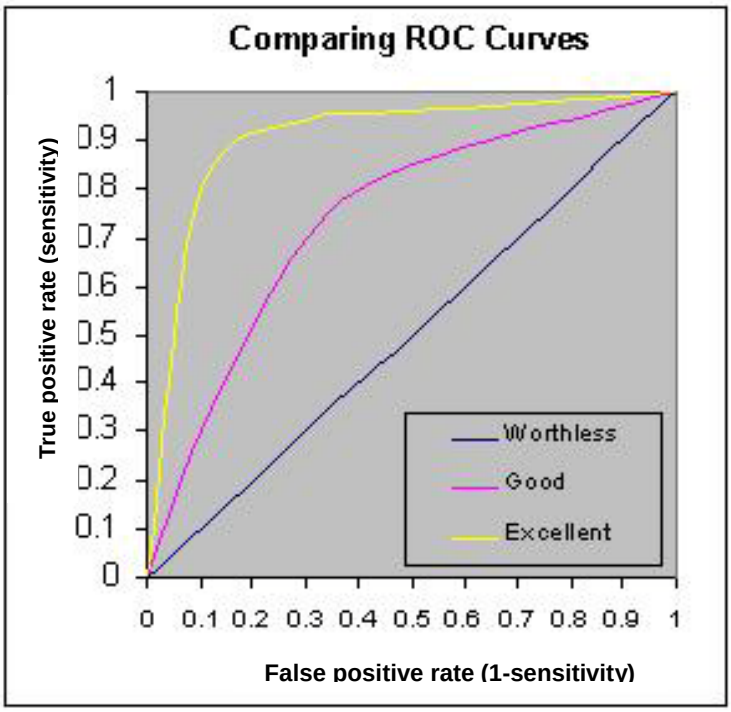


Figure 2.3: Comparing ROC curves

2.6 Caries experience and dental care of South Australian children

2.6.1 Prevalence and severity of dental caries among Australian children

Since 1977 there has been ongoing activity in Australia through the Australian School Dental Scheme Evaluation Program and the Child Dental Health Survey to monitor dental caries in children throughout the country (Carr 1982; Carr 1983; Carr 1988; Armfield et al. 2004). Comprehensive data on dental caries among Australian children have been collected evaluated and reported annually.

In general, the trend of dental caries in Australian children is similar to that of other Western countries (Marthaler 2004). The prevalence and severity of dental caries in Australian children decreased dramatically in the second half of the 20th century (Spencer et al. 1994). The DMFT score of 12 year old Australians was as high as 12 teeth in the 1950s, with a very high proportion of untreated decay. Almost all children of this age were affected by caries (Barnard 1956). The prevalence and severity of caries in children have decreased since the introduction of water fluoridation and the use of fluoride toothpaste in Australia. This trend continued through to the early 1990s, when the mean permanent DMFT score of 12 year old children was 1.2 teeth. There were very few permanent teeth missing due to caries in this age group. The trend of deciduous caries in 6 year old children followed a similar trend. The mean deciduous dmft of 6 year old children was around 2.0 in the early 1990s (Davies et al. 1997).

The caries experience in Australian children continued to decline in the first half of the 1990s (Armfield et al. 2003). However, the decreasing trend was significantly slower, and reached a plateau in 1996 with a dmft score of 1.45 among 6 year old children and 1.69 among 8 year old children. Some slight increases in mean deciduous dmft scores were observed in the second half of the last decade in children aged from 5 to 9 years. In the year 2000, the mean dmft of Australian children aged six and eight years was 1.65 (SD 2.73) and 1.82 (SD 2.61), respectively (Armfield et al. 2004). The per cent of caries-free children of those two ages were 56.6% and 51.1%, respectively. Around 65% of 12 year old children did not have caries in their permanent teeth and the mean permanent DMFT score of 12 year old children in 2000 was 0.84 (SD 1.60), however, by the year

2003/2004 the percentage of children with no caries experience goes down to 57.5% and mean DMFT among 12 year old children increase to 1.03 (Armfield et al. 2010).

2.6.2 School Dental Service in South Australia

The South Australian School Dental Service was established in 1922 and until the 1960s it provided services only to children in country areas of the state who did not have ready access to private dental practitioners. Treatment was provided by dentists and dental assistants (nurses) using mobile clinics and transportable equipment. Dental therapists were introduced to the school dental team in 1969 to reduce the cost of care and extend services to more children.

The School Dental Service grew rapidly in the 1970s due to additional Commonwealth funding and by 1981 it started offering dental care to all pre-school and primary school children in South Australia. By 1988, the School Dental Service (now part of the South Australian Dental Service) was able to offer dental care to all South Australian children up to the age of 16 years. In 1990, the service was offered to all high school students under the age of 18 years. By the late 1990s a small co-payment was introduced to SA SDS high school children.

South Australia currently has a highly developed dental programme for the provision of dental care for school children. The service is provided mainly by dental therapists. Children are invited to enrol in the SA SDS when they start school at age five years. Enrolment can occur at any time throughout their schooling. Children are able to access any clinic in the SA SDS system. Coverage of the SDS system is over 65% of the state's primary school child population (Slade 2004). Between 2002 and 2005, the period used for the current study, dental care was fully subsidised for children in primary school (aged 5–12 years, approximately).

Most of the clinicians who work for SADS are dental therapists. The dental therapy program was introduced in 1969 and the scope of practice is limited to children under 18 years of age. Further information on SADS clinicians will be presented in chapter 5.

2.6.3 Caries risk assessment in the School Dental Service

In the late 1980s, the concept of an individualised risk assessment and management strategy for caries in children had been presented to the South Australian SDS (Spencer, personal communication 2005). This strategy aimed to design an appropriate treatment

plan and service-mix based on an individual child's risk of developing disease. At each dental examination, the children would be classified as having either high-, medium- or low-risk of developing caries. The assessment would be based on past history and the current oral health status as determined at the current oral examination. Once the risk status of a child had been assigned, appropriate services (treatments or preventions) and recall interval would be determined for the individual.

The SA SDS adopted the proposed risk assessment strategy and implemented it as the Personalised Dental Care (PDC) programme (Chartier 1997). The risk classification made for each child was to be based on social, fluoride exposure and clinical factors. Clinical guidelines for classification of risk status were developed within each SADS health region. The decision regarding risk level was made by the dentist or dental therapist who assessed and provided care for the child. CRA classification dictated the recall period for each child.

The main objectives of the PDC programme were to:

1. design a series of strategies to individually assess a patient's risk status
2. design an appropriate treatment plan and service-mix, based on a thorough clinical diagnosis
3. provide treatments and preventive services in line with the individual's clinical diagnosis of need and assessment of future risk for developing further increments of dental disease and
4. recommend an appropriate individual recall interval for each child, appropriate for their circumstances, based on clinical judgement and experience(Chartier 1997) .

With the implementation of this programme, operators' time was expected to be optimised with more time for high-risk patients and relatively less for low-risk patients. The PDC also served as a resource allocation mechanism between children in the SDS as more preventive measures involving fluoride, fissure sealants, diet counselling, oral hygiene instruction and any other appropriate measures to reduce their risk status could be targeted to those who needed it most.

One of the aims of the risk assessment strategy was to maintain good oral health of the low-risk individuals while trying to improve the oral health of high-risk children by providing more oral care through more frequent visits. Since the introduction of the PDC

programme, the recall period for each child ranges from several months to 18–24 months depending on the level of risk assigned to that child.

With the increasing number of children enrolled in the SDS and the notion that a six-monthly dental check-up was not appropriate for every child, a risk assessment strategy was considered the most appropriate strategy to allocate resources to individual children.

This PDC programme has previously been evaluated for a number of purposes. It was reported that the extent of caries risk assessment practised by clinicians increased from 72.0% of the total examinations in 1991 to 93.5% of all recorded examinations in 1996 (Chartier 1997). Another study found that children in the high-risk group had a five times higher DMFS score than that of the low-risk group (Saemundssson et al 1997). In a study conducted in 1998/1999, Polster and Spencer found high risk children developed a greater amount of caries (net caries increment=0.47) compared to low and medium risk group (with net caries increments of 0.17 and 0.34 respectively) (Polster A 2003). They also reported that the high-risk group received twice the amount of treatment, and that preventive services such as fissure sealants are more routinely provided to high-risk children as compared with low-risk children (Polster A 2003).

2.6.4 Effect of recall interval on service delivery and oral health – a background to the Personalised Dental Care programme

Patients attending for a dental visit may or may not already have oral disease. The clinician examines the patient then forms a diagnosis and prognosis, and a risk assessment, to determine the intensity of treatment and/or the interval at which the individual must be re-assessed.

The effect of the interval between visits on oral health can be complex (Beirne et al. 2007). The frequency with which patients should attend for a dental check-up and the potential effects on oral health of altering recall intervals between check-ups have been the subject of ongoing international debate for several decades. Although recommendations regarding optimal recall intervals vary between countries and dental healthcare systems, six-monthly dental check-ups have traditionally been advocated by general dental practitioners in many developed countries (Beirne et al. 2007). However, this

recommendation has been criticised as being unnecessary or even harmful for some patients (Sheiham et al. 1985; Reekie 1997). It may be safe to extend this interval for some without any negative effect on oral health.

Concerns about the clinical effectiveness and cost-effectiveness of recall intervals have led to research on clinician behaviour concerning appointment assignment. The optimal length of the recall interval, i.e. how often to attend for a dental check-up, for the preventive maintenance of oral health in both children and adults has been the subject of debate (Sheiham 2000; Lahti et al. 2001). The recall interval debate has also been prompted by conflicting evidence on the beneficial and harmful effects of regular attendance and by diverging interpretations of that evidence (Beirne et al. 2007).

It has been reported that regular dental attendance was associated with improved oral health and that regular attendees had less untreated disease, lower rates of tooth loss, higher numbers of functioning teeth, and were less likely to suffer acute symptoms and to require emergency treatment (Sheiham et al. 1985; Murray 1996; Beirne et al. 2007). In addition, it has recently been reported that regular attendees suffered significantly less from the prevalence and severity of social and psychological impacts of dental health problems (Richards and Ameen 2002).

On the other hand, it has also been argued that regular attendees do not experience any major advantage over irregular attendees with respect to their total disease experience and that regular visits do not help to prevent the onset of further disease (Sheiham et al. 1985; Beirne et al. 2007). Concerns have also been expressed about the financial implications for patients associated with regular attendance, including time foregone in attending appointments, and the enhanced possibility for over-treatment associated with regular attendance (Sheiham et al. 1985; Reekie 1997; Beirne et al. 2007).

The effectiveness of this six-monthly recall interval has increasingly been questioned in light of recent changes in the epidemiology of dental diseases and in the interests of cost-containment and judicious use of scarce resources (Sheiham 2000). Over the last two decades, the prevalence and severity of dental caries in many developed countries has decreased dramatically and the rate of progression of the disease has slowed (Beirne et al. 2007). Caries experience in many populations also shows a skewed distribution with a majority of children and adolescents having little or no disease, whilst for a minority the caries experience remains relatively high (Hausen 1997; Spencer 1997). In particular, it

has been consistently observed that caries experience is generally more extensive and severe in lower socioeconomic status groups (Burt 2005). These factors have led to suggestions in a number of countries that the notion of a 'fixed and universal' recall interval is inappropriate and that recall intervals should be patient specific (Riordan 1997; Lahti et al. 2001; Beirne et al. 2007).

The School Dental Service in South Australia has, for example, adopted a practice of choosing recall intervals based on the clinician's assessment of a patient's risk of acquiring new disease (Riordan 1997; Saemundsson et al. 1997). This system was based on a classification of patients into 'low' or 'medium' or 'high' risk groups before determining a recall. Guidelines on recall intervals in the School Dental Service in South Australia state that high risk children should be seen 10-15 monthly and low-risk children 18–24 monthly.

The rationale underpinning the risk-based recall approach is that it should be possible to extend recall intervals for those individuals classified as low risk without incurring any undue detrimental effect on their oral health status and ultimately reducing resource consumption by these children (Beirne et al. 2007). Resources then would be available to facilitate relatively shorter recall intervals for individuals with higher risk of having new disease that is those having greater need for care. Studies carried out in the public dental services in Norway have suggested that appropriately individualised recall intervals (between 18 to 24 months) for low risk children and adolescents can reduce resource consumption without adversely affecting the outcome of care (Wang et al. 1992). Tan and others (Tan et al. 2006) concluded that based on the low annual caries increments, yearly dental examination intervals can safely be extended to 2-yearly intervals or even longer. Such longer recall intervals would help improve resource allocation. Resources saved by extending recall intervals can be redirected to the small proportion of children with higher disease levels. This will help render more school children dentally fit and reduce inequalities in oral health.

To summarise, the caries risk assessment process, as being practiced in the SA SDS, is to determine the level of care an individual would need in order to improve and maintain oral health. This important role of the caries risk assessment requires it to be properly developed and practised.

Chapter 3. Relationship between dental risk classification and observed dental caries rate among South Australian school children

3.1 Aims

This sub-study aims to describe dental caries experience and its rate of development during the study period and to examine the relationship between risk classification and dental caries.

The target population of this sub-study was children attending the South Australian School Dental Service (SA SDS). Data were collected annually through an ongoing survey: the Child Dental Health Survey.

3.2 Child Dental Health Survey

The Child Dental Health Survey is an ongoing national surveillance survey for children's dental health in Australia. The objectives of the survey are to document the annual prevalence and severity of dental caries among 5–17 year old children and to monitor the trend of caries over time. The survey is managed by the Australian Research Centre for Population Oral Health (ARCPOH) at the University of Adelaide. In South Australia, where the sample was drawn for this study, the target population was all children enrolled in the SA SDS.

Children are invited to enrol in the SA SDS when they start school at the age of 5 years. Enrolment can occur throughout school years. Children are able to access any clinic in the SA SDS system. Coverage of the SDS system is over 65% of the state's primary school child population (Slade 2004). Between 2002 and 2005, the period used for the current study, dental care was fully subsidised for children in primary school (aged approximately 5–12 years).

At enrolment and any recall visit, children are examined by a qualified dental therapist or, less frequently, a dentist, employed by SA SDS. Since 2000, data were recorded electronically on a computerised dental chart (EXACT/TITANIUM) which captured surface level caries experience for each primary and permanent tooth. Dental decay was recorded at the level of enamel cavitation and could be detected wholly by clinical

examination, radiographs or both. Clinical examinations were made using visual criteria, and clinicians elected whether or not to additionally use compressed air and/or an explorer. Bitewing radiographs were used when needed, based on the judgment of the examining clinician. The system is managed centrally by the South Australian Dental Service's Evaluation and Research Unit and transferred to ARCPOH periodically for inclusion in the Child Dental Health Surveys.

3.2.1 Study sample

The sampling frame for this study was children aged 5 to 15 years examined in the SA SDS between 2002 and 2005. All examinations of such children were exported from EXACT/TITANIUM, yielding over 170,000 records. The dataset included a unique identifier number for each child, permitting linkage of data from first and subsequent examinations of the same child during the period.

From the total of 171,732 dental examination records during the 2002–2005-period, 72,619 children aged 5–15 years had at least two archived examinations with a time interval between two examinations greater or equal to six months (Figure 3.1).

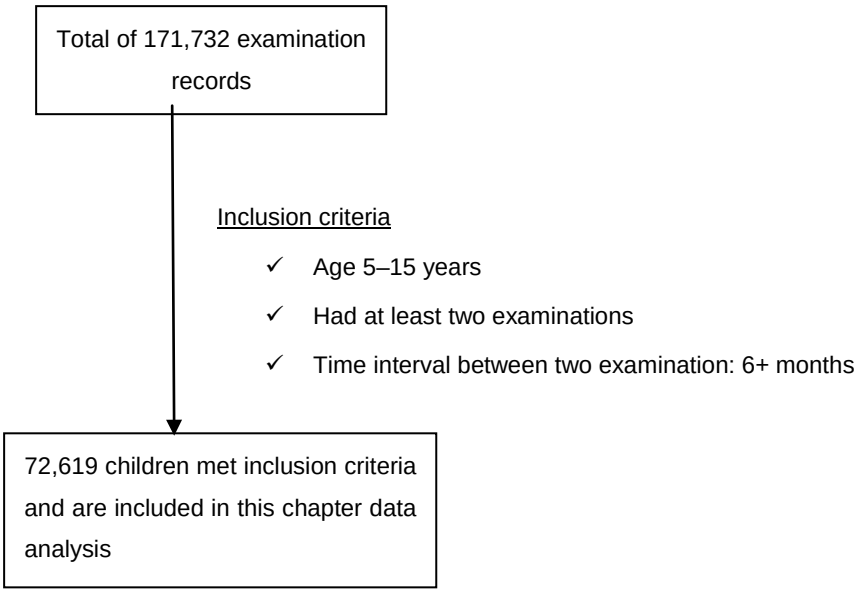


Figure 3.1: Study sample

Data items and data collection

Information recorded during each examination and exported from EXACT/TITANIUM included: caries experience of each tooth surface; child's risk status, as classified by the examining clinician; and socio-demographic indicators such as sex, residency location (postcode), country of birth, healthcare concession card status and Indigenous status. Based on children residency postcode, water fluoridation status was assigned.

3.2.1.1 Caries data

3.2.1.1.1 Dental caries measurement

Data describing dental caries experience were collected by dental therapists or dentists who performed routine clinical examinations of children at SA SDS clinics. The criteria and procedures for examinations have been used by school dental services for the Child Dental Health Survey and are largely unchanged since 1977 (Carr 1982; Carr 1983; Carr 1988; Armfield et al. 2004). Written instructions for the survey were provided to clinical staff describing the assessment of caries experience and recording procedures. The instructions were based on the World Health Organization (WHO 1998) and the National Institute of Dental Research (Beltran-Aguilar et al. 2002) criteria. Individual tooth surfaces were classified as decayed, filled or missing because of caries. An additional code designated surfaces that contained fissure sealants and that were otherwise sound and not restored. Five surfaces were coded for all teeth. For the deciduous dentition, additional guidelines were used to distinguish between teeth missing due to caries and teeth that might have been exfoliated (Palmer et al. 1984). The clinical staff were trained in assessment and recording of dental caries following the instructions. However, there were no additional procedures for calibrating examiners.

3.2.1.2 Dental caries risk measurement

Risk status of children was assigned by examining clinicians at each examination. Children were given one of three levels of risk: low-risk, medium-risk and high-risk. Risk status was assigned based on SDS guidelines and clinician's perception and experience of caries risk. The risk assessment criteria were based on historical and current oral health status as determined at the current oral examination. Other factors considered during examination were child's age, medical and social history, dietary

habits, sugar intake, oral hygiene, child and parent's motivation, fluoride exposure and salivary characteristics (see Appendix 1).

Clinicians used the designation of children as low-, medium- or high-caries risk to develop treatment plans tailored for each level of risk. This included provision of preventive and therapeutic services and the management of periodic recall and maintenance care.

3.3 Data management

3.3.1 Data combination

A total of ten SPSS data files exported from EXACT were transferred into SAS files and appended to each other for data management and analysis.

3.3.2 Selection of archived examination records

The first task during data management was to select from the appended dataset each child's first examination in the four year period ("baseline" examination). Dates from that baseline examination were used to further select a subsequent follow-up examination, if one existed. The first available visit by a child that was made 6 or more months after his/her baseline examination was chosen as the follow-up examination for that child. Data from the baseline and the selected follow-up examination were used for the analysis. Children with only one visit during the study period were excluded from the analysis.

3.4 Computation of indicators of dental caries

In this study, deciduous caries indices were calculated only for children aged 5–10 years; permanent caries indices were computed for children aged 6 years or older. Deciduous and permanent indices of decayed, missing or filled tooth surfaces (dmfs and DMFS) were calculated for the cross-sectional baseline examination. Two indices of caries rate during the follow-up period were calculated: net caries increment (NCI) and then caries incidence density (ID).

3.4.1 Computation of dmfs and DMFS indices

Tooth surface level data from baseline examinations were used to compute deciduous decayed, missing or filled tooth surfaces (dmfs/DMFS). Deciduous dmfs was calculated for children aged 5 to 10 years and permanent DMFS was calculated for children aged 6 to 15 years. The dmfs and DMFS scores were calculated as sum of decayed, missing or filled tooth surfaces due to caries of the deciduous or permanent dentition. For each child total number of dmfs +DMFS was calculated.

3.4.2 Computation of net caries increment

Net caries increment (NCI) is the most commonly used method in dental longitudinal studies to adjust for errors due to examiner misclassification or recording. Surface-specific dental caries data from the baseline and follow-up examinations were used to compute net caries increment. This calculation was based on a DePaola grid (Table 3.1) (DePaola 1990). This was based on the assumption that examiners made an equal number of false positive and false negative errors (Slade and Caplan 1999).

Table 3.1 Convention used to define events (De Paola grid) for caries increment computation

	Follow-up status of same surfaces						
Baseline status	Number of events						
	S	**D**	**F**	**M**	**U**	**P**	**FS**
Sound (S)	0	1	1	1	x	0	0
Decay (D)	-1	0	0	0	x	-1	0
Filled (F)	-1	1	0	0	x	-1	0
Missing due to caries (M)	x	x	x	0	x	x	x
Un-erupted (U)	0	1	1	1	0	0	0
Pre-cavitated (P)	0	1	1	1	x	0	0
Fissure sealant (FS)	0	1	1	1	x	0	0

0= no increment; 1= increment; -1= reversal; X= errors

This caries increment matrix is a method used for enumerating events by creating pairs of observations. Each pair of observations consists of baseline and follow-up status recorded for each tooth surface. The matrix was used to calculate separate caries increments for the coronal surfaces of deciduous and permanent teeth. In the deciduous dentition, there were 100 surfaces with paired observations per individual: five surfaces on each of 20 teeth. In the permanent dentition, there were 140 surfaces with paired observations per individual: five surfaces on each of 28 teeth (third molars were not enumerated). A symmetrical matrix was then created that accounts for all potential transitions between examinations that could have taken place at the surface level (DePaola 1990). The row and column headings for each matrix (Table 3.1) list clinical categories of dental caries status included in the examination protocol. Columns

represent the status observed at baseline and rows represent the status observed at follow-up. In this study, a 7x7 matrix was constructed that used mutually exclusive codes for sound, decay, filled, missing due to caries, un-erupted, pre-cavitated/white spot lesions and fissure sealant. The number in each cell of the matrix indicates one of four events: dental caries initiation (+1), dental caries reversal (-1), no event (0) and missing value (X). This calculation was based on the method that described by Slade and Caplan (1999). In this study, pre-cavitated lesions were considered as sound surfaces.

Examiner misclassification or recording errors can result in two types of errors: observed caries initiation when in reality it did not occur (false increment) or caries reversal when in reality it did not occur (false decrement). One way to correct for these errors is through calculation of net caries increment, where each child's number of reversals is subtracted from his/her number of initiations. This method assumes that the number of errors due to false increment is equivalent to the number of errors due to false decrements and the resulting net caries increment represents the corrected estimate of true caries activity (Slade and Caplan 1999).

3.4.3 Computation of caries incidence density rate

Broadbent and Thomson (Broadbent and Thomson 2005) summarised the computation and usage of caries increment in dental research as below. While net caries increment makes corrections for examiner misclassification and recording errors, the index is simply a count of affected surfaces, and therefore it does not make adjustment for two other factors that affect risk of dental caries: a) the number of surfaces at risk during the period of observation, and b) the period of time during which surfaces are at risk of developing caries. In order to make those adjustments, this study additionally calculated children's caries incidence density rate.

Incidence density (ID) is used in medical research as a measure and is a person-time incidence rate. Incidence rate is the rate at which new events occur in a population. The numerator is the number of new events occurring in a defined period and the denominator is the population at risk of experiencing the event during this period. Incidence density at person level can be calculated as follows (Equation 1).

Equation 1: Incidence density calculation in medical research

$$\text{Incidence density (ID)} = \frac{\text{Number of new disease events during the study period}}{\text{Total number of person years at risk in the study}}$$

Incidence density has been used in studies of dental caries since the late 1990s (Beck et al. 1997; Caplan et al. 1999). For dental studies, incidence density may be calculated at the person level and tooth surface level. Person-level calculation is similar to that described above. Incidence density at tooth surface-level is calculated as follows:

Equation 2: Incidence density of caries incidence at tooth surface level

$$\text{Incidence density (ID)} = \frac{\text{Number of new carious events during the study period}}{\text{Total number of surface years at risk in the study}}$$

Consistent with the life table method, any caries-related event (for example, decay, filling) or any change that affects time at risk (such as tooth loss for reasons other than caries or tooth eruption) is assumed to occur at the half-way point between examinations. Incidence density is considered to be the most accurate technique of measuring the rate at which new events occur, as it accounts for caries increments relative to the number of surfaces (or teeth) present (Broadbent and Thomson 2005), and the time that these surfaces are at risk of caries. It is particularly useful when measuring caries among children or older adults when the number of teeth and surfaces at risk differs substantially over time and among individuals.

In this study, incidence density was calculated for deciduous dentition, permanent dentition and the combined both deciduous and permanent dentitions. The method used the same DePaola grid (Table 3.1) to count the numerator number of events. A related grid (Table 3.2) was used to enumerate surface-years at risk.

Table 3.2: Convention used to enumerate surface-years at risk computation

	Follow-up status of same surfaces Time at risk						
Baseline status	**S**	**D**	**F**	**M**	**U**	**P**	**FS**
Sound (S)	1	0.5	0.5	0.5	x	1	1
Decay (D)	0.5	0	0	0	x	0.5	0.5
Filled (F)	x	0	0	0	x	x	x
Missing due to caries (M)	x	x	x	0	x	x	x
Un-erupted (U)	0.5	0.5	0.5	0.5	0	0.5	0.5
Pre-cavitated (P)	1	0.5	0.5	0.5	x	1	1
Fissure sealant (FS)	1	0.5	0.5	0.5	x	1	1

0: no time at risk; 0.5: half time at risk; 1: all time at risk; X: Errors

Table 3.3 shows a detailed example of calculating incidence density for three individuals and the group of three. In this example, child A had 10 teeth present at baseline in 2002. She had one caries-related event observed six months later (0.5 year interval). That event was assumed to have occurred during the mid-point of the 6-month observation period, thereby reducing the number of surface-years at risk by 0.5 years divided by 2 equal to 0.25 years. The number of tooth surfaces at risk was 10 teeth by 5 surfaces per tooth multiplied by 0.5 years and subtracting 0.25 years equal to 24.75 surface-years at risk. Incidence density for Subject A therefore was calculated by dividing number of events (one) by number of surface-years at risk (24.75) and multiplying by 100 (4%).

- Incidence density for child B (10 teeth, 1.5 years follow-up with no event) was 0%.
- Incidence density for child C (20 teeth, 2 events in 2 years) was 1%.

Incidence density for the group of three children was calculated by summing all events (three) and dividing by the total number of surface-years at risk of the three children (297.75). The calculated result, expressed as a percentage, was 1.0 per cent. The group's rate of caries can be interpreted as one newly affected surface, on average, per 100 surfaces at risk per year.

Table 3.3: Example of incidence density

Subject & number of teeth	Time interval	Number of events	Surface-years at risk	Incidence Density (% surfaces/year)
Child A 10 teeth	0.5 years	1	$10 \times 5 \times 0.5 - \frac{0.5}{2} = 24.75$	$\frac{1}{24.75} \times 100 = 4\%$
Child B 10 teeth	1.5 years	0	$10 \times 5 \times 1.5 = 75$	$\frac{0}{75} \times 100 = 0\%$
Child C 20 teeth	2 years	2	$20 \times 5 \times 2.0 - 2 \times \frac{2}{2} = 198$	$\frac{2}{198} \times 100 = 1\%$
Total		**3**	**297.75 surface-years**	

$$\text{Incidence density (whole group)} = \frac{3 \text{ events}}{297.75} \times 100 = 1\% \text{ surfaces/years}$$

In the mixed dentition, caries incidence density was calculated by combining deciduous and permanent dentition.

Table 3.4 shows a detailed example of combined deciduous and permanent caries incidence rate calculation. Child D who was nine years old had 10 deciduous teeth and 12 permanent teeth. During a 1.5 year period, child D developed one decayed surface (one event) in the deciduous dentition. There was no event in the permanent dentition. Total number of events in child D across mixed dentition was one, with a total of 164.25 surface-years at risk, therefore the incidence density rate was 0.6%. This means that this child had 0.6 newly-affected surfaces per 100 surface-years at risk.

Table 3.4: Example of incidence density for mixed dentition

Subject & number of teeth	Time interval	Number of events	Surface-years at risk
Child D 10 deciduous teeth	1.5 years	1	$10 \times 5 \times 1.5 - \frac{1.5}{2} = 74.25$
Child D 12 permanent teeth	1.5 years	0	$12 \times 5 \times 1.5 = 90$
Child D	1.5 years	1	74.25+ 90 = 164.25

Equation 8: $\text{Incidence density (ID)} = \frac{1}{164.25} \times 100 = 0.6\%$

For children aged 11 years or older, increment in the deciduous teeth was considered as 0. For children aged five years, increment in the permanent teeth was considered as 0.

3.5 Analytical plan

For this sub-study, the analytical plan was to generate univariate statistics to describe baseline characteristics of the sample, and to evaluate the association between clinician's designation of child's caries risk at baseline ("risk classification") and the child's subsequent rate of caries incidence density ("observed caries rate"). The analysis also compared baseline characteristics of children who met the inclusion criteria for this sub-study with characteristics of all children examined during the study period.

3.5.1 Dependent variables

Combined incidence density was the dependent variable in the analysis. The frequency distribution of combined ID was plotted and summary statistics were generated to describe its mean and variation. Mean values and 99% confidence intervals (99%CI) were calculated for the cohort of all children and for subgroups, classified according to explanatory variables (described below). Differences in ID between subgroups were evaluated statistically using comparison of 99%CIs. The study sample was large and hence, the probability of Type 1 error was elevated. Therefore, 99%CIs were used to compare between groups.

Confidence intervals for decay, missing and filled (dmfs/DMFS) index were calculated using SAS PROC MEANS. Confidence intervals of incidence density were calculated using a Poisson regression using SAS PROC GENMOD.

Proportions were compared between sub-groups using Chi-square test. Significantly different sub-groups are denoted with appropriate level of significance by means of p values.

3.5.2 Explanatory variables

The primary explanatory variable of interest was the clinician's risk classification recorded at the baseline examination for each child, recorded at three levels: low; medium; and high-risk. Socio-demographic characteristics of children recorded routinely during the examination were used as additional explanatory variables:

- sex

- age in years, and classified into three age groups: 5–7 years (mainly deciduous dentition), 8–12 years (mixed dentition) and 13–16 (permanent dentition)
- Indigenous status (whether or not the child was of Aboriginal or Torres Strait Islander descent)
- eligibility for government health care (whether or not the child was covered by a Healthcare Card or Pensioner Health Benefits card administered by the federal government's welfare agency, Centrelink)
- residential location (Adelaide or the rest-of-state)
- fluoridation status was assigned based on level of fluoride in public water supplies. Data were available from a database archived at ARCPOH. Areas where the fluoride level was 0.7ppm or higher were considered as fluoridated. Other areas were considered as non-fluoridated
- country of birth (Australia or elsewhere) were collected for every child who enrolled in the School Dental Service.

Baseline clinical findings were also used as additional explanatory variables:

- permanent DMFS and deciduous dmfs count and classification into two categories:
    - caries free, if sum of permanent and deciduous caries equal 0 and
    - having caries experience, if sum of DMFS and dmfs greater than 0
- presence of one or more fissure sealants in permanent teeth.

3.6 Results

3.6.1 Caries experience and risk status at baseline

From the total of 171,732 dental examination records during the 2002–2005 period, 71,619 children aged 5–15 years had at least two archived examinations with a time interval between two examinations greater or equal to 6 months. Data from those children were included in the analysis for this study. Less than 10% of children had only one visit. Those children were mainly aged 14–15 years at baseline.

The majority of children were born in Australia and were non-Indigenous (Table 3.5). There were more children in metropolitan Adelaide than in rural South Australia. Some 18% of children had a healthcare card, signifying that their family met the low-income requirement for government-assisted health care.

In general, the study sample that met the inclusion criteria for the study was similar in terms of sex distribution and residential location compared with the initial sample of children examined in the SA School Dental Service. Despite the difference in age distribution between the two groups (Table 3.6), the study sample had a similar prevalence of caries compared with the initial sample.

The study sample had a lower proportion of children with a healthcare card. Some 17.8% of children in the study sample had a healthcare card compared with 21.9% in the initial sample.

Table 3.5: Distribution of children by sociodemographic characteristics

	Study sample (n=71,619)	Initial sample (n=171,732)
Sex	(n=71,619)	(n=171,732)
Boy	50.8	50.9
Girl	49.2	49.1
Healthcare card	(n=71,619)	(n=171,049)
Yes	17.8	21.9
No	82.2	78.1
Born in Australia	(n=62,379)	(n=150,833)
Yes	95.7	94.2
No	4.3	5.8
Indigenous identity	(n= 60,002)	(n=146,182)
Indigenous	2.1	2.8
Non-Indigenous	97.9	97.2
Residential location	(n= 67,342)	(n=160,940)
Adelaide	66.5	66.4
Other areas	33.5	33.6
Caries free at baseline	(n=71,619)	(n=171,732)
Yes	53.4	52.5
No	46.6	47.5

All variables have a small number of missing values, n indicates effective sample for a variable, percentage indicates column percent.

The selected sample aged from 5–15; the initial sample from 4–18 years

Consistent with the previous finding of age-group differences, the average age of children in the study sample was 0.5 years less than the average age of children in the initial sample. It follows that caries experience of children in the study sample differed from the initial sample, although in different directions for the deciduous and permanent dentition (Table 3.6). Mean dmfs of children in the study sample was higher than that of the initial sample while mean DMFS of the study sample was lower than that of the initial sample (0.86 and 0.66 respectively).

Table 3.6: Caries experience of the selected and initial sample

	Study sample (aged 5–15 years)	Initial sample (aged 4–18 years)
Age at baseline, mean (99%CI)	9.00 (8.96-9.02)	9.62 (9.60-9.64)
dmfs, mean (99%CI)	2.41 (2.36-2.46)	2.09 (2.06-2.12)
DMFS, mean (99%CI)	0.66 (0.64-0.68)	0.86 (0.85-0.87)

The groups differed at p<0.01 if 99%CIs overlap
The selected sample aged from 5–15; the initial sample from 4–18 years

At the baseline examination, there were 15,049 (21.0%) children who were classified as low-risk, 41,473 (57.9%) as medium-risk and 15,097 (21.1%) children were in the high-risk for caries group (Figure 3.2). Some cases have missing information on level of assigned risk status at baseline.

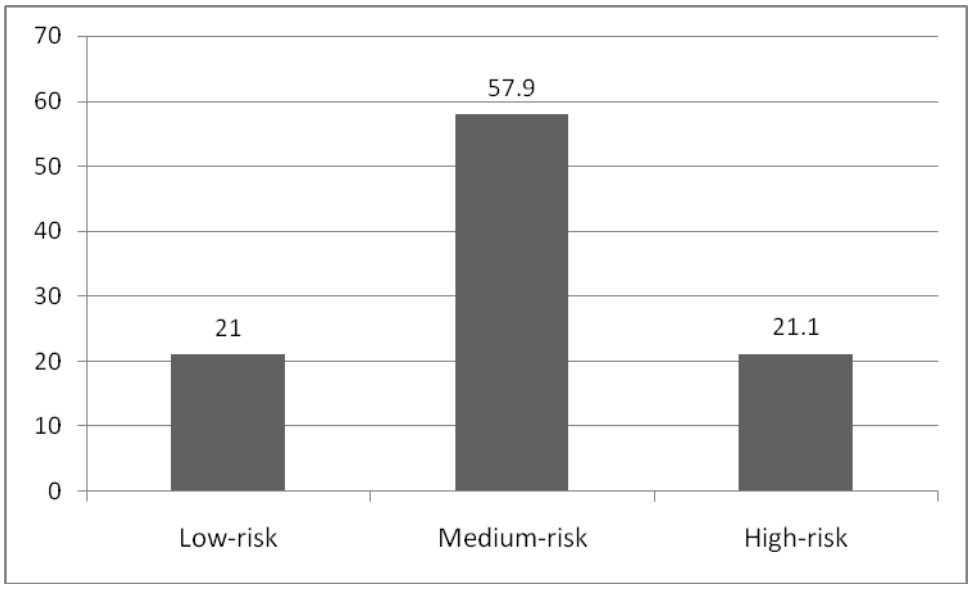
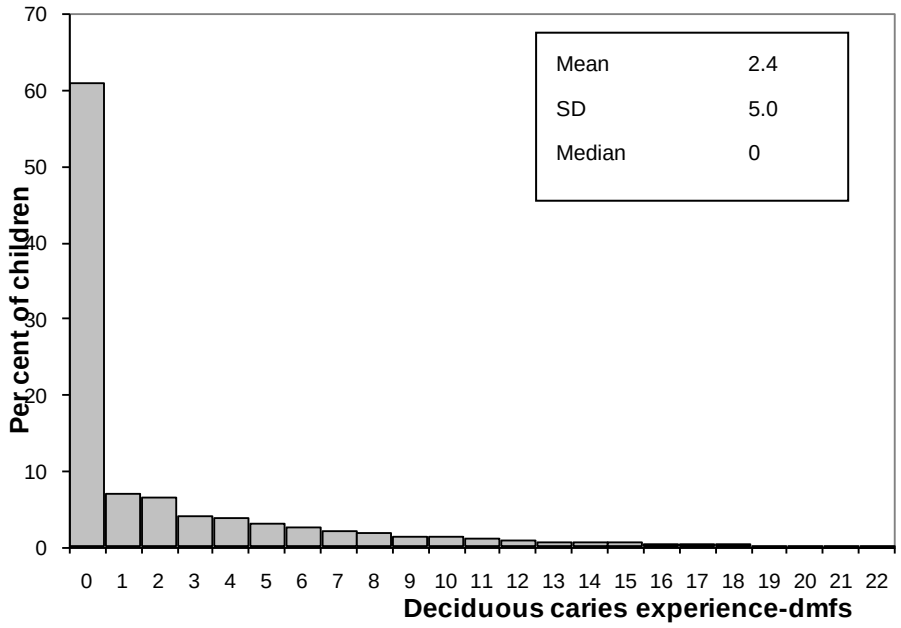


Figure 3.2: Percentage of children by risk classification at baseline

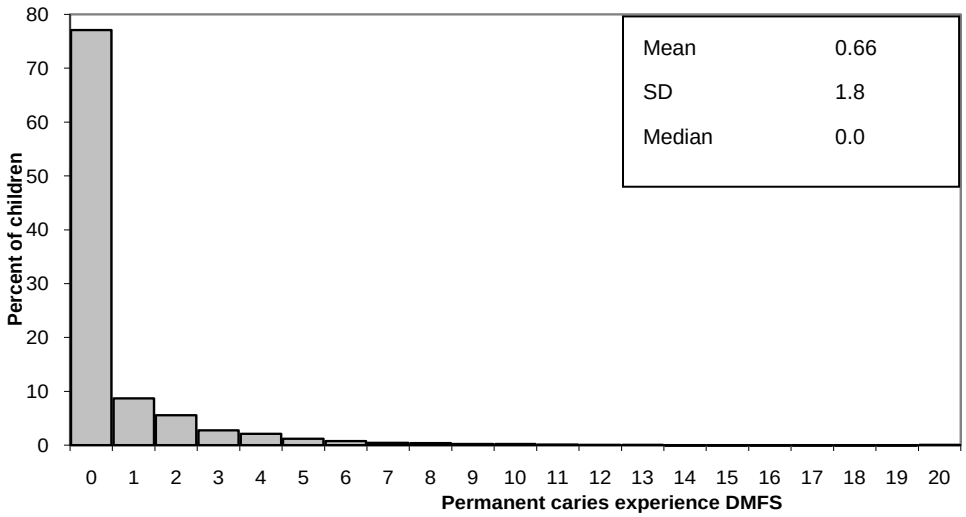
At baseline, over 60% of children aged 5–10 years old had no deciduous caries experience (Figure 3.3). The highest prevalence of caries experience was one affected surface. Only 10% of children had more than 3 affected surfaces. The skewness of deciduous dmfs score was 4.0.

Figure 3.3: Histogram of baseline dmfs distribution



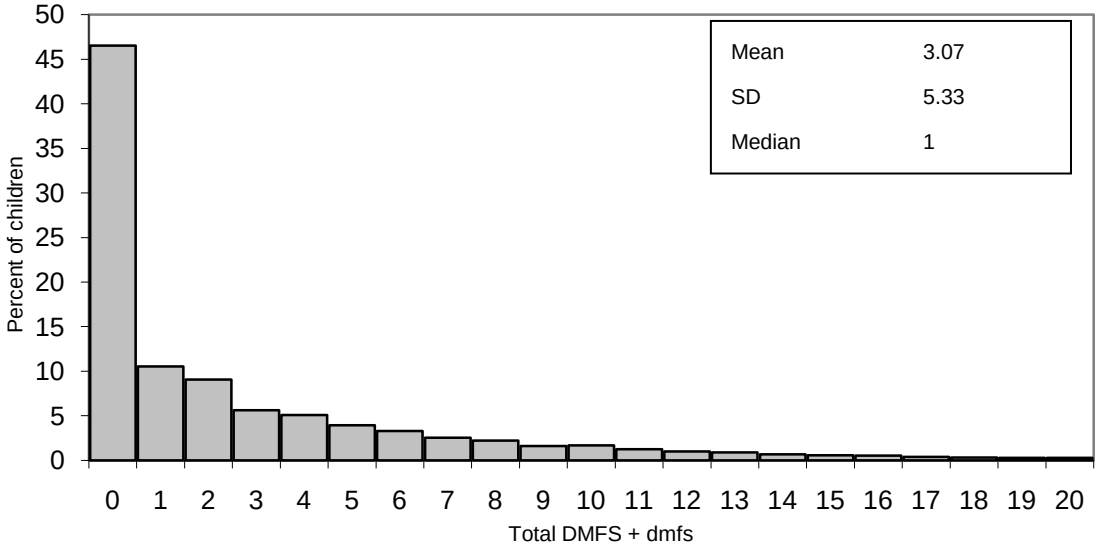
There was a more pronounced skewness in the distribution of permanent caries experience; DMFS (Figure 3.4). Over 75% of children aged 6 years or older had no caries on their permanent dentition. Of those with a permanent caries experience, the most frequent level was one affected tooth surface. Around 10% of the children had a DMFS score of more than 5.

Figure 3.4: Histogram of baseline DMFS distribution



There were only 45% of children who did not experience either deciduous or permanent caries experience. The highest percentage of children with caries experience had 1 or 2 affected deciduous and permanent tooth surfaces (Figure 3.5).

Figure 3.5: Histogram of baseline DMFS + dmfs distribution



There was considerable variation among socio-demographic subgroups in the distribution of caries at baseline (Table 3.7). Boys had significantly higher prevalence of deciduous caries experience and mean dmfs than girls, but lower prevalence of permanent caries experience and DMFS than girls. Deciduous caries experience was highest among the younger age group and decreased in the older two age groups while there was a reverse trend with permanent caries experience.

Children who were born overseas or who had a healthcare card or who were Indigenous had significantly higher prevalence and severity of caries on both deciduous and permanent dentition compared with non-Indigenous children. Children who resided outside of metropolitan Adelaide also had significantly more caries experience in the deciduous dentition compared with children who lived in Adelaide. The difference in deciduous caries experience was notable between children living in fluoridated and non-fluoridated areas. Almost 10% more children from non-fluoridated areas had caries prevalence, with almost one more decayed, missing or filled deciduous tooth surface. The differences were not so marked in the permanent dentition.

The difference in caries experience between risk groups at baseline was statistically significant. Children who were deemed as high-risk at baseline had almost 30 times higher the severity and almost ten times higher the prevalence of deciduous caries compared to the low-risk group. The corresponding ratios for permanent dentition were four and three times. The medium-risk group had an intermediate position.

Children who had had fissure sealants placed on their teeth had significantly higher caries experience on both deciduous and permanent dentition. The difference was more notable for the permanent dentition. Those children who had fissure sealants had over three-fold higher prevalence and severity of caries on permanent dentition.

Table 3.7: Baseline dental caries experience by study sample characteristics at baseline

	Deciduous dentition		Permanent dentition	
	Mean dmfs (99%CIs)	Prevalence %	Mean DMFS (99%CIs)	Prevalence %
Sex		*		*
Male, n=36,399	2.6 (2.5-2.7)	41.0	0.6 (0.5-0.7)	21.8
Female, n=35,220	2.2 (2.1-2.3))	37.8	0.7 (0.6-0.8)	24.1
Age groups		*		*
5–7 years, n=27,293	3.2 (3.0-3.3)	46.6	0.1 (0.1-0.1)	5.5
8–12 years, n=30,077[a]	2.2 (2.4-2.6)	42.2	0.8 (0.7-0.8)	30.2
13–15 years, n=10,249	NC	NC	1.8 (1.8-1.9)	54.4
Country of birth		*		*
Australia, n=59,710	2.4 (2.3-2.5)	39.6	0.6 (1.8)	23.0
Overseas, n=2,669	3.7 (3.6-3.8)	42.0	1.4 (3.4)	33.3
Healthcare card		*		*
Yes, n=12,493	2.2 (2.0-2.3)	41.0	1.1 (1.0-1.2)	32.5
No, n=59,126	2.5 (2.4-2.5)	32.3	0.6 (0.5-0.6)	20.8
Indigenous status		*		*
Indigenous, n=1,251	4.5 (3.9-5.1)	55.9	1.0 (0.8-1.2)	29.6
Non-Indigenous, n=58,751	2.4 (2.3-2.4)	39.1	0.7 (0.6-0.7)	23.1
Residential location		*		*
Adelaide, n=44,849	2.1 (2.1-2.2)	36.2	0.6 (0.6-0.6)	21.6
Other areas, n=22,493	2.9 (2.8-3.0)	45.3	0.8 (0.7-0.8)	26.1
Fluoride concentration in water		*		*
Non-fluoridated, n=10,032	3.2 (3.1-3.4)	47.5	0.8 (0.7-0.8)	26.6
Fluoridated, n=61,356	2.3 (2.2-2.3)	38.2	0.6 (0.6-0.7)	22.3
Risk status		*		*
Low, n=15,049	0.2 (0.2-0.2)	7.5	0.3 (0.3-0.3)	11.8
Medium, n=41,473	1.4 (1.3-1.4)	35.5	0.6 (0.6-0.6)	22.7
High, n=15,097	7.5 (7.4-7.7)	82.7	1.3 (1.2-1.4)	34.8
Fissure sealant		*		*
No, n=57,518	2.2 (2.2-2.3)	38.4	0.4 (0.4-0.4)	12.9
Yes, n=14,101	2.8 (2.7-2.8)	41.7	1.3 (1.2-1.3)	45.1

NC: not calculated

99%CI: 99% Confidence Interval. Groups are significant if their CIs do not overlap

* Significant chi square test, p<0.0001

[a] caries experience were calculated for children up to 10 years old for deciduous dentition

There was no difference between the sexes in distribution of clinician's risk classification at baseline (Table 3.8). Risk classification at baseline was strongly associated with age. Significantly fewer 5–7 year old children were in the low-risk group compared to other age groups (13% versus 24% and 35% respectively). The reverse was true for the high-risk group with 28% of 5–7 year old children being assigned in this group.

A greater percentage of children who had caries experience at the time of examination were assigned to the high-risk group by clinicians, compared to children who had no caries experience (37.2% and 2.4%, respectively) (Table 3.8). Children who were born in countries other than Australia, who were Indigenous, who lived in a regional area or in a non-fluoridated area, who had at least one fissure sealant on their permanent teeth were more likely to be assigned to the high-risk group rather than the corresponding groups that were Australian-born, non-Indigenous, capital city dwellers, residents of fluoridated areas, or who had no fissure sealants.

Table 3.8: Distribution of risk status at baseline by children's characteristics

	Baseline caries risk assessment		
	Low (%)	Medium (%)	High (%)
Sex			
Male, n=36,399	20.5	57.6	21.9
Female, n=35,220	21.9	58.0	20.1
Age groups*			
5–7 years, n=27,293	13.5	58.4	28.1
8–12 years, n=30,077	24.3	59.1	16.7
13–15 years, n=10,249	35.4	52.8	11.9
Country of birth*			
Australia, n=59,710	22.0	57.0	21.0
Overseas, n=2,669	17.9	52.4	29.8
Healthcare card*			
Yes, n=12,493	23.5	54.8	21.8
No, n=59,126	20.7	58.4	20.9
Indigenous status*			
Indigenous, n=1,251	13.6	49.9	36.5
Non-Indigenous, n=58,751	22.0	57.1	20.9
Residential location*			
Adelaide, n=44,849	20.1	61.0	18.8
Other areas, n=22,493	21.0	54.1	24.9
Fluoride concentration in water*			
Non-fluoridated, n= n=10,032	17.9	56.7	25.5
Fluoridated, n=61,356	21.7	58.0	20.3
Caries experience at baseline*			
Yes, n=38,204	7.3	55.5	37.2
No, n=33,415	37.2	60.4	2.4
Fissure sealant status*			
No, n=57,518	23.5	57.7	18.7
Yes, n=14,101	16.0	58.0	26.1

* significant different with p<0.001; Chi-square test

There was a strong positive association between risk classification and deciduous caries experience at baseline (Table 3.9). Children who were assigned high-risk status had on average seven times higher mean dmfs compared with low-risk children. The difference in baseline permanent caries experience between groups with different caries risk status was smaller. The high-risk children had a four times higher mean DMFS score compared with the low-risk children. The mean of combined DMFS + dmfs showed a 17-fold difference between high- and low- risk groups.

Table 3.9: Caries experience at baseline in three risk classification groups

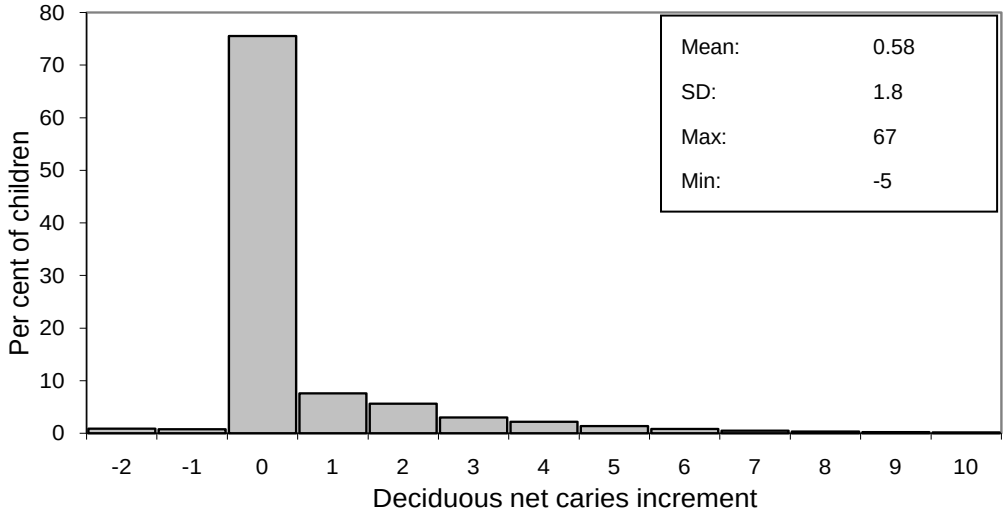
Risk classification at baseline	Baseline dmfs	Baseline DMFS	Baseline DMFS + dmfs
	Mean (99% CI)	Mean (99% CI)	Mean (99% CI)
Low	0.20 (0.19-0.22)	0.29 (0.27-0.31)	0.49 (0.47-0.52)
Medium	1.36 (1.33-1.39)	0.57 (0.56-0.59)	1.93 (1.90-1.96)
High	7.52 (7.40-7.65)	1.30 (1.25-1.34)	8.82 (8.70-8.95)

CI: Confidence Intervals. Within columns, subgroups are significantly different when their 99%CIs do not overlap

3.6.2 Net caries increment

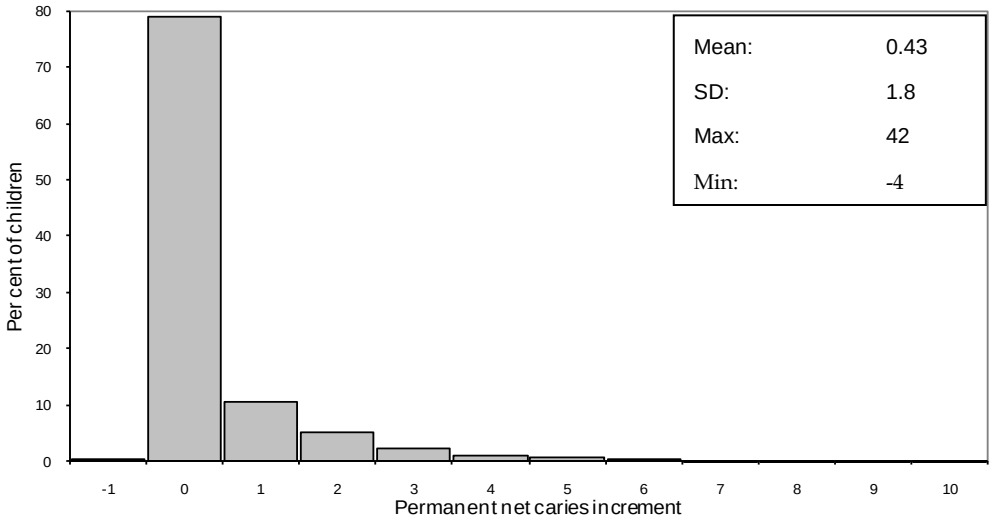
Approximately 75% of children had no net caries increment (NCI) in the deciduous dentition (Figure 3.6). A majority of children with new caries had one new affected surface. Only very few children had a high deciduous NCI whereas even fewer children had no increment, but did have some reversals.

Figure 3.6: Distribution of net caries increment of deciduous dentition



A similar distribution of permanent NCI was seen, with an even more pronounced skewness in permanent NCI (Figure 3.7). Almost 80% of children had no increment in their permanent dentition during the study period. Half of those who had a permanent NCI had increment of only one tooth surface. Only a small number of children had a NCI score of more than two tooth surfaces.

Figure 3.7: Distribution of net caries increment of permanent dentition



There was a significant increase in mean net caries increment of the deciduous dentition from the low-risk group to the high-risk group and a similar increase in net caries increment of the permanent dentition (Table 3.10). Low-risk children had 0.14 deciduous surfaces with caries increment, while high-risk children had a 10 times higher increment. Net caries increment of the permanent dentition among high-risk children was three-fold higher than that among the low-risk group. The combined caries increment was five times higher among the high-risk group compared with the low-risk group. The medium-risk group always had intermediate level of new caries increment.

Table 3.10: Mean of net caries increment by baseline risk status

	All	Baseline risk status		
		Low	Medium	High
	Mean (99% CI)	Mean (99% CI)	Mean (99% CI)	Mean (99% CI)
Net caries increment of deciduous dentition*	0.58 (0.57-0.60)	0.14 (0.13-0.15)	0.45 (0.43-0.46)	1.42 (1.37-1.46)
Net caries increment of permanent dentition*	0.43 (0.42-0.44)	0.25 (0.23-0.27)	0.39 (0.38-0.40)	0.72 (0.69-0.75)
Net caries increment of combined dentition*	1.01 (1.00-1.02)	0.39 (0.37-0.41)	0.83 (0.81-0.85)	2.13 (2.07-2.18)

*CI: Confidence Intervals. Within row, subgroups are significantly different when their 99%CIs do not overlap

3.6.3 Caries incidence density

3.6.3.1 Distribution of incidence density

The majority of children had caries incidence density of both deciduous and permanent dentitions of zero (Table 3.11). Some 70% of children did not develop any new caries in their deciduous dentition, while this percentage was even higher (78%) for permanent dentition. Of those children who had an incidence density above zero in either dentition, most developed caries on less than 5%of their surface-years at risk. The percentage of children who had an incidence density above zero in the deciduous dentition was higher than for the permanent dentition.

The distribution of incidence density for the deciduous dentition by baseline risk status is also presented (Table 3.11). The high-risk group had a significant greater percentage of children who had incidence density in the deciduous dentition above zero than the low- and medium-risk groups. Almost 90% of the low-risk children did not have an incidence density above zero in their deciduous teeth while more than half of the children in the high-risk group had an incidence density above zero.

Table 3.11: The distribution of deciduous caries incidence density

	Category of caries rate (% of children)			
	(ID=0)	(ID>0-5)	(ID>5-10)	(ID>10)
For all children	69.8	22.0	5.7	2.4
By baseline risk category				
Low-risk	89.1	9.6	1.0	0.3
Medium-risk	74.4	20.6	3.8	1.2
High-risk	46.3	33.8	13.3	6.7

The distribution of the incidence density for the permanent dentition by baseline risk status is presented in Table 3.12. The high-risk group had a significantly higher percentage of children who had an incidence density above zero than the low- or the medium-risk group. Almost 86% of the children in the low-risk group did not have an incidence density above zero in their permanent teeth, while this percentage was lower, 69%, in the high-risk group of children.

Table 3.12: The distribution of permanent caries incidence density

	Category of caries rate (% of children)			
	(ID=0)	**(ID>0-5)**	**(ID>5-10)**	**(ID>10)**
For all children	78.0	20.4	1.1	0.5
By baseline risk category				
Low-risk	85.8	13.7	0.3	0.2
Medium-risk	78.3	20.7	0.7	0.4
High-risk	68.6	27.0	3.1	1.4

The distribution of the combined permanent and deciduous dentition incidence density is presented (Table 3.13). Nearly two-thirds, 62.5% of children had the incidence density of zero (ID=0). The high-risk group had significant greater percentage of children who had incidence density above zero than the low- or medium-risk group. Around 81% of the children in the low-risk group did not have incidence density above zero in either dentition while this figure was lower, 37%, in the high-risk group of children.

Table 3.13 The distribution of combined permanent and deciduous caries incidence density

	Category of caries rate (% of children)			
	(ID=0)	**(ID>0–5)**	**(ID>5–10)**	**(ID>10)**
For all children	62.5	34.1	2.64	0.72
By baseline risk category				
Low-risk	81.3	18.3	0.4	0.1
Medium-risk	65.0	33.4	1.4	0.2
High-risk	36.8	52.0	8.4	2.8

3.6.3.2 Incidence density by children's socio-demographic characteristics

There were variations in caries incidence density estimates between groups defined by socio-demographic characteristics of the children (Table 3.14). Although there was no significant difference in the mean of the incidence density of the deciduous or permanent dentitions between boys and girls, boys had a significantly higher combined incidence density score compared with girls.

The incidence density (ID) values were significantly associated with healthcare card status, country of birth, Indigenous status, residential location, fluoridation status, and caries experience and risk classification at baseline.

There was a similar trend for both deciduous and permanent dentition. However, the values of incidence density and magnitude of the difference between groups was larger for the deciduous dentition. Children who had caries at baseline had five-fold the mean incidence density of the deciduous dentition compared with children who had no caries at baseline. The difference between the same groups was just more than two-fold for the permanent dentition. The combined incidence density reflected the similar trend of differences between subgroups defined by risk at baseline.

Children who were classified as high-risk at baseline had almost five times higher the incidence density value in the permanent dentition and almost nine times higher the ID values in the deciduous dentition compared with low-risk children. The difference of the combined ID score was around eight times higher. The medium risk children had intermediate ID values, which were more than two-fold of that of the low-risk children.

Table 3.14: Incidence density (calculated for whole group) by children's characteristics

	Deciduous dentition	Permanent dentition	Combined
	Incidence density (99%CI)	Incidence density (99%CI)	Incidence density (99%CI)
Sex			
Boys	1.18 (1.15–1.20)	0.39 (0.38–0.39)	0.66 (0.65–0.67)*
Girls	1.16 (1.13–1.18)	0.38 (0.37–0.39)	0.62 (0.61–0.63)
Healthcare card status			
Yes	1.24 (1.19–1.29)*	0.43 (0.42–0.44)*	0.65 (0.64–0.66)*
No	1.16 (1.14–1.18)	0.37 (0.37–0.38)	0.60 (0.59–0.62)
Country of birth			
Born in Australia	1.16 (1.14–1.18)*	0.38 (0.38–0.40)*	0.64 (0.63–0.64)*
Overseas	1.73 (1.61–1.86)	0.47 (0.44–0.50)	0.76 (0.71–0.80)
Indigenous status			
Yes	1.81 (1.65–1.98)*	0.64 (0.59–0.70)*	1.02 (0.94–1.10)*
No	1.17 (1.15–1.19)	0.39 (0.38–0.39)	0.63 (0.62–0.64)
Residential location			
Adelaide	1.05 (1.03–1.07)*	0.36 (0.35–0.36)*	0.58 (0.57–0.59)*
Other areas	1.39 (1.36–1.43)	0.47 (0.46–0.48)	0.76 (0.75–0.78)
Fluoride concentration in water			
Non-fluoridated	1.47 (1.38–1.57)*	0.45 (0.43–0.47)	0.81 (0.79-0.84)*
Fluoridated	1.01 (0.97–1.04)	0.41 (0.40–0.42)	0.64 (0.63-0.65)
Child age group			
5–7 years[a]	1.25 (1.22–1.27)	0.64 (0.61–0.66)*	1.08 (1.07-1.10)
8–12 years[b]	1.14 (1.11–1.17)	0.37 (0.36–0.38)	0.51 (0.50-0.52)
13–15 years	NC	0.42 (0.41–0.43)	0.42 (0.41-0.43)
Risk status at baseline			
Low	0.32 (0.30–0.34)*	0.17 (0.16–0.17)*	0.20 (0.19-0.21)*
Medium	0.84 (0.82–0.85)	0.37 (0.36–0.37)	0.52 (0.51-0.53)
High	2.83 (2.77–2.88)	0.99 (0.97–1.02)	1.74 (1.71-1.77)
Caries experience at baseline			
Yes	2.03 (2.00–2.06)*	0.56 (0.55–0.57)*	1.01 (0.99-1.02)*
No	0.41 (0.40–0.43)	0.19 (0.19–0.20)	0.27 (0.27-0.28)

*CI: Confidence Intervals. Within columns, subgroups are significantly different when their 99%CIs do not overlap
NC: not calculated
[a] density were not calculated for children 5 years old for permanent dentition
[b] Incidence density were calculated for children up to 10 years old for deciduous dentition

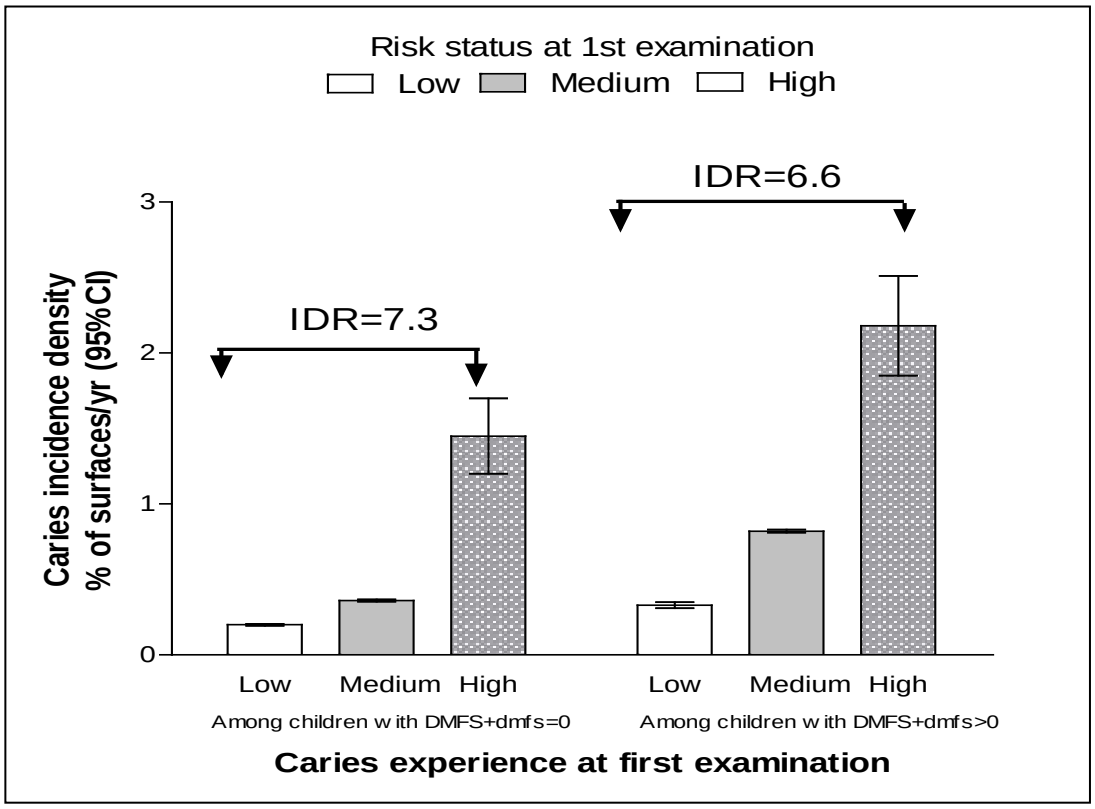
3.6.3.3 Stratified analysis of incidence density by baseline caries experience

Children were sub-grouped into having caries and being caries-free in both dentitions at baseline (Figure 3.8). Incidence density estimates of the two groups were calculated. The Incidence density ratio (IDR) was calculated by dividing the incidence density of the high-risk group by that of the low-risk group. The 95% confidence intervals (CI) of the IDR estimates were also calculated.

There was strikingly similar trend of caries development of the two groups regardless of caries experience at baseline. However, the children who had the disease at baseline had a somewhat higher incidence density ratio compared to the caries-free children.

The high-risk group among the caries-free children had a significantly higher incidence density estimate (1.45) compared with that of the low-risk group of the caries-free children. This high-risk group also had significantly higher ID compared to the low- and medium-risk groups of children who had caries at baseline. The low-risk group of caries-free children had the lowest estimated ID. The ID estimate of the medium-risk group of the caries-free children was similar to that of the low-risk group of the children who had caries at baseline. The high-risk group of the children who had caries at baseline had a significantly higher estimate of ID. The incidence density ratio between high risk and low risk groups among children with caries experience or without caries experience were similar (6.6 and 7.3, respectively).

Figure 3.8: Incidence density by caries experience at baseline



3.7 Summary of the chapter

This chapter confirmed that, as expected, there was a strong association between clinicians' risk classification and both caries experience at baseline and the actual rate of caries development. Furthermore, as illustrated in the stratified analysis (Figure 3.8), the association between clinician's risk classification and rate of caries development persisted even after adjustment for baseline caries experience. These findings were consistent with results from previous studies showing that clinicians' subjective assessment was a valid predictor of children's risk of developing caries.

3.7.1.1 The prevalence and severity of dental caries at baseline among South Australian children

In general, caries experience was relatively low in this study population. Data on dental caries collected in this study allowed for calculation of caries experience at different levels of caries risk status by child characteristics.

The decayed, filled and missing tooth surface index was used in this study. An often-cited opinion that the filled component of the dmf/DMF index was related to socioeconomic status was not true for this study population because the study sample was from school dental service users. These children had equal access to care without dependence on their household socioeconomic status. The missing tooth surface component was very low, and therefore it was not expected to influence the indices. Hence, the indices used reflected the pattern of dental caries in the South Australian child population.

The pattern of caries experience was similar between boys and girls in this study in both permanent and deciduous dentitions. Caries experience was higher in both permanent and deciduous dentitions among children who hold a healthcare card, who were born overseas, who were Indigenous or who live in non-fluoridated area. Children's country of birth and Indigenous status showed greater differences in disease experience – a similar pattern was observed in this study with different risk categories. These results are consistent with previous results reported by other authors (Saemundsson et al. 1997; Hausen et al. 2000; Polster A 2003). DMFS and dmfs among children who had at least one fissure sealant were higher than their counterparts who did not receive a fissure

sealant. One explanation for this phenomenon is that children who already had caries were more likely to receive a fissure sealant.

3.7.2 Summary of the findings

3.7.2.1 Caries rate among South Australian children during the study period

Association between risk status at baseline and caries incidence

Children of the high-risk group had, on average, the highest caries rate compared with the lower risk groups. This difference was observed regardless of children's caries experience at baseline. The incidence density ratios between the high-risk and low-risk groups were almost identical between children who had caries and children who were caries-free at baseline. This finding indicated that clinicians based their judgement on factors other than actual caries experience at baseline alone. This assumption will be evaluated in the other sub-studies later in this thesis.

Net caries increment (NCI): NCI of both deciduous and permanent dentitions was related to age. NCI was associated with country of birth, Indigenous status, and fluoride concentration in water. Once again, a similar pattern was observed. Children who were born overseas, who were Indigenous or who lived in non-fluoridated areas had a higher net caries increment than their counterparts. Caries experience at baseline showed the strongest association to NCI in both dentitions. There was a strong and positive association between level of disease at baseline and net caries increment during the follow-up. Risk assignment at the baseline examination was shown to be a good predictor of net caries increment in the follow-up period. NCI was also found to be related to fissure sealant status.

Incidence density (ID): Observed **c**aries incidence density followed a similar pattern as NCI. Children who were born overseas, who were Indigenous or who lived in non-fluoridated areas had a higher incidence density compared to their counterparts. There was no difference in incidence density between boys and girls.

3.7.3 Overview – strength and limitations

This sub-study was designed as a population-based prospective study with a large study sample that was representative of the child population. This design complied with the

aims of the sub-study to evaluate the relationship between baseline risk assignment and caries increment among South Australian children. Caries and socio-demographic data were prospectively collected from electronic patient records of the South Australian SDS across a 3 years and 9 months period. In South Australia, over 65% of school age children are enrolled in SDS. Hence, the study sample could be considered as being representative of the child population.

The decayed, filled and missing tooth surface index was used in this study. An often-cited opinion that the filled component of the dmf/DMF index was related to socioeconomic status was not true for this study population because the study sample included all school dental service users. These children had fully subsidised access to care regardless of their household socioeconomic status. The missing tooth surface component was very low. Therefore, it was not expected to influence the measurement of caries experience using the dmf/DMF index. Hence, the indices used reflect the pattern of dental caries in the South Australian school child population.

The dental caries data of some 72,619 children were collected by 153 clinicians (most were dental therapists). There may be some criticism that the data used to measure the outcome variable, dental caries rate, were collected by un-calibrated clinicians. However, these clinicians were similarly trained and used uniform clinical manuals to perform the examinations. In addition, the protocol was developed by experienced oral epidemiologists from the University of Adelaide in collaboration with South Australian Dental Service clinical leaders. This approach was also consistent with a recent statement by Hausen et.al (2001) that "In large enough settings, data obtained from patient records could possibly be used as a replacement for separate surveys". Also, analyses were based on the presence/absence of cavitated caries lesions (either filled or not), which is reliable (Evans et al. 1995). Also similar to a study in the UK (Milsom et al.), this study recorded cavitated caries lesions. Therefore, inter-examiner variability was likely to be minimal.

The time factor was important in computation of caries increment. Children in the general population may have different time intervals between their dental visits that may affect the amount of disease development during the recalls. The children in this study were of different age groups who would naturally have different numbers of teeth, deciduous and permanent, present in their mouth and hence, being at risk for

having caries. One advanced technique that was used in this study was the calculation of incidence density. The incidence density calculated in this study can adjust for different time intervals and number of teeth present in the mouth. The time and number of tooth surfaces present indicate the level of risk exposure for a child during the study period. Variation in risk exposure level was appropriately handled.

To summarise, this study can be considered as appropriately designed to pursue the specific aim of examining the association between risk prediction by clinicians in the real life clinical practice and the actual caries development in a large population study among South Australian children.

Chapter 4. Accuracy of clinicians' caries risk classification among South Australian school children

4.1 Introduction

Studies have shown that clinicians' subjective estimate of a child's risk of developing caries was the single best predictor of DMFS/dmfs increment in a multivariate model adjusting for other factors (Disney et al. 1992). The finding implied that caries risk could be reasonably predicted with information routinely available to clinicians at the time of examination, without the need for expensive or time consuming methods that have been promoted for caries risk assessment (e.g. laboratory count for *Streptococcus mutans*). This conclusion has been supported by studies from Finland (Alanen et al. 1994) where dentists achieved high specificity (Sp=90%) although low sensitivity in predicting caries risk (Se=44%) using their subjective judgement alone (Alanen et al. 1994). In that study, the combined sensitivity and specificity was 134 which was reasonable although lower than the threshold of 160 discussed by Stamm et al. (1991). Importantly, some individual dentists predicted caries with a high combined sensitivity and specificity that approached the threshold of 160 (Alanen et al. 1994).

Other studies have investigated factors that might contribute to clinicians' judgements about caries risk by studying child-related factors associated with clinicians' assessment of caries risk. A study of South Australian children reported that clinicians' assessment of caries risk was strongly associated with the caries experience of a child's teeth present at the time of assessment (Saemundsson et al. 1997). For example, among 6 year olds, mean dmfs of high-risk children was almost 50 times higher than mean dmfs of low-risk children (9.91 and 0.20 respectively). Among 12 year olds, mean DMFS of the high-risk children was 5 times greater than that of the low-risk children. However, that cross-sectional study did not investigate validity of clinicians' risk assessment, as judged against children's subsequent rate of caries development.

This sub-study estimated the accuracy of caries risk prediction by clinicians in the SA SDS. Variation in accuracy among clinicians was documented together with variation in

the profile of patients seen by clinicians. The sub-study also investigated characteristics of children that were associated with variation in clinicians' accuracy.

4.2 Terminology and conventions

In this sub-study, clinician accuracy in caries prediction was computed and used as the main dependent variable. This required selection of a "gold standard" indicator of children's caries rate. This indicator was used to cross-classify children according to the clinicians' classification of risk recorded at the baseline examination. The cross-classification was then used to calculate the indices that quantify accuracy of prediction: sensitivity and specificity. These concepts, and the conventions used in this study, are explained below.

1. Clinician accuracy is defined as the ability of clinicians to correctly predict further development of the condition that they are attempting to predict. In this sub-study, the condition was dental caries of both the deciduous and permanent dentition. SA SDS clinicians assessed and recorded the risk of developing new dental caries at each dental examination. Clinician accuracy was defined as the ability of a clinician to accurately predict the future caries rate.
2. Baseline examination was defined as the first recorded examination available in the dataset.
3. Caries rate was measured using incidence density and classified into three categories:
    - low rate of developing caries: incidence density of 0
    - medium rate of developing caries: incidence density greater than 0, but less than 1.2 newly-affected surfaces per 100 surface-years at risk and
    - high rate of developing caries: incidence density greater than or equal to 1.2 newly-affected surfaces per 100 surface-years at risk.

These thresholds were used to yield proportions of children with a low-, moderate- and high-rate of developing caries that were similar to proportions of the children who were predicted by clinicians to have low-, moderate- and high-risk.

Details of the method used to calculate caries rate are described below, in the Methods section. In this study, incidence density (ID) was chosen as a measure of actual caries

development for several reasons: 1) time interval between visits varied depending on the risk category assigned to the child at the baseline examination; 2) number of teeth present (hence at risk) for each child also varied. Incidence density was calculated as the probability of a new event for the total number of tooth surface-years at risk. Therefore, it adjusted for difference in time interval and in number of teeth between children in the study.

4. The observed rate of caries formed the gold standard for dental caries, that is the rate of the new disease observed during the interval between the baseline and the subsequent examinations.

For the purpose of calculating sensitivity and specificity, the three categories of caries rate were collapsed to a dichotomy by combining the low and medium rate into a category of low rate of developing caries, which was compared with a high rate.

Table 4.1: Schematic 2x2 table for calculation of sensitivity and specificity

Risk at baseline examination	Caries rate	
	High rate	Low/medium rate
Predicted high-risk	a	b
Predicted low/medium-risk	c	d

Equation 9: $$\text{Sensitivity} = \frac{a}{a+c}$$

Equation 10: $$\text{Specificity} = \frac{d}{b+d}$$

5. Sensitivity was defined as the proportion of children with a high-rate of new caries, who were correctly predicted to be at high risk at the baseline examination (Table 4.1 and Equation 9). When expressed as a percentage, the sensitivity can range from 0 to 100%.

6. Specificity was defined as the proportion of low/moderate-caries rate children who were correctly predicted to be at low risk at the baseline examination (Table 4.1 and

Equation 10). When expressed as a percentage, the specificity can range from 0 to 100%.

7. Overall accuracy was defined as sum of the sensitivity and specificity scores. When both are expressed as percentages, overall accuracy can range from 0 to 200%.

4.3 Methods

4.3.1 Data source and data management

The data source and data management have been described in Chapter 3, Sections 3.2, 3.3, and 3.4. In summary, this sub-study used data from 71,619 children aged 5–15 years who had at least two dental examinations separated by at least 6 months recorded in the SA SDS EXACT database. The sample for the present sub-study was further limited to those examinations conducted by clinicians who examined more than 20 children during the study period. This resulted in a dataset of 71,430 children and 133 clinicians. The clinical data permitted calculation of caries rate, which was used to classify children into three categories: low-, moderate-, and high-rate of caries, later dichotomised to a low/moderate-rate and high-rate of caries.

4.3.2 Statistical analysis

Sensitivity and specificity were the main outcome variables of the analysis in this sub-study. Sensitivity and specificity were calculated first for each individual clinician. Secondly, sensitivity and specificity were calculated for sub-groups of clinicians who shared the same characteristics.

The main aim of this sub-study was to provide descriptive statistics of sensitivity and specificity calculated at the individual clinician level. Those calculated levels of accuracy in caries risk assessment were used as the outcome variables in multivariate analyses that form the objectives of the final sub-study (Chapter 6).

The calculated sensitivity and specificity at the group level were also described here with the aim of exploring potential confounding effects by different characteristics of the clinicians. Accuracy of group of clinicians was computed by the volume of patients they had seen, the percentage of high risk children they had examined and the percentage of children who had baseline caries experience.

All other exploration between sensitivity, specificity and clinician's characteristics such as sex, age and type of degree will be presented in the final sub-study in Chapter 6.

4.3.2.1 Outcome variable:

Four steps were used to calculate sensitivity and specificity.

1. Computation of the caries rate.

Chapter 3 described details of the De Paola grid and computation method for permanent (for children over 5 years) and deciduous incidence density (dmfs was limited to ages 5 to 10 years).

2. DMFS and dmfs rates were combined by summing numerator increment of dmfs and DMFS, then dividing by the sum of deciduous tooth surface years at risk + permanent tooth surface years at risk.

3. Defining categories of caries rate.

In order to facilitate comparison with other available studies, low- and medium-categories of risk assigned by clinicians at baseline were collapsed into one group and those children were contrasted with children assigned to the high risk category. Similarly, the observed rate of caries was dichotomised by classifying children as having developed a low- to medium-caries rate if their observed incidence density was less than 1.2. Otherwise, children were considered as having a high-caries rate (true high-risk) if their incidence density was 1.2 or higher. The other reasons for aggregating three groups into two groups were: 1) sensitivity and specificity were meaningful only when prediction and gold standard are dichotomised; 2) implications for resource allocation were most relevant for high risk, not for low- versus-moderate risk children.

4. Calculation of sensitivity and specificity scores.

Sensitivity and specificity were calculated using contingency tables that cross-classified children according to clinician's baseline risk classification and observed rate of caries development.

The accuracy of each individual clinician was used to create a clinician-level data which contained 133 individual clinician records.

The distribution of each individual clinician's sensitivity and specificity were described and plotted on histograms.

4.3.2.2 Stratified analysis:

Explanatory variables were divided into 2 groups: Group 1 was the group of variables that described clinician performance and Group 2 included children's characteristics.

4.3.2.2.1 Clinician's variables:

For each clinician the number of children they had seen during the study period was counted and assigned into clinician-level data which contained data of 133 clinicians. The number of children who were assigned as high risk at the baseline examination for each clinician were counted and transformed into a percentage. This percentage represented the volume of high risk children they examined out of all the number of children they had seen during the study period.

Clinicians were categorised into three groups based on the number of children they had seen at baseline who were high risk children The percentage of children assigned at baseline to the high-risk category was calculated for each clinician and used to classify clinicians into three levels: those having less than 15% of patients as high-risk children (<15% PHR); from 15% to 30% PHR; and more than 30% patients as high-risk (30+% PHR).

4.3.2.2.2 Child's characteristics:

The accuracy of caries risk assessment was compared among groups of children with caries experience and no caries experience at baseline; among children who were examined by the same clinician in both baseline and follow-up examinations and children examined by different clinicians; among children who had one or more fissure sealant and those who did not have a fissure sealant placed on their teeth.

Three child characteristics stratifying strategies were used as follows:

1. Children were classified according to their baseline DMFS and/or dmfs into a caries-free groups (dmfs + DMFS = 0) and a caries-present group (dmfs + DMFS >0).
2. Children were classified either as recipients or non-recipients of fissure sealants during the follow-up period.
3. Children were classified either as having been examined by the same clinician at baseline and follow-up or having been examined by different examiners.

The general idea of doing the stratified analysis was to determine whether observed differences in Se+Sp between clinician subgroups might be confounded by (a) volume of high risk patients or (b) by child's baseline caries experience. The stratification by receipt of fissure sealants was an attempt to address the problem of treatment bias. Children classified as high risk are more likely to get preventive services than children classified as low risk. Hence, the observed rate of caries would be biased downwards for children in the high-risk group. Therefore, the clinician's accuracy might be lower than it would have been had children not received treatment. Stratification provides some insight into this phenomenon by computing accuracy separately for those who got sealants (where the bias is likely to be pronounced) and those who did not get sealants (where the bias is likely to be diminished).

Clinicians are varied in their ability to detect caries (Kay et al. 1988). The final stratification was trying to determine if diagnostic variation among clinicians might alter observed levels of accuracy. Stratification provided some insight into this phenomenon by computing accuracy separately for those children who were re-examined by the same clinician (where between-examiner variability is eliminated) and those who were examined by different clinicians (where between-examiner variability is present).

To illustrate the hypothesis that fissure sealant might alter the accuracy of caries risk assessment, two scenarios were set up below:

Table 4.2 and Table 4.3 show two scenarios of sensitivity and specificity among a hypothetical group of 500 children, 100 of whom were classified as high risk and 400 of whom were classified as low risk. In scenario 1, where no fissure sealants were applied, the 60% of high risk children developed caries, while only 12.5% of low risk children developed caries. Combined Se+Sep was 144.2. In scenario 2, when fissure sealants were used, only 30% of high risk children developed caries while the percentage was unchanged for low risk children at 12.5%. In this second scenario, accuracy was reduced to Se+Sp=120.8. While these numbers are hypothetical, they illustrate the expectation that accuracy should be greater in the absence of preventive care.

Table 4.2: Hypothetical scenario 1: sensitivity and specificity among children who did not receive fissure sealants

		Caries rate		
		Caries (No of children)	No caries (No of children)	Total (No of children)
Risk prediction	High risk	60	40	100
	Low risk	50	350	400
	Total	110	390	500

Example of calculation: Se= 60/110=54.5 Sp= 350/390=89.7

Table 4.3: Hypothetical scenario 2: sensitivity and specificity among children who did receive fissure sealants

		Caries rate		
		Caries (No of children)	No caries (No of children)	Total (No of children)
Risk prediction	High risk	30	70	100
	Low risk	50	350	400
	Total	80	420	500

Example of calculation: Se=30/80=37.5 Sp=350/420=83.3

Sensitivity and specificity of this study was then compared with other studies. The sensitivity or specificity was assessed as to whether it was better than chance alone (50%) or close to perfect (100%). Combined Se+Sp was also compared with score by chance alone (100%) or close to maximum score (200%).

4.4 Results

A total of 133 clinicians examined 71,430 children with two or more examinations within the time interval at least six months apart.

4.4.1 Descriptive statistics

Clinicians examined, on average, 550 children although the number ranged from 23 to 1500 (Figure 4.1).

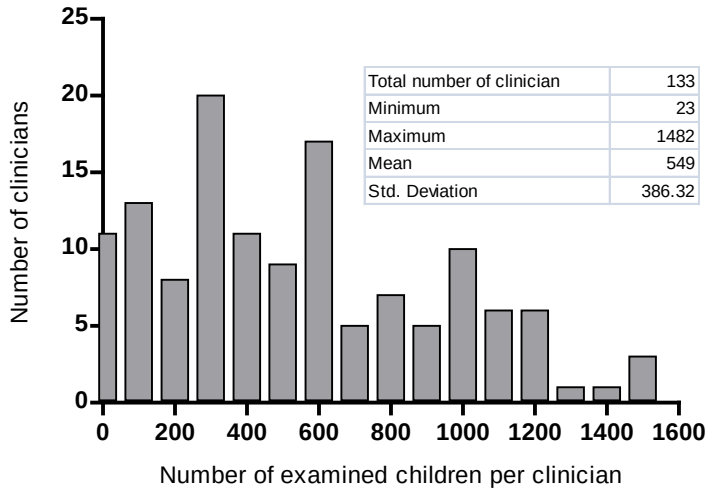


Figure 4.1: Distribution of number of examined children during study period per clinician

Most clinicians classified between 10–30% of the children as being in the high-risk category at the baseline examination (Figure 4.2). Fewer than 10 clinicians had assigned more than 50% of their children to the high-risk category.

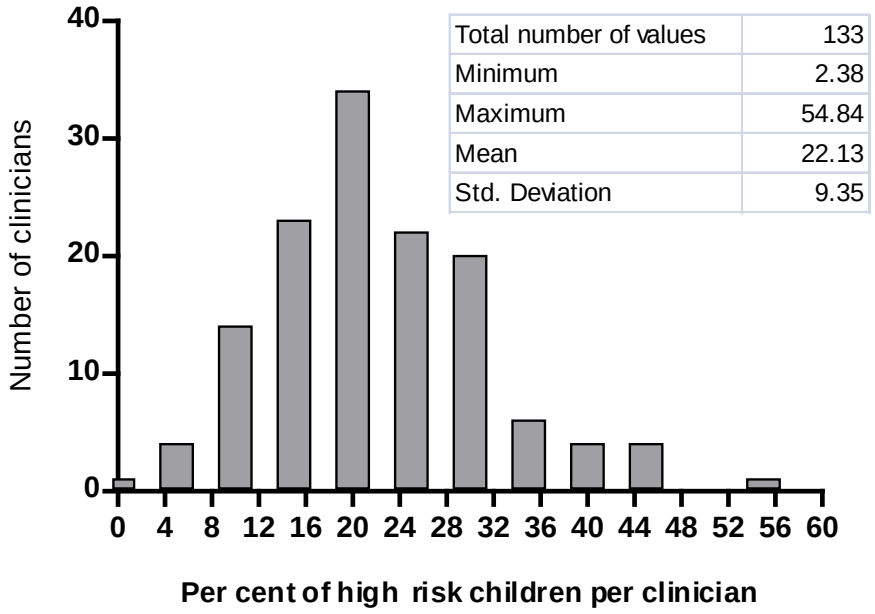


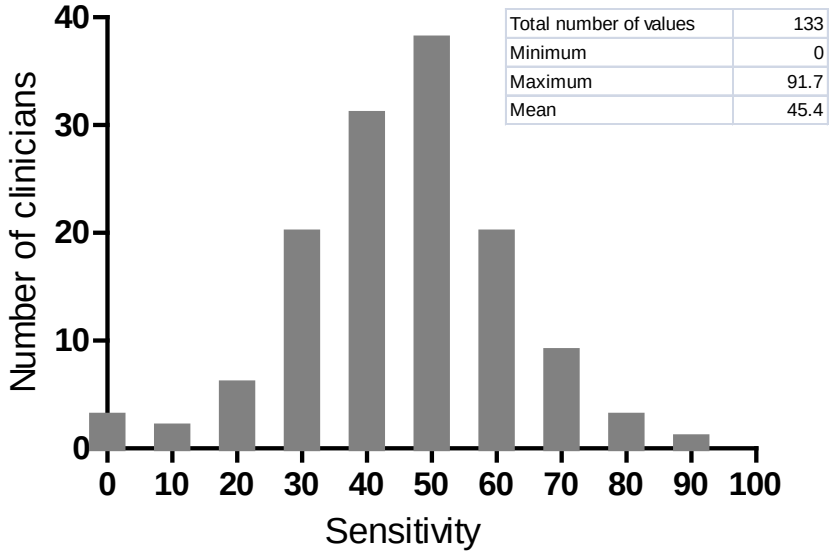
Figure 4.2: Distribution of high-risk children seen per clinician

4.4.2 Clinician-level accuracy in caries prediction

4.4.2.1 Distribution of clinician accuracy

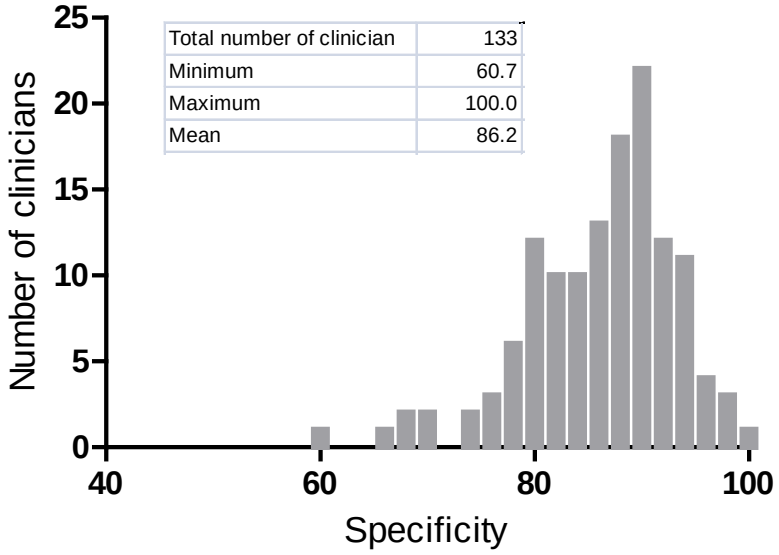
Clinicians varied in their sensitivity of caries prediction (Figure 4.3). The sensitivity score ranged from 0 to 92% with a mean score of 45.4%. The majority of clinicians achieved a sensitivity ranging from 40 to 60%.

Figure 4.3: Distribution of clinician's sensitivity



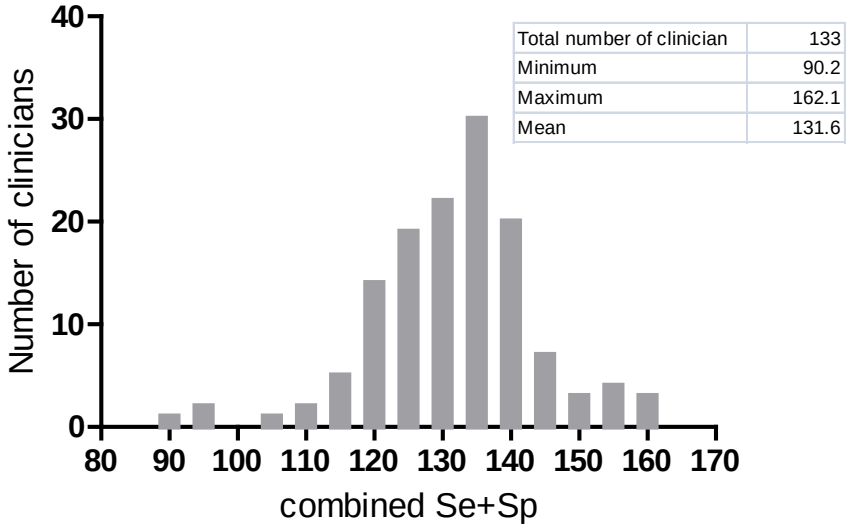
Clinicians varied in specificity, ranging from 61 to 100% (Figure 4.4). Most clinicians had specificity values within the range of 80 to 90%.

Figure 4.4: Distribution of clinician's specificity



The distribution of overall accuracy among clinicians revealed substantial variation, ranging from 100 to 160% (Figure 4.5). The majority of clinicians achieved combined Se+Sp within the range 130% to 140%, while only a small proportion of clinicians achieved a high accuracy with a combined score from 150 to 160%.

Figure 4.5: Distribution of clinician's combined sensitivity and specificity



4.4.3 Overall accuracy in caries prediction

Fewer than one half of children who actually developed a high rate of caries, were accurately predicted as having high risk for developing disease at baseline, yielding sensitivity of 47.5% (Table 4.4). In contrast, most children (specificity = 85.9%) who had a low rate of caries development were correctly predicted as having low or medium risk of developing disease at baseline examination. This percentage showed the overall specificity score observed during the study period. The observed overall combined sensitivity and specificity was 133.4%.

Table 4.4: Agreement between caries risk predicted at baseline and the actual gold standard caries rate during the study period

Clinician's risk classification at baseline examination	Follow-up		Total
	Incidence density (Gold standard)		
	>1.2	0–1.2	
	High rate	Low rate	
High risk, n (column %)	**6,997** (47.5%) [a]	**8,051** (14.1%)	15,048
Low /Medium risk, n (column %)	**7,831** (52.5%)	**48,551** (85.9%) [b]	56,382
Total	**14,828**	**56,602**	71,430
	sensitivity + specificity = 133.4		

Incidence Density: newly-affected surfaces per 100 surface-years at risk
a Sensitivity
b Specificity

4.4.3.1 Effect of provision of fissure sealants on accuracy of caries prediction

Among children who did not receive any new fissure sealants in the interval between baseline and the follow-up examination, screening (diagnostic) accuracy was similar to the preceding results for all subjects: sensitivity was 45.5%; specificity was 87.2%; and combined sensitivity and specificity was 132.7% (Table 4.5:). Overall accuracy was almost identical among the smaller group of 11,317 children who did receive one or more fissure sealants (132.4%); although sensitivity was higher (54.3%) and specificity was lower (78.1%).

A higher percentage of children with a high rate of caries development were correctly predicted to be high risk and a slightly lower percentage of children with a low rate of caries development were correctly predicted to be low or medium risk among those who received fissure sealants in the study period. Therefore, receipt of fissure sealants as a marker of increased preventive effort among children thought to be in need of such treatment led to increased sensitivity but decreased specificity of the caries risk prediction.

Table 4.5: Low/medium risk versus high risk and gold standard among children who did not receive any new fissure sealant during the study period

Risk status at baseline	Follow-up		Total
	Incidence density (Gold standard)		
	High rate >1.2%	Low or medium rate 0–1.2%	
Children who did not receive a new fissure sealant			
High, n (%)	5,483 (45.5) [a]	6,178 (12.8)	11,661
Low /Medium, n (%)	6,556 (54.5)	41,896 (87.2) [b]	48,452
Total, n	12,039	48074	60,113
		Se+Sp = 132.7	
Children who received one or more fissure sealant			
High, n (%)	1,514 (54.3) [a]	1,873 (21.9)	3,387
Low /Medium, n (%)	1,275 (45.7)	6,655 (78.1) [b]	7,930
Total, n	2,789	8,528	11,317
		Se+Sp = 132.4	

Incidence density: newly-affected surfaces per 100 surface-years at risk
a Sensitivity
b Specificity

4.4.3.2 Effect of the same examiner on accuracy of caries prediction

Among children, who were examined at both baseline and follow-up examination by the same clinician, sensitivity, specificity and combined sensitivity and specificity were 48.7%; 84.3% and 133.0% respectively (Table 4.6). When children were seen by different examiners, the level of agreement between predicted and observed caries rate was similar. The effect of being examined by different examiners on accuracy of caries risk assessment was minimal.

Table 4.6: Accuracy among children who were examined at both baseline and follow-up examination by the same clinician.

Risk status at baseline	Follow-up		Total
	Incidence density (Gold standard)		
	High rate >1.2%	Low or medium rate 0–1.2%	
Children who were examined by the same examiner			
High, n (%)	3,216 (48.7%)[a]	3,851 (15.7%)	7,067
Low /Medium, n (%)	3,393 (51.3%)	20,636 (84.3%)[b]	24,029
Total, n	6,609	24,487	31,096
	Se+Sp=133.0%		
Children who were examined by different examiners			
High, n (%)	3,781 (46.0%)[a]	4,200 (13.1%)	7,981
Low /Medium, n (%)	4,438 (54.0%)	27,915 (86.9%)[b]	32,353
Total, n	8,219	32,115	40,334
	Se+Sp=132.9		

Incidence Density: newly-affected surfaces per 100 surface-years at risk

a Sensitivity

b Specificity

4.4.3.3 Effect of baseline proportion of high risk children on accuracy of clinicians' caries prediction

An increase was observed in overall accuracy (Se+Sp) among clinicians who classified relatively higher proportions of children as high risk at the baseline examinations (Table 4.7). The increase was most pronounced for sensitivity which almost doubled, from 31.2% among clinicians who classified a small proportion of children as high risk at the baseline examination, to 60.7% for clinicians who classified a high proportion of children in the high risk category. Conversely, specificity decreased as the proportion of high-risk children examined at baseline increased.

Table 4.7: Overall sensitivity and specificity for clinicians with low/medium/high assignment of high-risk children

Risk status at baseline	Follow-up		Total
	Incidence density (Gold standard)		
	High rate >1.2%	Low or medium rate 0–1.2%	
Clinicians who classified a small proportion (0–15%) of children as high risk at baseline (n=27)			
High, n (%)	996 (31.2%)[a]	1,096 (6.9%)	2,092
Low /Medium, n (%)	2,201 (68.8%)	14,663 (93.1%)[b]	16,864
Total, n	3,197	15,759	18,956
	Se+Sp=124.3		
Clinicians who classified a moderate proportion of children (15–30%) as high-risk at baseline (n=62)			
High, n (%)	3,812 (47.5%)[a]	4,363 (14.4%)	8,175
Low /Medium, n (%)	4,213 (52.5%)	25,901 (85.6%)[b]	30,114
Total, n	8,025	30,264	38,289
	Se+Sp=133.1		
Clinicians who classified a high proportion of children (30+%) as high-risk at baseline (n=23)			
High, n (%)	2,189 (60.7%)[a]	2,592 (24.5%)	4,781
Low /Medium, n (%)	1,417 (39.3%)	7,987 (75.5%)[b]	9,404
Total, n	3,606	10,579	14,185
	Se+Sp =136.2		

Incidence density: newly-affected surfaces per 100 surface-years at risk
a Sensitivity
b Specificity

4.4.3.4 Effect of baseline caries experience on accuracy of caries prediction

The accuracy of caries risk assessment among children with or without baseline caries experience differed markedly (Table 4.8). Less than one tenth of children who were caries free at baseline had a high rate of caries development compared with a third among children who had caries at baseline. Sensitivity increased significantly from nearly 7% among baseline caries free children to 56.8% among children with caries at baseline examination. On the other hand, specificity decreased from 98% among caries free children at baseline to 71.5% observed among children who had caries. Overall accuracy was 128.3%, which is 24% higher than that of children who were without caries at baseline, 104.6%.

Table 4.8: Overall sensitivity and specificity among children without/with caries experience at baseline

Risk status at baseline	**Follow-up**		**Total**
	Incidence density* (Gold standard)		
	High rate ≥ 1.2	**Low or medium rate <1.2**	
Among children without caries experience at baseline			
High, n (col. proportion)	186 (**6.6**)[a]	609 (2.0)	795
Low /Medium, n (col. proportion)	2,650 (93.4)	29,898 (**98.0**)[b]	32,548
Total, n	2,836	30,507	33,343
sensitivity + specificity =**104.6**			
Among children with caries experience at baseline			
High, n (col. proportion)	6,811 (**56.8**)[a]	7,442 (28.5)	14,253
Low /Medium, n (col. proportion)	5,181 (43.2)	18,653 (**71.5**)[b]	23,834
Total, n	11,992	26,095	38,087
sensitivity + specificity **=128.3**			

*Incidence density: newly-affected surfaces per 100 surface-years at risk
a Sensitivity
b Specificity

4.5 Summary and discussion of the results

4.5.1 Overview

The combined Se+Sp of 133.4% (Table 4.4) indicated that the overall accuracy of clinicians in predicting dental caries was similar to that reported by other studies. Sensitivity of 47.5% was less than chance alone while specificity was at a good to excellent level of 85.9%.

There was marked variation in accuracy among clinicians (Figure 4.5). About 10% clinician achieved "good" overall accuracy (Sensitivity + Specificity was from 150 to 160%), while 5% had very poor overall accuracy estimates which was less than chance (100%).

The observed variation in clinicians' accuracy was similar to that reported in an in-vitro study of UK dentists (Kay et al. 1988). In that UK study, 10 dentists visually evaluated the same 30 extracted molars for evidence of occlusal caries requiring restoration. Teeth were serially sectioned and examined visually by two other dentists to establish "gold standard". The best dentist could achieve a score of 150 (Se=65, Sp=85) while the worse one gained a score of 103 (Se=41, Sp=62).

Overall accuracy was 133.4% (Table 4.4) similar to the results reported in a Finish study (Alanen et al. 1994). Furthermore, the clinicians' judgement in this sub-study proved to be similar in accuracy to statistical prediction models that use multivariate statistical methods to combine a potentially large number of child-characteristics to predict caries. Importantly, neither this study, nor those statistical methods, reached the recommended threshold of 160% needed for public health screening/diagnostic program of caries (Stamm et al. 1991).

The level of accuracy was not influenced by whether the child was examined by the same or by a different examiner. This finding provided an indication of overall uniformity among examiners in the procedures used to diagnose and record caries. Furthermore, the associations between potential factors with accuracy in risk assessment were unlikely to be affected by examiner errors that might exist. The finding is important in interpreting the level of accuracy in caries risk assessment from a population perspective.

Another important methodological finding was that overall accuracy did not differ between children who received fissure sealants between examinations and children who did not receive fissure sealants between examinations. Fissure sealants are an effective caries preventive measure (Newbrun 1990; Bader and Shugars 1995; Ismail and Gagnon 1995; Weintraub 2001; Adair 2003; Locker et al. 2003; Bader et al. 2004; Ahovuo-Saloranta et al. 2008). In this population, high-risk children were significantly more likely to receive fissure sealants compared with the children who had lower risk. Therefore, the more intensive use of fissure sealants in high-risk children was expected to reduce the rate of new caries during the follow-up period. Table 4.5 shows evidence of this effect. High-risk children who received fissure sealants had a lower rate of caries development than high-risk children who did not receive sealants. Similarly, low-risk children who received sealants had a lower rate of caries development than those low-risk children who did not receive sealants. This was expected to result in lower accuracy among the children who received sealants than among children who did not receive new sealants. However, the observed overall accuracy was virtually identical between the two groups.

A possible reason for this finding might be that the effect of fissure sealant on caries increment in this child population was small. Also, the difference in the underlying rate of caries increment between the high-risk and the low-risk groups was substantial. The preventive effect of fissure sealants was not enough to offset the difference in caries rate between the two risk groups. It was possible to conclude that the accuracy of caries risk assessment in this study population was not significantly biased by the preventive treatment provided to the high-risk children.

There was a possibility that the high-risk children received a higher level of other preventive measures such as oral hygiene instruction and fluoride applications. However, relevant information was not available to evaluate any possible bias associated with the provision of those preventive measures in the accuracy of caries risk assessment in this population.

Sensitivity was greater among clinicians who saw a high proportion of high-risk children at baseline compared to clinicians who saw a low proportion of high-risk children at baseline. Conversely, as the proportion of children assigned to the high-risk category increased, specificity decreased, although by a smaller margin than the change in sensitivity. The consequence was that overall accuracy was highest for the group of

clinicians with the highest propensity to assign children to high risk. This will be further discussed in the Discussion (Chapter 7).

The overall accuracy was notably higher among children with baseline caries experience than children with no caries experience at the baseline examination. In fact, the level of accuracy among children with no caries at baseline was just little better than chance alone (Se+Sp=105). Therefore, the level of observed accuracy was expected to depend significantly on children's characteristics. The level of accuracy observed for the clinicians in this study will need to be adjusted for their patients' characteristics in multivariate models. Such analysis is presented in Chapter 6.

Note that stratum-specific Se+Sp were both lower than the overall Se+Sp. This is because the crude effect of CRA's accuracy (in Table 4.4 and Table 4.8) is confounded by baseline caries prevalence. The confounding occurs because: a) baseline caries prevalence is associated with CRA classification and b) baseline caries prevalence is associated with incidence density. After adjustment for baseline caries prevalence (Table 4.8), a smaller effect of CRA's accuracy on incidence density was observed within each stratum. In fact, there was effect modification due to the baseline caries experience. In the absence of caries experience, CRA's accuracy was only slightly better than chance alone. However, when there is past caries experience, clinicians have achieved a fair to good level of accuracy. This suggested that clinicians somehow used information about caries experience when doing CRA. At a population oral health level, it suggests that CRA would be less informative in children with no caries experience.

4.5.2 Strengths and limitations of this sub-study

This sub-study measured accuracy in caries risk assessment in a real-life clinical situation. Most previous studies of caries risk assessment used data collected in the purposively designed trials where specific criteria were used to control for possible variation. Such studies provided "proof-of-principle" evidence of the caries risk assessment process. However, their specific conditions may preclude full generalisation to the real-life situation.

Clinicians in this study were not specifically trained for a caries risk assessment trial. Their performance of caries risk assessment was based on their education, experience and perception, and practice regulations applied at their clinics. This is unavoidable in

any real-life clinical situation. Findings of this study therefore provide evidence of the effectiveness of caries risk assessment in the South Australian Dental Service.

Time interval between examinations in purposively-designed caries risk assessment studies was often set to be uniform. Caries increment is time-dependent. Therefore, net caries increment was often the "gold standard" of choice in those studies. This was not possible in this study, where the time interval between examinations varied considerably among children. For that reason, incidence density was used as the "gold standard" in this study which helped to overcome that problem.

The "gold standard" was the decision of multiple clinicians' assessment of caries incidence between baseline and follow up examinations which might have caused some potential sources of bias such as clinician thoroughness or recall bias. For example, if some clinicians knew that a child was classified as high-risk at the baseline examination, they might be more thorough in their examination compared to when examining a child who had a low-risk status. However, in this study, differences were not found in clinician accuracy among children who were examined by the same clinician or different clinician at follow up examination (Table 4.6).

The study relied on clinicians recording in the electronic patient record of teeth that were cavitated, which the clinicians subsequently observed and/or treated. Although the clinicians involved in the study were not calibrated, it was not believed that inter-examiner variation in diagnosis would play a large role in the results of the study for a number of reasons. Data for this study were drawn from clinical archives, which reflected real life conditions. Also, clinicians were similarly trained and used uniform clinical manuals to perform the examinations. Furthermore, the protocol was developed by experienced oral epidemiologists from the University of Adelaide in collaboration with South Australian Dental Service clinical leaders. This study recorded cavitated caries lesions wich can be of clinical significance. This recording of late stage disease means that inter-examiner variability among multiple clinicians involved in the study was minimal.

Incidence density adjusts for different time interval as well as different number of teeth (or tooth surfaces at risk of developing new caries during a specified period of time). The importance of adjusting for difference in number of teeth or tooth surfaces at risk has been discussed (Beck et al. 1995). There has been no other study reporting the use of

incidence density as the measure of caries development in caries risk assessment. Hence, this study was expected to fill in the gap. However, unlike studies of caries aetiology, where incidence density is calculated separately for the permanent and deciduous dentition, this study combined permanent and deciduous caries rates. This reflects the real life situation. Clinicians based their risk assessment on the information of whole mouth and assigned child's risk level of developing caries in his/her full dentition not the risk of developing caries for permanent or deciduous teeth present.

4.5.3 Implication of the findings

This study was the first to apply stringent epidemiological standards in evaluating the accuracy of caries risk assessment using data collected in a real-life, not purposively controlled clinical situation. Therefore, the findings have practical implications for patients, parents and SA SDS. The potential effect of varying accuracy level between children with different characteristics such as caries experience at baseline will be further explored in the following Chapters.

The study findings expand the applicability of complex evaluation of accuracy of screening/diagnostic and prognostic procedures to routine dental clinical practice. This is important as the accuracy of any procedure is best evaluated in a population-representative sample. It is believed that this study is one of the first to satisfy the representativeness of the study sample.

The findings of this sub-study provided theoretical validation for further analysis of the accuracy of caries risk assessment presented in the following chapters. Clinician-related factors contributing to the accuracy of caries risk assessment are evaluated in Chapter 5. Chapter 6 evaluates the possible role of clinician-related and child-related factors in the caries risk assessment process. Chapter 7 then evaluates the overall accuracy of caries risk assessment and variation between clinicians in accuracy of their caries risk assessment.

Chapter 5. Distribution of clinicians' perceptions and practices regarding caries risk assessment

This chapter will report findings from a mail-questionnaire sub-study in which SA SDS clinicians were asked to describe their perceptions and practices regarding caries risk assessment. The questionnaire was designed to measure characteristics of clinicians that were hypothesised to be predictive of their accuracy in assessing caries risk. This chapter provides descriptive findings from the questionnaire, while subsequent chapters examine the relationship between clinician characteristics and accuracy of caries risk prediction.

5.1 Aims

1) To describe clinicians' clinical practices, perceptions and beliefs regarding caries risk assessment.
2) To develop summary measures of clinicians' clinical practices, perceptions and beliefs regarding caries risk assessment.
3) To examine the relationship between clinicians' characteristics and the summary measures of clinical practices, perceptions and beliefs regarding caries risk assessment.

5.2 Method

A cross-sectional mailed-questionnaire survey was conducted among the target population of all SA SDS dentists and dental therapists who provided care to children during 2002–04. Questionnaires were completed between October and December 2004.

5.2.1.1 Source of subjects

All 31 dentists and 134 dental therapists who had worked for the SA SDS during 2002–2004 were invited to participate in this survey.

5.2.1.2 Questionnaire design

The 10 page questionnaire is presented in Appendix 2: Survey Documents. It had four sections:

1. **Clinician demographics**: questions were asked about year of graduation, year of birth, country of birth and sex.
2. **Clinician work experience**: questions were asked about type of degree, practice location, number of hours spent chairside with patients and busyness of the clinic (number of clinicians working in that clinic). These variables were adopted and modified from the Longitudinal Study of Dentist Activity (Brennan 1999).
3. **Clinical examination procedures in caries risk assessment**: clinicians were asked if they considered the following factors when they conducted examinations and determined a child's risk classification: tooth crowding and alignment; dental fluorosis; about lighting and use of transilluminating during examination; whether they cleaned and dried teeth before the examination; and the average number of bitewing radiographs taken per every 10 examinations. They were also asked about child social circumstances, dietary and oral hygiene habits, and fluoride exposure history and caries risk assessment. These items were derived from a study of caries diagnostic and CRA (Malmo University). Responses were scored from 1 (never) to 5 (always) for each particular item.
4. **Perceptions and beliefs regarding caries risk assessment:** forty questions were asked about clinicians' perception of caries risk assessment. The questions were based on items reported by Disney et al (1992). These variables were: caries experience, tooth morphology, dietary and dental behavioural factors, fluoride exposure and clinician confidence (dela Cruz et al. 2004).
   Responses to questions about perceptions and beliefs were recorded using five point Likert-type scales. For example, responses regarding the importance of past caries in caries risk assessment ranged from "Definitely not important" to "Definitely very important". A response options of "Don't know" was also provided.

5.2.1.3 Content validation of the questionnaire

The questionnaire was first developed based on the existing instruments available in the literature (Disney et al. 1992); (dela Cruz et al. 2004); (Brennan 1999). The drafted questionnaire was later discussed with an expert panel comprising of three SA school dental service clinicians and three senior researchers in ARCPOH. This expert panel reviewed the relevance, clarity and conciseness of the items included in the questionnaire, and changes were made where needed. The revised questionnaire was

pilot tested in a group of dental clinicians who were not from the sub-study's target population. Further amendments were made to the final version of the questionnaire based on verbal feedback from the pilot study participants.

5.2.1.4 Mailing and questionnaire processing

Questionnaires, reminder and follow-up approaches were mailed consistent with the data collection methodology recommended by Dillman (2000). The first mailing had a cover letter which described the purpose of the study together with a letter of support for the study from the General Manager of SA Statewide Dental Services. SADS also permitted staff to complete the questionnaire during their work time. There was a reply-paid envelope in which to return the completed questionnaire directly to the author. Two weeks following the first mailing a reminder letter was sent. Two weeks later, the first follow-up package with a replacement questionnaire, a second reminder letter and reply-paid envelope was mailed to those clinicians who had not yet responded. Up to two follow-up approaches were conducted. The last mailing was sent to all subjects of the study. This mailing included a Christmas card and thanked clinicians who had returned their questionnaires.

To comply with privacy requirements of the SA Department of Health, mailings were managed by SA SDS. This was necessary because the unique identification code for each employee was printed on the questionnaire. The code was identical to the code used in the TITANIUM/EXACT database, permitting subsequent linkage between questionnaire responses and clinical data recorded by individual clinicians. Completed questionnaires were returned to the author for data entry and analysis. The identity of clinicians was not known to the author. On the other hand, detailed responses to the questionnaire were not disclosed to the SA SDS. These procedures were used to safeguard confidentiality.

5.2.1.5 Data analysis

5.2.1.5.1 Data reduction

The items in each battery were subjected to a process of scale development. Several groups of items were examined separately. A total of 22 items of clinical practices usually undertaken by the clinician during dental examinations were separated into two scales:

1. 12 items on routine clinical examination procedures (Question 1, Appendix 2), and bitewing radiographs per 10 children (Question 6, Appendix 2), (Conducting dental examination) and
2. 10 items on interview information for caries risk assessment (Question 2, Appendix 2).

A total of 40 items of clinician's perceptions and beliefs were grouped into another two scales:

1. 17 items of clinician's perceptions and beliefs regarding clinical factors (Question 4, Appendix 2) (Clinical factors), and
2. 23 items of clinician's perceptions and beliefs regarding non-clinical factors (Question 4) (Non-clinical factors).

Responses were scored from 1 (Always) to 5 (Never) for each particular item in the questionnaire. The "Don't know" response was coded as missing for all relevant items. The direction of responses was reversed for all items for subsequent scale development. Therefore, higher item scores indicate people who usually undertake procedures more frequently or who perceived indicators of caries risk as more important.

These four batteries of items were analysed using factor analysis to identify items within each battery which are more closely related. Those items were then used to form appropriate sub-scales for further analysis (Kim 1978).

The purpose of the factor analysis procedure was to identify a relatively small number of underlying dimensions or factors that account for most of the variation in item-level responses. Sub-scales derived from factor analysis were the examined for reliability (Brennan 1999).

The factor analyses were performed using principal components with varimax rotation (SAS, V9.1), and reliability of the factor-based sub-scales was assessed by Cronbach's alpha (SPSS, v11). Analysis involved determining the number of factors with eigenvalues greater then 1.0, examination of scree plots, measuring sampling adequacy by Kaiser-Meyer-Olkin (KMO) scores, examination of residuals, examination of communalities and variance explained by each factor. Final decisions on the number of factors to be accepted included consideration of explained proportion of sample variance, knowledge of the subject matter and reasonableness of the results (Johnson RA

1988; Brennan 1999). Retaining factors with eigenvalues greater than 1.0 is commonly used, based on heuristic and practical grounds (Kim 1978), but this criterion is considered most reliable when the number of variables is between 20 and 50. If the number of variables is less than 20 there is a tendency to extract a conservative number of factors, while there is a tendency to extract too many factors with eigenvalues greater than one when there are 50 or more variables (Brennan 1999). While scree plots can also be used to determine the number of factors, this is often very subjective (Kim 1978). Similarly, the substantive importance attached to the proportion of variance explained by each factor also involves judgement, and may be set at whatever the researcher considers to be important. Hence, Kim and Mueller (1978) conclude that there is no unambiguous rule to use when selecting the number of factors. Final judgement often involves the reasonableness of the solution and knowledge of the subject matter (Brennan 1999). Sampling adequacy relates to the degree to which the subset of variables used in the analysis represents a potentially larger domain, with a Kaiser's measure of sampling adequacy (KMO) of 0.50 or better being adequate (Kim 1978). Communality measures the common factor variance of a variable (that is variance shared in common with other variables). The proportion of variance that is unique to each item is then the respective item's total variance minus the communality. A communality of 0.3 or less indicates that a variable may be unreliable (Child 1970). A large communality value (that is, greater than 0.3) indicates that a large percentage of the sample variance of each variable is accounted for by the factors (Johnson RA 1988).

The final factor-based scales were constructed giving consideration to the reasonableness of the factors (e.g. interpretation, conceptual coherence) and reliability of the scales. For ease of interpretation, the scales were calculated by summing the items that loaded substantially on one factor (factor loading > 0.45) and dividing by the number of items to achieve a scale ranging from 1 to 5.

The reliability of the scales and their individual items was empirically examined through the calculation of Cronbach's alpha coefficients. Cronbach's alpha is used as a measure of the 'Internal Consistency Reliability' of the scale (that is, items in the scale measure the same construct). Alpha values are based on the average correlation among the items on a scale. Cronbach's alpha is therefore expressed as a correlation coefficient, ranging in value from 0 to +1. Generally an estimate of 0.70 or higher is required for judging a scale

reliable. Cronbach's alpha measures the internal consistency of the items with values above 0.70 providing an indication of adequate reliability (Streiner David L 2003).

5.2.1.5.2 Statistical analysis

Analyses were conducted using the SAS v9.1 statistical package (ACITS and Statistical Services 1995). Simple descriptive statistics were used to describe characteristics, experience and their CRA routine and perceptions of CRA among this survey population. Analysis of variance (ANOVA) was also used to examine relationships between clinicians' routine practice and perceptions of CRA and their characteristics and experience.

Results present the detail of the response to the data collection, age, sex and work experience of respondents, descriptive data on distributions and measures of central tendency, and scale development. Inferential statistics are then presented on the associations of clinicians' characteristics and scales of CRA.

5.2.1.5.3 Ethical issues

Ethical approval for this sub-study was given from the University of Adelaide Human Research Ethics Committee. The Executive Board of the South Australian Dental Service also reviewed and approved the sub-study. Participation in the mailed questionnaire survey was voluntary. The mailing was conducted by South Australian Dental Service staff. Responses were sent directly to the researchers at the University of Adelaide. Personal identities of the participants were not known to the researchers. Likewise, responses of the participants were not disclosed to the South Australian Dental Service.

5.3 Results

This section presents details of response rate and characteristics of the participants including age, sex and work experience. Descriptive data on distributions and measures are presented for groups classified according to clinicians' characteristics. Inferential statistics are then presented on the associations of clinicians' characteristics and scales and sub-scales of CRA.

5.3.1 Response rate and characteristics of participants

Questionnaires were completed by 134 of the 165 clinicians in the target population, representing 82.8% of those eligible. Response rates were marginally higher among dental therapists compared with dentists (Table 5.1). Two clinicians were no longer living at the listed address, while 29 failed to return a questionnaire or declined to participate. No longer working in the School Dental service was the main reason for non-participation.

Table 5.1: Response rate by dentist and dental therapist

	Total sample	Dentist	Dental therapist
Number sampled	165	31	134
Response			
Number of people	134	23	111
Percentage	82.4	74.2	82.8

The majority of clinicians were females and Australian-born (Table 5.2). The modal age group was 41–50 years (41.3% of clinicians) and only 12.7% were aged 23–30 years. Nearly one half of respondents had 21–30 years experience working in dentistry.

The majority of respondents practised as dental therapists (83%) while the other 17% were dentists. More than half of respondents reported working part-time, whilst only 2.4% reported they were employed on a casual basis.

Table 5.2: Description of clinicians' characteristics

Clinicians' characteristics	%
Sex	***n=134***
Male	11.4
Female	88.6
Age group	***n=126***
≤30 years	12.7
31–40 years	25.1
41–50 years	41.3
More than 50 years	20.6
Born in Australia	***n=131***
Yes	79.4
No	20.6
Type of degree	***n=134***
Dentist	17.2
Certificate of DT	53.0
Diploma of DT	29.8
Work status	***n=129***
Full-time	39.5
Part-time	58.1
Casual	2.4
Length of experience	***n=130***
≤10 years	20.8
11–20 years	18.5
21–30 years	46.1
More than 30 years	14.6
Practice location	***n=134***
Adelaide	54.5
The rest of state	45.5
Worked hours spent chairside with patients per day	***n=119***
Less than 4 hours	6.7
4–6 hours	44.6
More than 6 hours	48.7
Number of clinicians at work place	***n=124***
No other clinicians	51.6
1–2 other clinicians	31.5
More than 2 other clinicians	16.9

* Some categories do not sum to 134 because of missing responses regarding clinician characteristics

5.3.2 Clinical practices usually undertaken during examination and caries risk assessment

Clinical practices included conducting a dental examination, taking radiographs and interview information for CRA.

5.3.2.1 Conducting dental examination

The most frequently reported clinical practice was drying teeth before and during a dental examination, reported by 98% of clinicians as a practice conducted "always", while disclosing solution was used least frequently (Table 5.3). Most items were skewed to one end of the distribution, with items “drying teeth”, “use blunt probe”, “assess Angle classification”, “assess tooth alignment”, “assess tooth crowding” and “assess fluorosis” skewed towards “Always” while “using cotton roll for tooth isolation” or “using disclosing solution” were skewed towards “Never”. Only four items (“brush teeth”, “clean debris”, “dental floss” and “light transillumination” for checking caries presence at aproximal surfaces) had a percentage greater than 20% for the mid-point response of “sometimes”.

Table 5.3: Distribution of dental examination procedures undertaken by the clinician for caries risk assessment

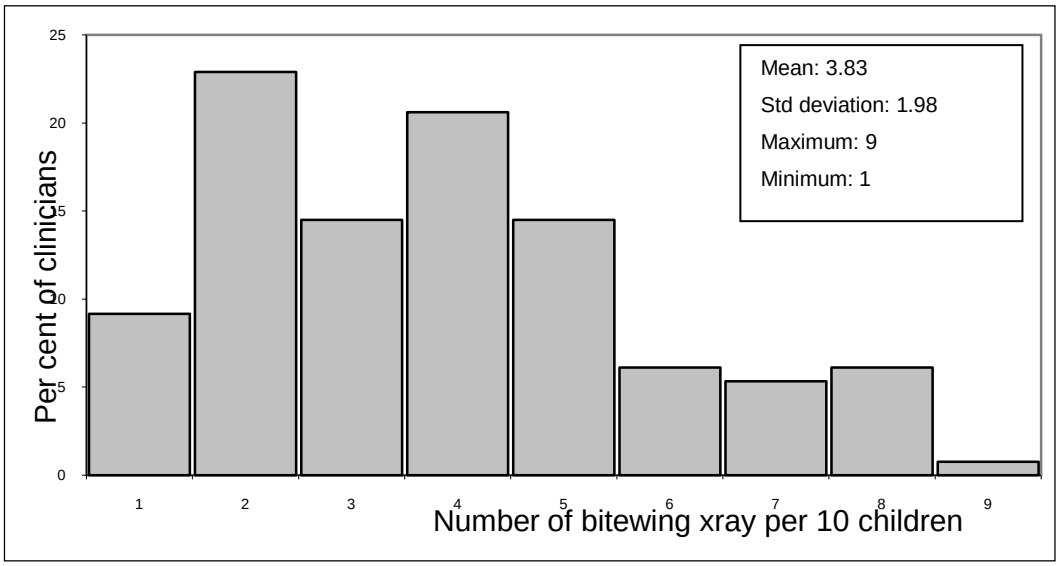
Question: When you conduct an initial or recall examination, how often do you…? **Clinical examination procedures**	Distribution of responses (%)							
	Always	**Often**	**Sometimes**	**Rarely**	**Never**	**Mean**	**SD**	**Skewness**
Dry teeth with compressed air during examination?	97.7	1.5	0.8	0.0	0.0	**4.9**	0.2	-7.74
Assess teeth for crowding?	79.7	17.3	2.3	0.8	0.0	**4.8**	0.5	-2.45
Assess tooth alignment in the dental arch?	73.7	22. 6	3.8	0.0	0.0	**4.7**	0.5	-1.60
Assess the child's orthodontic (Angle) classification?	62.4	24.8	12.0	0.0	0.8	**4.5**	0.8	-1.48
Look for signs of dental fluorosis?	55.6	30.1	9.8	3.0	1.5	**4.4**	0.9	-1.45
Use a blunt probe to detect caries in a questionable area?	51.5	28.0	14.4	3.8	2.3	**4.2**	1.0	-1.3
Clean approximal surfaces with dental floss before examination?	18.8	16.5	35.3	20.3	9.0	**3.2**	1.2	0.03
Use transillumination or reflected light for caries diagnosis?	21.2	9.1	32.6	18.9	18.2	**3.0**	1.4	0.14
Clean debris and calculus before examination?	2.3	10.5	54.9	25. 6	6.8	**2.8**	0.8	-0.03
Ask a child to brush his/her teeth before the examination?	3.0	2.3	33.1	48.9	12.8	**2.3**	0.8	2.75
Isolate teeth with cotton rolls during examination?	0.0	0.0	7.5	30.8	61.6	**1.5**	0.6	1.06
Use disclosing solutions or tablets to detect caries?	0.7	2.3	5.3	14.4	77.3	**1.3**	2.8	1.50

SD: Standard deviation;

5.3.2.2 Distribution of average number of bitewing radiographs taken per 10 children

The average number of bitewing radiographs reported per 10 examined children was 2.8, with most clinicians reporting 2–5 bitewing radiographs every 10 children (Figure 5.1). About 10% of clinicians took only 1 radiograph every 10 children. Arround 15% of the clinicians took from 6–10 radiographs per every 10 children they examined.

Figure 5.1: Distribution of average number of bitewings taken per 10 children examined by each clinician



5.3.2.3 Interview information for CRA

The most frequently reported question asked of patients related to brushing frequency, which was reported by 72% of clinicians as a question asked "Always", while questions about stressful life events were asked least frequently (Table 5.4). Most items were skewed to one end of the distribution, with 70–90% of always or often asking about “brushing frequency”, “fluoridated toothpaste”, “type of toothpaste” and “sugar intake”. In contrast, more than 60% of clinicians “never” or “rarely” asked questions about “stressful life events and coping”. Questions about “amount of toothpaste”, “method of clearing” and “type of drinking water” were asked with greater variability among clinicians.

Table 5.4: Distribution of interview information for caries risk assessment items

Question: During an initial or recall examination, how often do you ask a child or his/her parents/caregivers information about…?

Question asked of patients	Distribution of responses (%)							
	Always	**Often**	**Sometimes**	**Rarely**	**Never**	**Mean**	**SD**	**Skewness**
Child's frequency of brushing?	72.4	23.9	3.0	0.0	0.0	**4.70**	0.5	-1.5
Child's frequency and quantity of sugar intake?	35.8	50.7	11.2	0.7	0.7	**4.21**	0.7	-0.9
Whether or not the child uses fluoridated toothpaste?	32.0	42.0	17.9	3.7	3.0	**3.98**	1.0	-1.0
Method of clearing toothpaste after brushing (rinsing or spitting)?	27.6	35.1	30.6	3.7	2.2	**3.83**	1.0	-0.5
Type of toothpaste: low concentration or standard fluoridated toothpaste?	17.9	35.8	39.6	3.7	2.2	**3.64**	0.9	-0.3
Type of drinking water that child usually drinks (tap water, bottled water or tank water)?	17.9	26.9	44.0	8.2	2.2	**3.50**	1.0	-0.1
Amount of toothpaste placed on his/her toothbrush?	10.4	27.6	40.3	18.7	2.2	**3.26**	1.0	0.0
Child's stressful life events?	0.0	6.0	38.1	42.5	12.7	**2.38**	0.8	-0.0
Child's general coping in school (e.g. academic, social coping)?	1.5	7.5	26.1	42.5	23.9	**2.17**	0.9	0.6

SD: Standard deviation;

5.3.3 Clinician's perceptions and beliefs regarding caries risk assessment

Clinicians' perceptions and beliefs regarding CRA are comprised of two components: clinician's perceptions and beliefs on clinical factors; and clinician's perceptions and beliefs on non-clinical factors

5.3.3.1 The distribution of the clinician's perceptions and beliefs on clinical factors

Most of the items on perceptions and beliefs about clinical caries risk factors were skewed towards "Definitely important" (Table 5.5). Responses were scored from "Definitely not important" to "Definitely important" for each particular item. Almost 100% of clinicians considered that items such as "number of cavities", "past caries" and "white spot lesions" were "Definitely important" (98%; 78% and 84% respectively). The distribution of only three items such as "dental occlusion", "tooth alignment" and "tooth crowding" were not strongly skewed. Only the item on dental occlusion had over 40% of responses with neutral responses.

Table 5.5: Distribution of clinician perceptions and beliefs regarding clinical factors for caries risk assessment

Question: Based on your clinical experience and judgment, how important is each of the following in assessing children's risk of dental caries?

Description of items*	Distribution of responses (%)							
	Def. important	**Prob. important**	**Neutral**	**Prob. not important**	**Def. not important**	**Mean**	**SD**	**Skewness**
Number of new cavities	97.8	2.2	0.0	0.0	0.0	**4.97**	0.1	-6.5
White spot lesions	83.6	16.4	0.0	0.0	0.0	**4.83**	0.4	-1.8
Past caries	78.4	20.9	0.75	0.0	0.0	**4.78**	0.4	-1.6
Surface area of carious lesions	72.6	19.6	6.8	0.0	0.7	**4.64**	0.7	-2.2
The depth of carious lesions	70.7	22.6	6.0	0.8	0.0	**4.63**	0.6	-1.7
Saliva flow rate	56.1	39.4	4.5	0.0	0.0	**4.52**	0.6	-0.8
Deep pit and fissure	54.7	33.6	9.0	0.0	0.0	**4.48**	0.7	-0.9
Hypoplasia	58.7	30.8	9.8	0.0	0.7	**4.47**	0.7	-1.4
MS count	48.3	37.9	12.1	0.0	1.7	**4.31**	0.8	-1.4
Presence of plaque	48.5	35.8	9.7	5.8	0.0	**4.27**	0.9	-1.1
Unstimulated salivary pH	41.6	41.5	16.1	0.8	0.0	**4.24**	0.7	-0.5
Stimulated salivary pH	40.5	42.2	16.4	0.9	0.0	**4.22**	0.7	-0.5
Presence of gingivitis	42.5	37.3	11.2	6.7	2.2	**4.11**	1.0	-1.2
Tooth crowding	39.1	38.4	15.8	6.0	0.7	**4.09**	0.9	-0.9
Presence of fluorosis	22.4	32.1	36.6	6.7	2.2	**3.66**	1.0	-0.3
Tooth alignment	17.7	40.8	26.9	11.5	3.1	**3.58**	1.0	-0.5
Dental occlusion	9.9	22.1	40.5	17.6	9.9	**3.05**	1.1	-0.1

Responses were scored from "Definitely important" to "Definitely not important"

SD: Standard deviation;

5.3.3.2 The distribution of the clinician's perceptions and beliefs on non-clinical factors

The distribution of the clinician's perceptions and beliefs on non-clinical caries risk factors is presented in Table 5.6. Responses were scored from "Definitely important" to "Definitely not important" for each particular item. Items on "sweet snack" or "sugar drink prior to bed", "diet high in fermentable carbohydrate", and "sugar drink" were strongly skewed towards "Definitely important". The importance of "family composition", "parents' occupation" and "country of birth" were least emphasised by clinicians.

Table 5.6: Clinician's perceptions and beliefs of non-clinical caries risk factors

Description of items*	Distribution of responses (%)							
	Def. important	Prob. important	Neutral	Prob. not important	Def. not important	Mean	S.E	Skewness
Sweet snack or sugar drink prior to bed	96.2	3.1	0	0	0.7	**4.99**	0.03	-8.7
Sugar drink	91.8	7.5	0	0	0.7	**4.9**	0.04	-6.4
Sweet snacks	89.5	9.7	0	0	0.7	**4.87**	0.03	-5.6
Regular use of medication	76.1	23.1	0.8	0	0	**4.75**	0.04	-1.4
Diet high in fermentable carbohydrate	77.6	19.4	2.2	0	0.7	**4.73**	0.05	-3
Using fluoride toothpaste	75.4	20.9	3	0.8	0	**4.71**	0.05	-2.1
Tooth-brushing	73.9	19.4	3.7	2.2	0.7	**4.63**	0.06	-2.5
Fluoridated water	67.9	27.6	3	0.8	0.8	**4.61**	0.06	-2.3
General health	47.8	38.8	11.2	0.7	1.5	**4.31**	0.07	-1.4
Residence in rural areas	27.5	51.5	19.1	2.3	0	**4.04**	0.06	-0.4
Fluoride supplements	28.4	44.0	23.1	3.7	0.8	**3.96**	0.07	-0.6
Flossing	27.8	45.1	21.1	5.3	0.7	**3.94**	0.08	-0.6
Topical fluoride applications	31.3	38.1	23.9	6.0	0.8	**3.93**	0.08	-0.5
Caries in mother	31.3	35.1	24.4	8.4	0.8	**3.88**	0.08	-0.5
Caries in sibling	23.3	49.6	15.8	10.5	0.7	**3.84**	0.08	-0.7
General personal hygiene	27.1	41.5	20.3	9.8	1.5	**3.83**	0.08	-0.6
Frequency of dental check-up	29.3	34.6	25.5	7.5	3.0	**3.79**	0.09	-0.6
Non-English speaking background	18.9	46.2	25.8	8.3	0.8	**3.74**	0.07	-0.5
Parents' education	23.7	40.5	23.7	9.2	3	**3.73**	0.08	-0.6
Family composition	15.1	38.6	32.6	11.4	2.3	**3.53**	0.08	-0.3
Country of birth	13.4	41.8	32.1	7.5	5.2	**3.51**	0.08	-0.6
Family's income	18.1	35.4	36.1	13.1	2.3	**3.44**	0.08	-0.2
Parents' occupation	5.4	20.9	48.1	16.3	9.3	**2.97**	0.08	-0.2

Responses were scored from 1 (Definitely not important) to 5 (Definitely important)
SE: standard error (mean)

5.3.4 Confidence in routine practice

The majority of dental clinicians in the SA SDS reported that they were "Very confident" with diagnosing caries and treating caries (70.9% and 77.6% respectively) (Table 5.7). However, only a small minority of clinicians (<5%) reported that they were "Very confident" in identifying the cause of caries, predicting future caries or preventing future caries.

Table 5.7: Distribution of confidence items

	Very confident	*Somewhat confident*	*Not at all confident*
Identifying the cause of caries (%)	37.3	30.5	2.2
Diagnosing caries (%)	70.9	29.1	0.0
Treating caries (%)	77.6	22.4	0.0
Predicting future caries (%)	14.9	82.1	3.0
Preventing future caries (%)	9.0	77.6	13.4

5.3.5 Development of summary measures

5.3.5.1 Clinical practices usually undertaken during dental examination and caries risk assessment

5.3.5.1.1 Conducting dental examination

Items listed in Table 5.3 were used within a factor analysis. There are four factors with an eigenvalue greater than one. SAS help online stated that "If the residual correlations or partial correlations are relatively large (> 0.1), then the factors are not doing a good job explaining the data" (SAS 9.1 Help and Documentation). Most of the residual correlations or partial correlations among items in this analysis are greater than 0.1 indicating that the correlations among the 12 items cannot be reproduced fairly accurately from the retained factors. The root mean squared off-diagonal residual is 0.15. The inspection of the partial correlation matrix yields similar results: the correlations among the 12 items after the retained factors are accounted for are almost greater than 0.1. The root mean squared partial correlation is 0.23, indicating that four factors can not accurately account for the observed

correlations among the 12 items. Furthermore, the combination of items to form a subscale did not make sense. For example, according to the factor analysis (Table 5.8) F2 was the combination of "Dry air before examination" and "Look for sign of dental fluorosis". These two items were difficult to be grouped under a title for one subscale. In addition, results showed a similar trend when using 3 or 5 factors solution. For above mentioned reasons, factor analysis was not applied for reducing items of question 1 (Appendix 2). In order to reduce this battery of items we decided to eliminate 4 items based on the distribution of items (Table 5.3). Almost all (98%) clinicians reported that they always "dried teeth with compressed air during examination". Therefore, "drying teeth with compressed air during examination" was eliminated from further analysis. Items "Isolate teeth with cotton rolls during examination" and "Use disclosing solutions or tablets to detect caries" were not required in the SA SDS examination protocol and therefore were not presented in the analysis. Item "Assess Angle occlusion" was not presented as it was not considered relevant to caries risk assessment. Finally 8 individual items left was " Brush teeth before examination", "Clean debris before examination", "Floss teeth before examination", "Use blunt probe to detect caries", "Use reflected light to detect caries", "Assess tooth alignment", "Assess tooth crowding" and "Look for signs of dental fluorosis". Those items were used as 8 practices factors during routine dental examination and caries risk assessment. Individual question about "number of bitewing radiographs taken per 10 children" was also used as another practice during dental examination and caries risk assessment.

Table 5.8: Factor analysis of clinician routine dental examination

Initial statistics (a)				Final statistics (b)					
Variance					Factor loading				
Factor	Eigen-value	%	Cum.%	Items label	F1	F2	F3	F4	h2
1	2.5	21.0	21.0	Brushing teeth before examination	-0.11	0.02	**0.72**	0.19	0.6
2	1.5	12.7	33.7	Clean debris before examination	0.16	-0.07	0.17	**0.79**	0.7
3	1.3	11.0	44.7	Floss teeth before examination	-0.14	0.26	0.20	0.41	0.3
4	1.1	9.4	54.1	Isolation	-0.01	0.49	0.10	0.14	0.3
5	1.0	8.7	62.8	Dry air before examination	-0.04	**0.77**	0.04	0.01	0.6
6	1.0	8.0	70.8	Use blunt probe to detect caries	0.01	0.07	-0.31	**0.61**	0.5
7	0.8	6.9	77.7	Use reflected light to detect caries	0.30	0.23	0.41	-0.20	0.3
8	0.8	6.5	84.2	Disclosing solution	0.07	0.06	**0.68**	-0.04	0.5
9	0.6	5.3	89.4	Assess Angle occlusion	**0.74**	-0.07	0.15	0.17	0.6
10	0.6	4.9	94.3	Assess tooth alignment	**0.86**	0.00	-0.02	0.05	0.7
11	0.4	3.2	97.6	Assess tooth crowding	**0.84**	0.15	-0.07	-0.13	0.8
12	0.3	2.4	100.0	Look for signs of dental fluorosis	0.46	**0.68**	-0.03	-0.14	0.7
				Variance (%)	**20.3**	**12.0**	**11.1**	**10.8**	
				Cronbach α	**0.71**	**0.32**	**0.34**	**0.03**	

(a) Method= Principal components analysis

(b) Rotation= varimax

h^2= communuality (i.e. the proportion of an item's variance explained by a factor structure)

Kaiser's measure of sampling adequacy = 0.62

R^2 of the residual correlation matrix=0.15

R^2 of partial correlation=0.23

Items which loaded on a factor are indicated in the table by a box around the factor loading

There were 10 statistically significant associations between clinician characteristics and the eight practices reported in Table 5.9. Clinicians, who were born in other countries, reported "cleaning debris before examination", "use of reflected light to detect caries" and "look for sign of fluorosis" more frequently than clinicians who were born in Australia. Clinician age and practice duration was associated with "using reflected light to detect caries". Dentists were less likely to report that they "cleaned debris before examination" than dental therapist with a diploma of dental therapy. Full-time clinicians were associated with a higher frequency of "assessing tooth crowding" and "checking for signs of fluorosis". Clinicians, who worked with only one or two other clinicians in a clinic, reported a higher level of "using dental floss to clean approximal surfaces" than clinicians who worked in clinics with more staff.

Table 5.9: Variation in conducting dental examination among clinician subgroups

Clinician characteristics	Brush teeth before examination	Clean debris before examination	Floss teeth before examination	Use blunt probe to detect caries	Use reflected light to detect caries	Assess tooth alignment	Assess tooth crowding	Look for signs of dental fluorosis
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Sex of clinician								
Male	2.0 (0.8)	2.8 (1.1)	2.7 (1.1)	3.9 (0.8)	3.3 (1.4)	4.9 (0.4)	4.8 (0.6)	4.4 (1.1)
Female	2.4 (0.8)	2.8 (0.8)	3.2 (1.2)	4.3 (1.01)	2.9 (1.4)	4.7 (0.5)	4.8 (0.5)	4.3 (0.9)
Age of clinician (years)					* *			
≤30	2.5 (1.1)	2.8 (1.1)	3.1 (1.2)	4.4 (1.1)	3.4 (1.5)	4.8 (0.5)	4.8 (0.7)	4.4 (1.0)
31–40 years	2.3 (0.7)	3.0 (0.6)	3.3 (1.3)	4.4 (0.8)	2.3 (1.3)	4.6 (0.6)	4.6 (0.6)	4.3 (0.8)
41–50 years	2.2 (0.7)	2.7 (0.8)	3.0 (1.1)	4.2 (0.9)	3.1 (1.2)	4.7 (0.5)	4.8 (0.7)	4.4 (0.9)
More than 50 years	2.5 (0.9)	2.6 (0.8)	3.3 (1.4)	4.0 (1.2)	3.0 (1.4)	4.8 (0.4)	4.7 (0.5)	4.3 (0.9)
Country of Birth		*			*			*
Australia	2.3 (0.8)	2.7 (0.8)	3.2 (1.2)	4.2 (1.0)	2.8 (1.4)	4.7 (0.5)	4.7 (0.5)	4.2 (1.0)
Overseas	2.4 (0.9)	3.1 (0.8)	3.2 (1.4)	4.3 (0.8)	3.5 (1.3)	4.8 (0.5)	4.9 (0.3)	4.7 (0.5)
Practice duration					* *			
≤10 years	2.5 (1.0)	2.9 (1.1)	3.3 (1.3)	4.3 (0.8)	3.2 (1.4)	4.7 (0.6)	4.8 (0.5)	4.5 (0.7)
11–20 years	2.2 (0.7)	2.9 (0.6)	2.8 (1.3)	4.4 (0.9)	1.9 (1.2)	4.5 (0.6)	4.5 (0.8)	4.0 (1.0)
21–30 years	2.2 (0.8)	2.8 (0.8)	3.2 (1.0)	4.2 (1.0)	3.2 (1.2)	4.7 (0.5)	4.8 (0.4)	4.0 (0.9)
More than 30 years	2.6 (1.0)	2.4 (0.7)	3.3 (1. 4)	3.8 (1.3)	3.3 (1.3)	4.8 (0.4)	4.8 (0.4)	4.3 (1.0)
Practice location								
Adelaide	2.3 (0.9)	2.7 (0.8)	3.2 (1.3)	4.2 (1.0)	2.9 (1.3)	4.7 (0.6)	4.7 (0.6)	4.2 (1.0)
The rest of the state	2.4 (0.8)	2.9 (0.8)	3.1 (1.1)	4.3 (0.9)	3.1 (1.4)	4.7 (0.5)	4.8 (0.5)	4.5 (0.7)

Table 5.9: (continued)

Clinician characteristics	Brush teeth before examination	Clean debris before examination	Floss teeth before examination	Use blunt probe to detect caries	Use reflected light to detect caries	Assess tooth alignment	Assess tooth crowding	Look for signs of dental fluorosis
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Type of degree		*			*			
Dentist	2.3 (1.0)	2.8 (0.9)	2.7 (1.2)	4.0 (0.9)	3.6 (1.3)	4.8 (0.5)	4.9 (0.5)	4. 5 (1.0)
Certificate of dental therapy	2.3 (0.8)	2.6 (0.8)	3.2 (1.1)	4.2 (1.1)	2.8 (1.2)	4.6 (0.6)	4.7 (0.5)	4.4 (0.7)
Diploma of dental therapy	2.5 (0.8)	3.1 (0.8)	3.4 (1.3)	4.4 (0.9)	2.9 (1.5)	4.7 (0.5)	4.7 (0.6)	4.2 (1.1)
Work status							*	*
Full-time	2.5 (1.0)	2.9 (0.8)	3.0 (1.2)	4.3 (0.9)	3.1 (1.4)	4.9 (0.4)	4.9 (0.3)	4.6 (0.8)
Part-time	2.2 (0.7)	2.7 (0.8)	3.3 (1.2)	4.2 (1.1)	2.8 (1.4)	4.6 (0.6)	4.7 (0.6)	4.2 (0.9)
Chairside hours with patients per day								
Less than 4 hours	2.5 (1.0)	2.6 (0.9)	3.0 (1.1)	4.2 (1.1)	3.3 (1.6)	4.6 (0.7)	4.6 (0.8)	4.2 (1.2)
4–6 hours	2.2 (0.6)	2.7 (0.7)	2.7 (1.2)	4.5 (0.7)	2.4 (1.1)	4.6 (0.6)	4.6 (0.7)	4.1 (1.1)
More than 6 hours	2.3 (0.8)	2.8 (0.8)	3.3 (1.2)	4.2 (1.0)	3.0 (1.3)	4.7 (0.5)	4.8 (0.4)	4.5 (0.6)
Number of clinicians in clinic			**					
None	2.4 (0.8)	2.6 (0.7)	3.0 (1.1)	4.2 (1.0)	2.7 (1.5)	4.6 (0.6)	4.7 (0.5)	4.2 (0.9)
1–2 other clinicians	2.2 (0.8)	2.9 (0.9)	3.5 (1.2)	4.3 (1.0)	3.0 (1.2)	4.8 (0.4)	4.8 (0.5)	4.5 (0.9)
More than 2 other clinicians	2.5 (1.1)	2.7 (0.7)	2.6 (1.1)	4.1 (0.9)	3.3 (1.5)	4.7 (0.7)	4.7 (0.6)	4.3 (0.9)

Ranged from 1 (never) to 5 (always)

* ANOVA test; significant with $p<0.05$ for difference in mean values in column below asterisk

The number of bitewing radiographs taken per 10 children varied by clinicians' characteristics (Table 5.10). Age of clinician, clinicians' practice duration and type of degree were significantly associated with the average number of bitewings taken per every 10 children. Younger clinicians and clinicians with less than 10 years of experience took more bitewings for children than older clinicians and those with more than 10 year of experience. However, this association was not monotonic as clinicians in the oldest age group and clinicians with more than 30 years of experience were more likely to take more bitewings than middle-aged clinicians and clinicians with 10 to 30 years experience. Dental therapists took more bitewings than dentists.

Table 5.10: Number of bitewings taken per 10 children by clinicians' characteristics

	Number of bitewings taken per 10 children Mean (SD)
Sex of clinician	
Male	3.7 (1.9)
Female	4.2 (2.0)
Age of clinician	*
≤30	5.3 (2.1)
31–40 years	3.5 (1.6)
41–50 years	3.3 (1.7)
More than 50 years	4.1 (2.4)
Country of Birth	
Australia	3.6 (1.8)
Overseas	4.4 (2.1)
Practice duration	*
≤10 years	5.1 (2.0)
11–20 years	3.4 (1.6)
21–30 years	3.2 (1.5)
More than 30 years	4.4 (2.5)
Location	
Adelaide	4.0 (1.8)
The rest of the state	3.7 (2.1)
Type of degree	*
Dentist	3.3 (1.7)
Certificate of dental therapy	4.9 (2.3)
Diploma of dental therapy	4.2 (1.9)
Work status	
Full-time	4.1 (2.1)
Part-time	3.7 (1.8)
Worked hours spent chairside with patients per day	
Less than 4 hours	4.0 (2.3)
4–6 hours	3.6 (2.0)
More than 6 hours	3.8 (1.9)
Number of clinicians in a clinic	
None	3.8 (1.9)
1–2 other clinicians	3.7 (2.0)
More than 2 other clinician	4.2 (2.0)

Number of bitewing ranges from 1–10

* ANOVA test; significant with $p<0.05$ for difference in mean values in column below asterisk

5.3.5.2 Interview information for CRA

Table 5.11 presents the results of a factor analysis of the relevant child/parents interview information collected for caries risk assessment. There were two factors with eigenvalues greater than 1.0. The analysis yielded a two factor solution. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was used to test if the data fit a two factor solution well. Overall, the sampling adequacy was acceptable, with KMO of 0.71 (which is above the recommended level of 0.60 (Kim 1978), and the communality values were all above 0.30, indicating the factors accounted for a large percentage of the sample variance of each variable. The off-diagonal elements of the residual correlation matrix are all close to 0.01, indicating that the correlations among the 9 items can be reproduced fairly accurately from the retained factors. The root mean squared off-diagonal residual is 0.09. Both the Cronbach's alpha values were higher than 0.75. Therefore, it was accepted that the scales were reliable.

Items which loaded on a factor are indicated in the table by a box around the factor loading. The first factor (F1 - Child behaviour) consists of information on fluoride exposure and general diet and hygiene items. The second factor (F2 - Stressful events and family circumstances) consists of information on "child stress, circumstances and general coping". "Amount of toothpaste" item has ambiguous loadings. If we allowed the third factor, the item, "Source of drinking water" it became ambiguous, therefore it was eliminated from analysis. Ideally, we expect a single significant loading for each variable on only one factor. It is not uncommon, however, to observe *split loadings*, a variable which has multiple significant loadings. On the other hand, if there are variables that fail to load significantly on any factor, then it is appropriate to critically evaluate these variables and consider deriving a new factor solution after eliminating them (SAS 9.1 Help and Documentation).

Table 5.11: Factor analysis of items on interviewing for CRA

Initial statistics[(a)]				Final statistics[(b)]			
	Variance				Factor loading		
Factor	Eigenvalue	%	Cum.%	Items label	F1	F2	h^2
1	3.2	35.0	35.0	Brushing	0.68	-0.06	0.5
2	1.4	15.0	50.0	Using fluoride toothpaste	0.63	0.13	0.4
3	0.9	11.0	61.0	Type of toothpaste	0.64	0.24	0.5
4	0.8	9.0	70.0	Amount of toothpaste	0.47	0.44	0.4
5	0.8	8.0	78.0	Rising or spitting	0.68	0.16	0.5
6	0.7	7.0	85.0	Source of drinking water	0.58	0.25	0.4
7	0.6	6.0	92.0	Sugar intake	0.63	-0.01	0.4
8	0.4	5.0	97.0	Stress and circumstances	0.12	0.81	0.6
9	0.3	3.0	100.0	General coping	0.02	0.89	0.7
				Variance (%)	**37.0**	**15.0**	
				Cronbach α	**0.75**	**0.71**	

(a) Method= Principal components analysis

(b) Rotation= varimax

h^2= communuality (i.e. the proportion of an item's variance explained by a factor structure)

Kaiser's measure of sampling adequacy=0.71

R^2 of the residual correlation matrix=0.09

R^2 of partial correlation=0.33

Items which loaded on a factor are indicated in the table by a box around the factor loading

The 6 items regarding behaviours that loaded on the first factor were summed to produce a "child's behavioural" subscale, which had a mean of 3.9 and standard deviation of 0.6. The two remaining items were summed to produce a "child stressful life events and family circumstances" subscale, and it had a lower mean of 2.3 (SD=0.7). The difference in mean subscale scores indicated that clinicians were more likely to ask patients about their dental behaviours than their psychosocial background.

Table 5.12 presents variation among clinician subgroups in their patient interviewing for CRA subscale scores. Questions regarding child behaviours were more likely to be asked by clinicians born elsewhere. Clinician's country of birth and practice duration was significantly associated with the subscale "child stressful life events and family circumstances". Clinicians who were not born in Australia were also more likely to collect information on "child stressful life events and family circumstances". Clinician with less than 10 years experience were most likely to collect information on "child stressful life events and family circumstances" while the clinicians with 10 to 20 years of experience were least likely to do so.

Table 5.12: Sub-scale score for child-related information collected by clinicians by clinician characteristics[(a)]

	Child Behaviours		Child stressful life event and family circumstances	
	Mean	**SD**	**Mean**	**SD**
Sex of clinician				
Male	3.5	0.6	2.3	0.6
Female	3.9	0.5	2.3	0.8
Age of clinician				
≤ 30	4.0	0.5	2.5	0.6
31–40 years	3.8	0.6	2.1	0.8
41–50 years	3.8	0.5	2.2	0.6
51+ years	3.9	0.6	2.5	0.9
Country of Birth	*		*	
Australia	3.8	0. 5	2.1	0.7
Overseas	4.1	0.6	2.6	0.8
Practice duration			*	
<10 years	4.0	0.6	2.6	0.6
10–20 years	3.7	0.5	1.9	0.9
20–30 years	3.8	0.5	2.2	0.7
>30 years	4.0	0.6	2.4	0.9
Location				
Adelaide	3.9	0.5	2.3	0.6
The rest of the state	3.8	0.6	2.3	0. 8
Practice of degree				
Dentist	3.6	0.06	2.2	0.1
Certificate of DT	3.9	0.1	2.5	0.06
Diploma of DT	4.0	0.08	2.2	0.08
Work status				
Full-time	3.8	0.6	2.4	0. 6
Part-time	3.9	0.7	2.2	0.7
Chairside hours with patients per day				
Less than 4 hours	3.8	0.7	2.1	0.7
4–6 hours	3.8	0.5	2.2	0.7
More than 6 hours	3.9	0. 5	2.3	0.8
Number of clinicians in a clinic				
None	3.8	0.6	2.2	0.7
1–2 other clinicians	4.0	0.5	2.3	0.8
More than 2 other clinician	3.7	0.5	2.5	0.7

(a) scales range from 1 (never) to 5 (always)

* ANOVA test; significant with p<0.05 for difference in mean values in column below asterisk

5.3.5.3 Clinician's perceptions and beliefs about clinical factors regarding caries risk assessment

Table 5.13 presents the results of a factor analysis of clinicians' perception of clinical items. A four-factor solution was chosen based on eigenvalues greater than 1.0. The first factor accounted for 29% of the variance, but the remaining factors accounted for less than 10% of the variance. The measure of sampling adequacy (KMO) was 0.71 which is higher than the acceptable level (0.60). A four-factor solution, comprising 17 items is presented.

The items on fluorosis and hypoplasia had low communality values and they tended to load together but had low reliability measured by Cronbach's alpha and added little explanatory value as a subject matter dimension (Brennan 1999). If a fifth factor was allowed, fluorosis loaded on the fifth factor but hypoplasia is still ambiguous, therefore a four factors solution was accepted and fluorosis and hypoplasia were eliminated from further analysis.

The four factor solution had communality values all above 0.30, indicating the factors account for a large percentage of the sample variance. The values of Cronbach's alpha ranged from 0.6 to 0.8, indicating adequate reliability for the items loading strongly on each factor, which are indicated by boxes around the factor loadings in the table.

The factor structure and items loading on each factor obtained from the factor analysis was interpreted as follows:

- The first factor (QF 1-Ecology) comprised a range of items related to saliva condition, such as "saliva flow rate", "unstimulated salivary pH" and "stimulated salivary pH".
- The second factor (QF 2-Plaque) consisted of items relating to tooth morphology and level of oral hygiene practice, such as "deep pit and fissure", "tooth crowding", and "presence of plaque and gingivitis".
- The third factor (QF 3-Current caries) comprised items related to the severity of current caries disease, such as "number of new cavities", "the surface area of carious lesion", and "the depth of carious lesion".

- The fourth factor (QF 4-Past caries) had experience of disease related items, such as “past caries” and “white spot lesion”.

Table 5.13: Clinician's perceptions and beliefs on clinical factors regarding caries risk assessment

Initial statistics [a]				Final statistics [b]					
Factor	Eigenvalue	Variance		Factor loading					
		%	Cum.%	Items	QF1	QF2	QF3	QF4	h^2
1	5.0	29.4	29.4	Number of new cavities	-0.01	-0.04	0.62	0.45	0.6
2	2.0	11.6	41.0	Past caries	0.10	0.12	-0.10	0.72	0.6
3	1.7	9.9	51.0	White spot lesions	0.16	0.22	0.21	0.62	0.5
4	1.4	8.1	59.1	Surface area of carious	0.14	0.19	0.80	-0.15	0.7
5	1.0	7.1	66.1	The depth of carious lesions	0.10	0.18	0.89	0.03	0.8
6	0.9	5.6	71.7	Deep pit and fissure	0.24	0.57	0.02	0.48	0.6
7	0.9	5.1	76.8	Dental occlusion	0.22	0.70	0.10	-0.27	0.6
8	0.8	4.5	81.2	Tooth alignment	0.33	0.68	0.16	0.04	0.6
9	0.6	3.8	85.1	Tooth crowding	0.42	0.55	0.12	0.12	0.5
10	0.5	3.4	88.4	Presence of plaque	-0.08	0.59	-0.03	0.35	0.5
11	0.4	2.7	91.1	Presence of gingivitis	-0.15	0.70	0.07	0.19	0.5
12	0.4	2.5	93.6	Presence of fluorosis	0.10	0.45	0.14	0.09	0.2
13	0.3	1.9	95.5	Saliva flow rate	0.80	0.15	-0.02	0.12	0.7
14	0.3	1.6	97.1	Unstimulated salivary pH	0.89	0.16	0.08	-0.03	0.8
15	0.2	1.5	98.6	Stimulated salivary pH	0.87	0.15	0.09	0.02	0.8
16	0.1	1.0	99.6	MS count	0.66	-0.07	0.24	0.32	0.6
17	0.1	0.4	100.0	Hypoplasia	0.34	0.37	-0.06	0.27	0.3
				Variance (%):	18.9	16.9	12.4	11.7	
				Cronbach α	0.88	0.77	0.68	0.63	

(a) Method= Principle component

(b) Rotation= varimax

h^2= communuality (i.e. the proportion of an item's variance explained by a factor structure)

Kaiser's measure of sampling adequacy = 0.67

R^2 of the residual correlation matrix=0.08

R^2 of partial correlation=0.21

Items which loaded on a factor are indicated in the table by a box around the factor loading

Shaded items represent those that did not load on any factor

Four subscales were computed by summing items that loaded heavily on the subscales shown in Table 5.14. Fluorosis and hypoplasia were not used to compute subscales scores because they had ambiguous loadings. The mean values for those subscales ranged from 3.9 to 4.8. The subscales were treated as continuous variables, ranging from 1 "Definitely not important" to 5 "Definitely important". Scores from 4 to 5 represent a perception of the importance of an individual factor.

The average rating of importance was greatest for items regarding "past caries", while "Plaque" subscale had the lowest average rating of importance.

Table 5.14: Distribution of clinician's perceptions and beliefs on subscale for clinical factors regarding caries risk assessment[(a)]

	Description of subscale	N	Mean	SD
QF1	Ecology	134	4.34	0.6
QF2	Plaque	134	3.90	0.6
QF3	Current caries	134	4.75	0.4
QF4	Past caries	134	4.80	0.3

(a) subscale range from 1 (definitely not important) to 5 (definitely important)

There were five statistically significant associations between clinician characteristics and the four practices reported in Table 5.15. The differences between groups were relatively small.

Sex of clinician was significantly associated with perception of importance of the "Plaque" subscale, with females having a higher perception of importance. Age of the clinician was associated with perception of a greater importance for the "Ecology" subscale. Practice duration was associated with the "current caries" subscale. However, this association was not monotonic. Type of degree was associated with "Plaque" and "Current caries" subscales. Clinicians with a diploma of dental therapy placed greater importance of "Plaque" subscale and less importance of "Current caries" subscales than clinicians with other types of qualifications.

Table 5.15: Clinician's perceptions and beliefs on subscales for clinical factors regarding caries risk assessment by clinician characteristics[a]

	Ecology		Plaque		Current caries		Past caries	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Sex of clinician			*					
Male	4.6	0.4	3.6	0.6	4.6	0.7	4.6	0.3
Female	4.3	0.6	3.9	0.6	4.8	0.4	4.8	0.4
Age of clinician	*							
≤ 30	4.4	0.5	3.9	0.4	4.7	0.5	4.9	0.4
31–40 years	4.1	0. 6	3.9	0.4	4.7	0.5	4.7	0.4
41–50 years	4.5	0.5	4.0	0.6	4.9	0.3	4.9	0.3
51+ years	4.4	0.6	3.7	0.6	4.7	0.5	4.7	0.4
Country of Birth								
Australia	4.3	0.6	3.9	0.6	4.8	0.4	4.8	0.3
Overseas	4.3	0.7	4.0	0.5	4.7	0.5	4.7	0.4
Practice duration					*			
<10 years	4.3	0.6	4.0	0.6	4.6	0.5	4.8	0.4
10–20 years	4.1	0.6	3.9	0.5	4.7	0.4	4.7	0.4
20–30 years	4.4	0.5	3.9	0.6	4.9	0.2	4.8	0.3
>30 years	4.5	0.6	3.7	0.6	4.6	0.5	4.8	0.3
Location								
Adelaide	4.3	0.6	4.8	0.6	4.7	0.4	4.9	0.3
The rest of the state	4.3	0.6	4.0	0.6	4.6	0.5	4.8	0.4
Type of qualification			*		*			
Dentist	4.5	0.6	3.6	0.6	4.8	0.3	4.7	0.3
Certificate of DT	4.4	0.5	3.9	0.6	4.8	0.5	4.9	0.3
Diploma of DT	4.2	0.6	4.0	0.5	4.5	0.5	4.8	0.4
Work status								
Full-time	4.3	0.6	3.9	0.6	4.7	0.5	4.8	0.4
Part-time	4.3	0.6	3.9	0.6	4.9	0.4	4.8	0.3
Worked hours spent chairside with patients per day								
Less than 4 hours	4.3	0.6	3.8	0.6	4.8	0.3	4.9	0.3
4–6 hours	4.3	0.6	3.9	0.4	4.8	0.3	4.8	0.3
More than 6 hours	4.3	0.6	3.9	0.6	4.7	0.5	4.8	0.4
Number of clinicians in a clinic								
None	4.3	0.6	3.9	0.7	4.7	0.4	4.9	0.3
1–2 other clinicians	4.4	0.6	3.9	0.6	4.8	0.4	4.8	0.4
More than 2 other clinicians	4.3	0.7	4.0	0.5	4.8	0.4	4.8	0.3

(a) subscales range from 1 (definitely not important) to 5 (definitely important)

* ANOVA test; significant with p<0.05 for difference in mean values in column below asterisk

5.3.5.4 Clinician's perceptions and beliefs on non-clinical factors regarding caries risk assessment

Table 5.16 presents the results of a factor analysis of the clinician's perceptions and beliefs on non-clinical items. Six factors had eigenvalues greater than 1.0, plus another factor had an eigenvalue just below 1.0. The first factor accounted for 26% of the variance, the second factor accounted for 17% of the variance, but none of the remaining factors accounted for more than 7.7% of the variance. The measure of sampling adequacy was high (0.82). A four-factor solution, comprising 19 of the original set of 23 items is presented.

This solution was developed through consideration of four- to seven-factor solutions, initially comprising all 23 items. However, a four-factor solution was the best way to group items together that make sense. This solution explained 55% of variance, which was good in comparison to the preceding factor analysis. The three-factor solutions was run, however, this solution only explained 50% of variance. Therefore, in terms of developing summary measures of clinician's perceptions and beliefs regarding caries risk assessment, a four-factor solution was sensible.

The four-factor solution had communality values all above 0.30 except for item 23 (Table 5.16), indicating the factors account for a large percentage of the sample variance. The values of Cronbach's alpha are above 0.70, indicating adequate reliability for the items loading strongly on each factor, which are indicated by boxes around the factor loadings in Table 5.16.

The factor structure and items loading on each factor obtained from the factor analysis was interpreted as follows:

- The first factor (NC 1 - Diet) comprised a range of items related to diet, such as "diet high in fermentable carbohydrate", "sweet snacks", "sweet snack or sugar drink prior to bed".
- The second factor (NC 2 - Socioeconomic status) consisted of items relating to socio demographic status, such as "income", "education", and "family composition" and an item which related to socioeconomic status, "Caries in mother".

- The third factor (NC 3 - Fluoride exposures) comprised items related to general health, such as “use of medication” and items related to fluoride exposure such as “topical fluoride”, “fluoride supplement” and “fluoride toothpaste use”.
- The fourth factor (NC 4 - Dental behaviour) had mainly dental behaviour related items, such as “flossing”, “tooth-brushing”, and “frequency of dental check-up”.

Residence in rural areas, country of birth, general personal hygiene and caries in sibling were not used to compute subscale scores because they had ambiguous loadings (SAS 9.1 Help and Documentation).

Table 5.16 Factor analyses of clinician's perceptions and beliefs on non clinical factors regarding caries risk assessment

Initial statistics[a]				Final statistics[b]					
Factor	Eigen values	Variance			Factor loading				
		%	Cum.%	Items	NC1	NC2	NC3	NC4	h2
1	5.9	25.7	25.7	Non E speaking background	-0.01	0.72	0.19	-0.07	0.6
2	4.0	17.3	43.0	Family's income	-0.05	0.88	0.03	0.10	0.8
3	1.8	7.7	50.7	Residence in rural areas	0.02	0.43	0.40	-0.19	0.4
4	1.3	5.7	56.4	Family composition	-0.10	0.75	0.06	0.19	0.6
5	1.2	5.2	61.7	Parents' education	-0.02	0.77	0.01	0.32	0.7
6	1.2	5.0	66.7	Parents' occupation	0.06	0.74	0.04	0.08	0.6
7	0.92	4.2	70.8	Country of birth	0.37	0.33	0.37	-0.32	0.5
8	0.82	3.6	74.5	General personal hygiene	0.44	0.35	0.07	0.44	0.5
9	0.73	3.2	77.7	Tooth-brushing	0.48	-0.15	0.11	0.57	0.6
10	0.7	3.0	80.7	Flossing	0.39	0.14	0.17	0.67	0.6
11	0.6	2.6	83.2	Frequency of dental check-up	0.38	0.16	0.15	0.65	0.6
12	0.5	2.3	85.6	Diet high in fermentable carbohydrate	0.78	0.08	0.08	0.24	0.7
13	0.5	2.2	87.8	Sweet snacks	0.91	0.00	0.07	0.09	0.8
14	0.4	2.0	89.7	Sugar drink	0.88	-0.05	0.12	0.09	0.8
15	0.4	1.8	91.5	Sweet snack or sugar drink prior to bed	0.91	-0.09	0.01	0.04	0.8
16	0.4	1.6	93.1	Fluoridated water	-0.15	0.24	0.58	0.17	0.4
17	0.3	1.5	94.6	Topical fluoride applications	0.07	0.08	0.77	0.13	0.6
18	0.3	1.3	95.9	Fluoride supplements	0.08	-0.04	0.81	0.09	0.7
19	0.2	1.1	97.0	Using fluoride toothpaste	-0.01	0.07	0.50	0.43	0.4
20	0.2	1.0	98.0	General health	0.25	0.27	0.48	-0.09	0.4
21	0.2	0.9	99.0	Regular use of medication	0.25	0.04	0.47	0.16	0.3
22	0.1	0.6	99.6	Caries in mother	0.10	0.50	0.33	-0.10	0.4
23	0.0	0.4	100.0	Caries in sibling	-0.01	0.23	0.14	0.22	0.1
				Variance (%)	18.4	17.2	12.4	8.8	
				Cronbach α	0.82	0.823	0.72	0.75	

(a) Method= Principle component

(b) Rotation= varimax

h^2= communuality (i.e. the proportion of an item's variance explained by a factor structure)

Kaiser's measure of sampling adequacy = 0.82

Cronbach alpha for scale containing all items = 0.859

R^2 of the residual correlation matrix=0.01

R^2 of partial correlation=0.16

Items which loaded on a factor are indicated in the table by a box around the factor loading

Shaded items represent those that did not load on any factor

The distribution of the perceived importance of non-clinical caries risk factors is presented in Table 5.17. These subscales are treated as continuous variables, ranging from 1 "definitely not important" to 5 "definitely important". Scores from 3 to 5 represent a perceived importance of non-clinical caries risk factors. The "diet" subscale was considered to be very important to CRA by most clinicians with a mean score of 4.7, while the least importance was placed on the "socioeconomic status" subscale (mean score of 3.6).

Table 5.17: Distribution of clinician's perception and beliefs on sub-scales for non clinical caries risk factors[(a)]

	Description of sub-scale	n	Mean	SD
NC1	Diet	134	4.7	0.4
NC2	Socioeconomic status	134	3.6	0.6
NC3	Fluoride exposure	134	4.4	0.5
NC4	Dental behaviours	134	4.1	0.7

[(a)] scales range from 1 (definitely not important) to 5 (definitely important)

There were only two significant differences in clinician's perceptions and beliefs of non clinical caries risk factor subscales by clinician characteristics as presented in Table 5.18.

The statistically significant differences occurred for sex of clinician for the "socioeconomic status" scale. Male clinicians were more likely to perceive the "socioeconomic status" sub-scale as an important factor compared with female clinicians. Dentists put a higher level of importance on the "socioeconomic status" sub-scale compared with dental therapists.

Table 5.18: Clinician's perceptions and beliefs on clinical factors regarding caries risk assessment by clinician characteristics[(a)]

	Diet		Socioeconomic status		Fluoride exposure		Dental behaviours	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Sex of clinician			*					
Male	4.7	0.7	4.0	0.3	4.2	0.6	4.0	0.5
Female	4.7	0.5	3.5	0.6	4.4	0.5	4.2	0.7
Age of clinician								
≤ 30	4.5	0.3	3.7	0.6	4.4	0.4	4.1	0.6
31–40 years	4.7	0.3	3.4	0.6	4.3	0.5	4.2	0.6
41–50 years	4.7	0.3	3.6	0.6	4.4	05	4.1	0.7
51+ years	4.6	0.4	3.7	0.8	4.4	0.4	4.0	0.7
Country of Birth								
Australia	4.7	0.5	3.6	0.6	4.4	0.5	4.2	0.7
Overseas	4.7	0.3	3.7	0.7	4.4	0.4	4.2	0.8
Practice duration								
<10 years	4.7	0.3	3.7	0.6	4.4	0.5	4.3	0.7
10–20 years	4.7	0.3	3.4	0.7	4.3	0.6	4.2	0.6
20–30 years	4.7	0.3	3.6	0.7	4.4	0.5	4.1	0.7
>30 years	4.3	0.9	3.8	0.6	4.4	0.4	3.8	1.0
Location								
Adelaide	4.7	0.6	3.6	0.7	4.3	0.5	4.2	0.8
The rest of the state	4.6	0.3	3.5	0.6	4.4	0.4	4.1	0.6
Type of degree			*					
Dentist	4.6	0.6	4.0	0.6	4.3	0.5	3.8	0.8
Certificate of Dental Therapy	4.6	0.3	3.5	0.5	4.4	0.4	4.2	0.8
Diploma of Dental Therapy	4.8	0.3	3.5	0.7	4.4	0.5	4.3	0.5
Work status								
Full-time	4.7	0.3	3.7	0.6	4.4	0.4	4.2	0.7
Part-time	4.6	0.5	3.5	0.7	4.4	0.5	4.1	0.7
Chairside hours spent with patients per day								
Less than 4 hours	4.5	0.9	3.7	0.5	4.4	0.5	4.1	1.0
4–6 hours	4.8	0.1	3.6	0.6	4.4	0.4	4.3	05
More than 6 hours	4.7	0.3	3.6	0.7	4.4	0.5	4.1	0.7
Number of clinicians in a clinic								
None	4.6	0.7	3.5	0.7	4.4	0.5	4.2	0.8
1-2 other clinicians	4.6	0.3	3.6	0.5	4.3	0.4	4.1	0.7
More than 2 other clinician	4.7	0.3	3.7	0.8	4.4	0.5	4.2	0.7

(a) scales range from 1 (definitely not important) to 5 (definitely important)

* ANOVA test; significant with $p<0.05$ for difference in mean values in column below asterisk

5.4 Discussion

5.4.1 Overview of findings

In this study, several clinical procedures in caries risk assessment were almost universally practised by SA SDS clinicians and several beliefs regarding caries were almost universally held. However, there was considerable variability reported in clinicians' use of some risk-assessment procedures (e.g. use of bitewings, consideration of child's stressful life events and social circumstances). It proved difficult to compute summary measures of practices, perceptions and beliefs regarding caries risk assessment using factor analysis, a procedure that is often useful for data reduction. Regardless of how summary variables were computed, there was a striking lack of variability in reported risk assessment practices, perceptions and beliefs between subgroups of clinicians, classified by demographic characteristics, work experience and work environment.

5.4.2 Strengths and limitations

To the author's knowledge, this is the first study to report on clinicians' clinical practices, perceptions and beliefs regarding caries risk assessment. There were only few available instruments that might effectively collect information on these factors. Therefore, the questionnaire was developed with a large number of items that might plausibly be related to caries risk assessment. Because of the large number of items and new questionnaire, factor analysis was done in an attempt to find underlying constructs. Two underlying factors on child's social and family circumstances were identified. Four other underlying factors on clinician's perception and belief of clinical factors on caries risk assessment and another four underlying constructs on clinician's perception and belief of non-clinical factors on caries risk assessment were identified.

The study sample included all clinicians who worked for the SA SDS during 2002–2004. The study achieved a high participation rate (82%). Therefore, the reported results were likely to reflect the true estimates of the clinician population in the SA SDS. Furthermore, during the study period, the SA SDS provided dental care to approximately two thirds of primary school children in SA. Hence, the findings are relevant for a substantial majority of SA children.

All the participants worked for a single dental care provider. It is likely that the uniform policies and practice guideline created by SADS might have influenced caries risk assessment practices and beliefs reported by the respondents. That effect might override the true beliefs of the participants, or it might shape their beliefs. And it almost certainly reduced variability of responses, and hence probably reduced power to detect effects of clinician characteristics on beliefs/practices. Hence, there is a need for a further investigation in a more heterogeneous environment to better understand the association between caries risk assessment practices and perceptions with the outcome of clinician prediction of caries development.

This sub-study provided a basis for an important link between the findings of clinicians' practices and beliefs, outcomes of their practices and the oral health outcomes of the children in this study. The evaluation of this relationship is presented in Chapter 6.

5.4.3 Interpretation of the results

Many of the practices were reported almost universally, or with very little variation, producing skewed distributions for most of the items concerning clinicians' clinical practices. Almost 100% of clinicians dried teeth and used a blunt probe as an aid in diagnosing carious lesions. This is consistent with principles which are well documented.

There was greater variation in clinicians' frequency of querying information for caries risk assessment. Frequency of sugar intake and tooth brushing were asked frequently by clinicians, while fluoride exposure was asked less frequently. Child and family circumstances were asked least. This pattern was consistent with much of what is taught in dental schools, where importance of diet and oral hygiene for caries prevention are emphasised, despite the absence of evidence for their aetiological influence.

A similar situation pertained to clinicians' perceived importance of clinical risk factors. The common risk factors for caries were uniformly perceived by the respondents. However, there was more variability in perceived importance of non-clinical risk factors.

For example, all clinicians rated number of new cavities presented at examination or past caries experience as important in assessing children's risk of dental caries. New caries presented and past caries are strong predictors of caries development in the future (Beck et al. 1992; Disney et al. 1992; Leverett et al. 1993; Li and Wang 2002). The frequency of other non-clinical factors such as the importance of child socioeconomic status was normally distributed. That item was found to be associated with clinicians' characteristics. These results again showed that this questionnaire had reasonable face validity.

The factor analysis was generally of marginal value in attempting to produce summary scores. Nearly half of variability in responses was not explained in some factor solutions. Perhaps there was insufficient variation among clinicians or perhaps there were other CRA questions that should have been asked. However, if the results were valid, it suggests that multiple underlying constructs contribute to CRA, and that those constructs cannot be easily statistically summarised.

In general, there were few differences by clinician characteristics, either in individual items (for clinical practices) or factor subscales (for perceptions/beliefs).

When statistically significant differences were observed, they were usually small in magnitude of mean difference. Also, these differences were not always monotonic. There was no single clinician characteristic that was associated with all individual or summary measures of clinical practices, perceived importance of clinical risk factors, and perceived importance of non-clinical risk factors.

In general, the observed lack of variability may be due to homogeneity of the sample of clinicians. It may also be due to the limited number of the questions that were used. Additionally, this was a self-reported responses questionnaire, which means the perceived answer of "often" or "rarely" might vary between clinicians. There may also be other unmeasured clinician factors that are more strongly associated with variation in CRA. However, the findings suggest that clinicians were fairly uniform in their beliefs and practices about CRA. This could also be true for procedures in caries risk assessment. Therefore, perceived procedures in caries diagnosis, a technical task, would show little clinician variability.

However, there is well-documented evidence of variation in clinicians' actual diagnosis of caries and in developing treatment plans (Rytomaa et al. 1979; Noar and Smith 1990). This paradox demonstrated that there can be a difference between perception and actual practice. That difference could potentially affect the level of accuracy in caries risk assessment where the actual clinical practice could have more influence. However, as caries risk assessment was mostly based on the past caries experience, this effect was expected not to bias the estimate of the accuracy of caries risk assessment.

Chapter 6. Factors associated with accuracy of clinicians' caries risk classification among SA school children

6.1 Introduction

Categorising patients by their risk of caries has been advocated as an initial step in determining appropriate preventive and treatment interventions. Several caries risk classification schemes designed for use in daily practice, have been described recently. In South Australia, since 1990, the School Dental Service (SDS) has adopted the caries risk assessment and management strategy (Chartier 1997). Because caries risk assessment (CRA) schemes are intended to help in guiding prevention and treatment-related decisions, the accuracy of CRA is expected to have implications for both the cost of care and patient disease outcomes. To date, little information has been reported describing performance of CRA schemes applied in clinical practice.

This sub-study aimed to examine the influence of clinician-related factors and child-related factors on the accuracy of caries risk assessment, performed by the SDS clinicians in routine clinical practice. It was hypothesised that sensitivity and specificity of caries risk assessment could be increased by collecting further information at the clinician level and at the child level. The main research questions were:

1. Which clinical procedures and perceptions in caries risk assessment improve clinicians' accuracy of caries risk assessment?
2. Which child-related factors need to be taken into account in predicting new caries development?

This chapter presents results of different statistical models that examine factors at the clinician and child levels influencing the estimated accuracy of caries risk assessment. Potential gains in the accuracy level by certain factors are presented and discussed.

6.2 Methods

This section presents the research methods adopted for this sub-study including data management, selection of dependent and independents variables, and the statistical approach.

6.2.1 Data management

6.2.1.1 Data sources

Datasets used for this sub-study are summarised in Figure 6.1. Two datasets used previously in sub-studies were used in this analysis. Briefly, dataset no. 1 (child data) included 71,619 children who were aged from 5–15 years, who had a time interval between the two examinations of at least 6 months. This dataset was used for the analysis in Chapter 3. As the criteria for calculating clinician accuracy (sensitivity and specificity) for each clinician required at least 20 subjects per clinician to form two by two tables, the number of children decreased slightly from 71,619 children to 71,430. These children were seen by the 133 clinicians as discussed in Chapter 4.

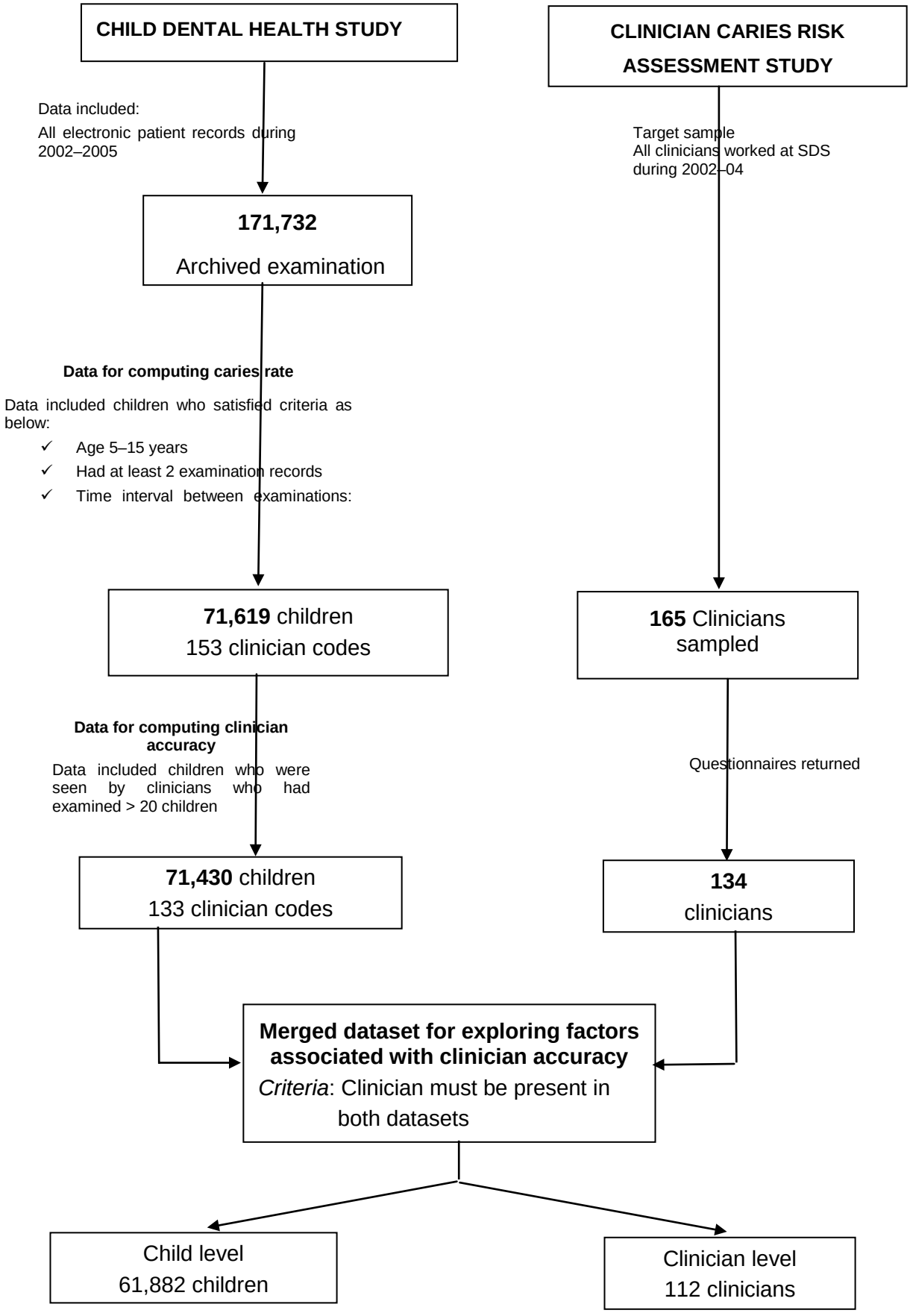
Dataset no. 2 (clinician data) was the responses of 134 clinicians who participated in the clinician survey. Descriptive findings of that survey were presented in Chapter 5.

6.2.1.2 Data merging

These two datasets were merged as shown in Figure 6.1. The identifier for merging these data was done by using clinicians' identification numbers. The datasets were merged using a many-to-one approach. Final data included 61,882 children who were examined by 112 clinicians. Approximately 10,000 children were not included resulting in the total number of 61,882 in the final merged dataset. The reason for this reduction was that 22 clinicians, who examined those children, did not participate in the clinician survey, mostly as they no longer worked for the SA SDS. These two datasets were merged and used in the subsequent analysis to explore clinician accuracy and factors associated with clinician accuracy.

At each step, the subsequent dataset were compared with previous ones to identify any discrepancies caused by reduction in number of records. The representativeness of the estimates was evaluated.

Figure 6.1: Schematic of subjects included in the study by each stage



6.2.2 Analytical approach

An analysis of representativeness of 61,882 children and 112 clinicians was done before any further analysis. The results of this analysis are presented in the Results section.

6.2.2.1 Analytical approaches

The general approach was to construct multivariate models identifying clinician and child's characteristics that were independently associated with the accuracy of CRA. This was conducted separately at two levels. The clinician-level analysis used the clinician as the unit of analysis while the child-level analysis used the child as the unit of analysis. Accuracy for the clinician-level analysis was quantified as the sum of the sensitivity and specificity of risk prediction computed from among all children examined by the clinician. Accuracy for the child-level analysis was quantified separately as sensitivity (the proportion of children predicted to have high-risk among those who developed a high rate of caries) and specificity (the proportion of children predicted to have low risk among those who developed a low rate of caries). Bivariate associations between the outcome variables and each putative explanatory variable (child and clinician's factors) were evaluated. Factors which were significant in the bivariate analysis were then included in further multivariate models to identify independent effects of explanatory variables.

6.2.2.1.1 Outcome variables: sensitivity and specificity

Similar to the method used in Chapter 4, caries rate (caries incidence density estimated and presented in Chapter 3) was used as a gold standard to compute sensitivity and specificity. The baseline and follow-up examination of the child was used in these computations. In order to facilitate comparison with other available studies, low- and medium- categories of risk assigned by clinicians at baseline were aggregated into one group and those children were contrasted with children assigned to the high risk category. Similarly, the observed rate of caries was dichotomised by classifying children as having developed a low- or medium-caries rate if their observed incidence density was less than 1.2. Otherwise, children were considered as having a high-caries rate (true high-risk) if their incidence density was 1.2 or higher. This incidence density cut off level (1.2% of surfaces at risk-years) was

used to define the high rate of developing the disease during the follow-up. This cut-off level resulted in a proportion of children with a high rate of developing caries similar to the proportion of those children where were classified as high risk at baseline. However, this method might have resulted in some expected information loss. The agreement (kappa) was also considered. However, its use would not enable comparison with other studies.

The dependent variables, sensitivity and specificity, were used as continuous variables. The potential range among clinicians was 0–100 for Se and for Sp and 100–200 for combined Se+Sp.

6.2.2.1.2 Explanatory variables

The independent variables used in the analysis were grouped into categories of clinician factors and child factors (Table 6.1). Clinician factors were: clinicians' demographics and work experience, clinical practices, interview information for CRA, clinicians' perceptions and beliefs of clinical caries risk factors, clinicians' perceptions and beliefs of non-clinical caries risk factors, and clinician reported confidence in CRA. The development of these variables was described in Chapter 5. The child factors were: child's demographics, child's socioeconomic status, and child caries experience at the baseline examination. Child caries experience and child socio-demographic factors were reported in Chapter 3.

Table 6.1: Independent variables

	Items or subscale
Clinician factors*	
Reported daily clinical practices	• Brush teeth before examination • Clean debris before examination • Floss teeth before examination • Use blunt probe to detect caries • Use reflected light to detect caries • Assess tooth alignment • Assess tooth crowding • Look for signs of dental fluorosis
Interview information for CRA	• Child behaviours • Stressful life events and family circumstances
Clinicians' perceptions and beliefs of clinical caries risk factors	• Ecology • Plaque • Current caries • Past caries
Clinicians' perceptions and beliefs of non-clinical caries risk factors	• Diet • Socioeconomic status • Fluoride exposure • Dental behaviours
Reported confidence in CRA	• Identifying the cause of caries • Diagnosing caries • Treating caries • Predicting future caries • Preventing future caries
Clinician characteristics	Age, sex, type of degree, country of birth, work status, length of experience, practice location, worked hour per day, number of clinician work with
Child factors	
Child socioeconomic characteristics	Age, sex, country of birth, healthcare card, Indigenous, residence in urban/rural area, in fluoridated/non-fluoridated area
Child caries experience	DMFS, dmfs recorded at baseline

* Questionnaire is presented in Appendix 2

6.2.2.1.3 Analyses

The analyses aimed to assess the contribution of clinician and child factors to the accuracy of caries risk assessment in the SA SDS. The accuracy of caries risk assessment was measure by sensitivity, specificity and combined sensitivity and specificity. These measures were modelled controlling for clinician age and sex. As outlined in Table 6.2, the analysis was conducted at two levels. The first level, clinician level, used clinicians as a unit of analysis with child characteristics aggregated by each clinician. The other level of analysis, child level, used children as the unit of analysis. At this level, information of the examining clinician was applied to all the children seen by that clinician.

Table 6.2: Outline of child and clinician models of clinician accuracy

	Clinician level	**Child level**
Unit of analysis	Clinician	Child
Sample size	112	61,882
Child variables (child factors)	Aggregated for each clinician from all children seen by the clinician	Included
Clinician variables (clinician-related factors)	Included	Applied to each child seen by the clinician
Significance level in bivariate analysis	p value ≤0.05 with either Se, Sp or Se+Sp	—
Method of multivariate analysis	Generalised Linear Model Regression for a continuous outcome variable	Log-binomial regression for a dichotomised outcome variable
Rationale for this analysis	To identify degree to which child- and clinician characteristics influence accuracy of CRA at the clinician level	To identify degree to which child- and clinician characteristics influence accuracy of CRA at the child level

6.2.2.2 Clinician level analysis

Sensitivity and specificity were computed by the method described in Chapter 4 for each clinician and used as the dependent variable.

Means and proportions of child factors for clinician-level were computed from all children, who were seen by an examiner to form a series of child factors for the clinician-level analysis. SAS PROC SUMMARY was used to compute the following percentages for each clinician: percentage of girls as patients, percentage of patients classified as high-risk, percentage of children holding a healthcare card, percentage of children born overseas, percentage of Indigenous children, percentage of children who lived in a fluoridated area, and percentage of children who had no caries experience at baseline. Mean age and mean deciduous dmfs and permanent DMFS of children at baseline were also computed per clinician. These summary variables were merged into a dataset built for the 112 clinicians.

The clinician survey dataset together with the summarised characteristics of children, examined by each of the 112 clinicians were used for analysis in this sub-study.

6.2.2.2.1 Bivariate analysis

Bivariate analysis of the dependent clinician accuracy variables and the independent variables was conducted. Scores of items which formed subscales from the factor analysis in the Chapter 5 were used to subdivide the clinicians into groups. The 95% confidence intervals (CI) of estimates were used to test differences among clinician groups. The independent variables of reported daily clinical practices, interview information for CRA, clinicians' perceptions and beliefs of clinical caries risk factors, and clinicians' perceptions and beliefs of non-clinical caries risk factors, were dichotomised into categories of less than the median number or equal to or greater than the median number. Summary variables for child characteristics for each clinician were also dichotomised into categories of less than the median or equal to or greater than the median. Analysis of variance was applied to test for association between clinician accuracy and clinician or child factors, with a significance level set at $p<0.05$.

6.2.2.2.2 Multivariate analysis

The multivariate analysis at the clinician level involved Generalised Linear Regression models (GLM) using PROC GLM in SAS 9.0.

Separate multivariate models were generated for each of three dependent variables: sensitivity, specificity and combined sensitivity and specificity. The selection of factors to be included in the models was based on p values of the associations in the bivariate analysis. Factors that had a p value of less than or equal to 0.05 in the bivariate analysis with the outcome variable were included in the multivariate models. Age and sex of clinician were also routinely selected as covariates in the models.

Two models were generated for each of the outcome variables in the clinician-level analysis. Model 1 adjusted for clinician factors and Model 2 extended the first model by adding child factors. Model 1 aimed to examine the effect of clinician practices on the accuracy of caries risk assessment while Model 2 evaluated and adjusted the effect of child factors on the level of caries risk assessment accuracy.

6.2.2.3 Child level analysis

Clinician's overall accuracy was calculated in Chapter 4(Figure 4.3, Figure 4.4 and Figure 4.5). In this analysis, clinicians' overall accuracy (Se+Sp) and clinicians' factors were merged to each individual child's record. Clinicians' factors which were significant in clinician-level multivariate analyses were chosen to be included in this child-level analysis.

Clinicians with different scores of overall accuracy (Se+Sp) were divided into three groups. Clinicians with the combined Se+Sp value of less than or equal to 120 were grouped into the low level of accuracy group; clinicians with a range of overall accuracy from 120-less than 140 were grouped into the medium level of accuracy group and clinicians who had overall accuracy greater than or equal to 140 were considered having a high level of accuracy. Clinician sensitivity, specificity and overall accuracy (Sp+Se) were imputed to the record of each child who was examined by that clinician at baseline.

Clinician factors collected in the clinician survey (Chapter 5) were linked to records for all of the children each clinician had seen, with the child forming the unit of analysis.

6.2.2.3.1.1 Multivariate analysis

A number of multivariate regression models were generated using SAS PROC GENMOD. The purpose of these models was to estimate proportions of variance in sensitivity and specificity scores that could be explained by certain child-related and clinician-related factors. To achieve this purpose, children were stratified into groups with a high rate of caries, i.e. with incidence density of 1.2 or higher (for sensitivity score) and with a low rate of caries (for specificity score). Risk status at baseline was then used as a dichotomised outcome variable in the respective models. The models estimated probabilities using binomial distribution and identity link. Level of significance, direction and magnitude of the effect of each factor were evaluated.

In the models for sensitivity, the estimate of being predicted as high-risk of developing caries at baseline among children who had developed a high caries rate was estimated. The intercept of this model was the estimated sensitivity in the population when all factors were zero. The estimates of individual factors indicated direction and magnitude of effect of those factors. If the estimate of a factor were positive, adding that factor to the model would increase the sensitivity of the total model. In contrast, if the estimate of a factor was negative, adding that factor would decrease the total sensitivity.

In the models of specificity, probability of being predicted as low risk at baseline among children who had a low rate of the disease during the follow-up were estimated. Similarly, direction and magnitude of the effect of individual factors were presented as the estimates of the models.

Model building:

Table 6.3: Summary of model developing

	Model for sensitivity The probability of having high-risk status at baseline among children who had a high rate of caries was modelled	**Model for specificity** The probability of having low-risk status at baseline among children who had a low rate of caries was modelled
Sub-sample:	Children who developed a high rate of caries	Children who developed a low rate of caries
Model 1 Used child characteristics as independent variables only	Outcome: being high-risk at baseline	Outcome: being low-risk at baseline
Model 2 Used child characteristics adding clinician overall accuracy	Outcome: being high-risk at baseline	Outcome: being low-risk at baseline
Model 3 Used child characteristics adding clinician characteristics	Outcome: being high-risk at baseline	Outcome: being low-risk at baseline

There were three stages of model building.

- Model 1 used only child characteristics including sex, country of birth, residence, healthcare card status, Indigenous status and caries experience.
- Model 2 extended Model 1 with estimates of clinician overall accuracy. Clinician accuracy was described in section 6.2.2.3. Basically, clinicians were grouped into three categories: low accuracy clinician, moderate accuracy clinician and high accuracy clinician.
- Model 3 used child characteristics and clinician characteristics. This model includes all child characteristics and clinician variables which were statistically significant associated with clinician accuracy found in clinician-level multivariate analysis.

Based on estimates of the multivariate regression Model 2, two scenarios were set up to evaluate direction and magnitude of effects of children factors on the accuracy estimates. Clinician accuracy was estimated among children who had a more

favourable risk profile (children who were born in Australia, non-cardholders and those who resided in fluoridated areas) and among children who had a less favourable risk profile (children who were born overseas, who were cardholders and who resided in non-fluoridated areas).

Based on estimates of Model 3, two groups of clinicians (clinicians who collected less information on child stress and family circumstances and who took fewer bitewing radiographs, versus the group of clinicians who frequently collected information on child stress and family circumstances and frequently took bitewing radiographs) were compared.

6.2.3 Development of caries prediction models

This section describes development of the predictive models that would better predict future caries for children in the SADS. The purpose of this analysis was to develop an algorithm that would increase the overall accuracy of caries risk assessment for this child population. The outcome variable was the rate of caries during the follow-up, dichotomised as high rate (incidence density of 1.2 or higher) or low rate (incidence density of less than 1.2). Factors that were found to influence the sensitivity and specificity scores in section 6.2.2 were used as predictive factors in these models, in addition to the risk status assigned by the clinicians at baseline.

Last model was run among only children with no caries experience at baseline.

Logistic regression was used to generate these predictive models. A series of models were consecutively generated. The outcome variable was dichotomised as having high rate of caries during the follow-up (incidence density of 1.2 or higher) versus having low or medium rate of caries.

For Model 1, the clinician judgement of caries risk was used to predict future caries for children.

Level of dmft+DMFT at baseline examination was added to Model 1 to form Model 2. Children's DMFT+dmft were grouped into four groups: children with no caries experience at baseline (DMFT+dmft=0), children who had from 1 to 5 surfaces with caries experience (1≤DMFT+dmft<5), children who experienced from 5–10 surfaces

with caries experience (5≤DMFT+dmft<10) and children with 10 or more surfaces with caries experience (DMFT+dmft≥10).

Model 3 extended Model 2 by adding age group of the children. Three age groups were used: 5-7 year olds (mainly deciduous dentition), 8–12 year olds (mixed dentition) and 13–15 year olds (mainly permanent dentition).

Model 4 extended Model 3 by including a number of child demographic and socioeconomic characteristics that were available in the electronic patient record system. The factors were: healthcare card holder status, Indigenous status, residence in fluoridated or non-fluoridated areas and country of birth.

The performance of each model was defined as that test with the highest combined sensitivity and specificity. Receiver Operating Curve (ROC) was used to evaluate the performance of each model. The area under curve and 95% CI were measured for each model and then compared among these models.

6.3 Results

There were 112 clinicians who examined 61,882 children included in the analysis.

6.3.1 Representative of sample

There was no significant difference among the full sample of 131 clinicians who participated in the clinician CRA survey, presented in Chapter 5, and the final sample of 112 clinicians who were included in this analysis (Table 6.4).

Table 6.4: Representativeness of clinician's sample

Clinicians' characteristics	Full sample	Sample of 112 clinicians
Sex	***n=131***	***n=112***
Male	11.4	10.0
Female	88.6	90.0
Age group	***n=126***	***n=112***
≤30 years	12.7	19.6
31–40 years	25.1	23.2
41–50 years	41.3	38.4
More than 50 years	20.6	18.4
Type of degree	***n=134***	***n=112***
Dentist	17.2	13.4
Certificate of DT	53.0	53.6
Diploma of DT	29.8	33.0
Length of experience	***n=130***	***n=112***
≤10 years	20.8	25.0
11–20 years	18.5	17.0
21–30 years	46.1	43.7
More than 30 years	14.6	14.3

Child characteristics and baseline deciduous dmfs and permanent DMFS were compared between the full sample and the sample used for this analysis. There was no difference in child characteristics and level of disease among the full sample and the sample used for this analysis (Table 6.5 & Table 6.6).

Table 6.5: Representative of child sample

	Full sample (n=71,619)	Sample used in this study (n=61,882)
Sex		
Boy	50.8	50.8
Girl	49.2	49.1
Healthcare card		
Yes	17.8	18.3
No	82.2	81.7
Born in Australia		
Yes	95.7	95.8
No	4.3	4.2
Residential location		
Adelaide	66.5	65.8
Other areas	33.5	34.2

Table 6.6: Mean age, dmfs and DMFS scores of this study sample and full sample

	Full sample n=71,619	Sample used in this study n=61,882
Age at baseline, mean (99%CI)	9.00 (8.96–9.02)	9.00 (8.9–9.0)
dmfs, mean (99%CI)	2.41 (2.36–2.46)	2.44 (2.40–2.49)
DMFS, mean (99%CI)	0.66 (0.64–0.68)	0.67 (0.66–0.69)

6.3.2 Analysis at the clinician-level

6.3.2.1 Bivariate analysis

6.3.2.1.1 Clinician-level analysis

Similar to the level of accuracy reported in Chapter 4 for 133 clinicians, the sensitivity for all 112 clinicians was averaged at 48.0 (range from 0 to 92) and specificity was 84 (range from 61 to 100).

There was only one daily clinical practice characteristic of clinicians that was significantly associated with accuracy: the frequency of taking bitewing radiographs (Table 6.7). Clinicians who took more bitewing radiographs per every 10 children had a significantly higher sensitivity score compared with those who took fewer radiographs (51.8 versus 44.4). The specificity score was slightly lower among those who took more x-rays compared with the other group. However, the difference was not significant. Therefore, the overall accuracy among clinicians who took more radiographs was significantly higher than those who took fewer radiographs (135.0 and 129.3 respectively).

Other clinician characteristics were not significantly associated with sensitivity and specificity scores (Table 6.7). Clinicians who asked children to "brush their teeth" and "clean debris" before the caries examination had slightly better sensitivity and overall accuracy than their colleagues. However, the difference was not statistically significant. Frequent "use of transillumination" to detect caries was associated with a greater sensitivity score of 4.4 units and a greater overall accuracy of 1.7 units. Neither of these improvements was significant. Clinicians who "assessed tooth alignment", "assessed tooth crowding" and "assessed presence of fluorosis" had a slightly greater sensitivity score and overall accuracy compared with the group who less frequently assessed those conditions. The differences were not statistically significant. These results might imply that clinicians who more frequently assessed all conditions in a child's mouth might be more thorough and hence were more accurate in their disease prediction. However, individually, those practices were not associated with a significant increase in accuracy.

Table 6.7: Clinician accuracy by clinician daily clinical practices

Clinical practices	n	Sensitivity mean (95%CI)	Specificity mean (95%CI)	Se+Sp mean (95%CI)
All subjects		**48.2 (45.2–50.8)**	**84.8 (83.4–86.2)**	**132.8 (130,9–134.7)**
Brush teeth before examination				
Less (item<median)	105	49.5 (46.2–52.7)	83.4 (81.3–95.5)	131.3 (128.6–134.0)
More (item≥median)	6	54.2 (36.1–72.3)	83.0 (73.6–92.5)	137.2 (125.2–149.3)
Clean debris before examination				
Less (item<median)	97	49.4 (46.1–52.7)	83.4 (81.2–85.6)	131.0 (128.3–133.8)
More (item≥median)	14	51.8 (39.5–64.1)	83.4 (79.0–87.7)	135.2 (126.5–144.0)
Floss proximal surfaces before examination				
Less (item<median)	71	49.8 (45.9–53.8)	82.6 (80.0–85.3)	130.8 (127.3–134.2)
More (item≥median)	40	49.5 (43.9–55.1)	84.8 (81.9–87.6)	133.0 (129.0–137.1)
Use blunt probe to detect caries				
Less (item<median)	22	48.8 (43.1–54.6)	83.2 (79.9–86.6)	132.1 (128.7–135.4)
More (item≥median)	88	47.7 (44.4–50.9)	85.0 (83.4–86.6)	132.7 (130.5–134.9)
Use transillumination to detect caries				
Less (item<median)	78	46.6 (43.7–51.2)	84.9 (83.1–86.7)	131.0 (128.5–133.6)
More (item≥median)	32	51.0 (47.3–54.9)	84.0 (81.6–86.0)	132.7 (126.5–139.3)
Assess tooth alignment				
Less (item<median)	5	35.7 (16.1–55.4)	86.6 (75.5–97.7)	122.3 (99.1–145.5)
More (item≥median)	106	50.5 (47.3–53.7)	83.2 (81.2–85.2)	132.1 (129.5–134.7)
Assess tooth crowding				
Less (item<median)	4	25.5 (9.4–60.4)	95.2 (79.6–110.7)	120.7 (87.5–153.9)
More (item≥median)	108	47.9 (42.1–51.6)	83.0 (81.0–85.0)	131.9 (129.3–134.5)
Look for signs of dental fluorosis				
Less (item<median)	16	43.7 (33.7–53.7)	83.9 (78.7–89.2)	128.3 (120.7–135.9)
More (item≥median)	95	48.5 (45.6–51.2)	84.6 (83.1–86.5)	133.1 (131.4–135.0)
Average number of bitewings taken every 10 children				
Less (item<median)	55	44.4 (40.2–48.6)*	85.7 (83.5–87.9)	129.3 (126.2–132.5)*
More (item≥median)	57	51.8 (50.1–59.0)	83.5 (78.1–84.4)	135.0 (133.0–137.7)

CI: Confidence Intervals. Within columns, subgroups are significantly different when their 95%CIs do not overlap

* Statistically significant

The collection of "stressful events and family circumstances" was associated with sensitivity and specificity scores (Table 6.8). Clinicians who were less likely to collect information on their patient's "stressful events and family circumstances" had a significantly lower sensitivity score compared with those who were more likely to collect that information. However, the latter group had lower specificity score. This difference in specificity was not significant. Overall, clinicians who collected less information on their patient's stressful life events and family circumstances had a significantly lower combined Se+Sp score.

Table 6.8: Accuracy by collecting relevant information for CRA scales

Clinician-related factors	n	Sensitivity mean (95%CI)	Specificity mean (95%CI)	Se+Sp mean (95%CI)
Child behaviours				
Less (scale<median)	50	47.0 (44.1–51.8)	85.7 (83.4–87.2)	132.75 (129.5–135.7)
More (scale≥median)	62	48.8 (46.5–57.0)	84.2 (77.5–84.8)	132.8 (126.0–135.1)
Stressful events and family circumstances				
Less (scale<median)	62	44.8 (40.8–48.9)*	85.8 (84.2–87.5)	130.6 (127.8–133.5)*
More (scale≥median)	50	51.8 (50.7–55.9)	83.6 (81.1–85.9)	135.3 (133.7–137.5)

CI: Confidence Intervals. Within columns, subgroups are significantly different when their 95%CIs do not overlap

* Statistically significant

None of the four sub-scales of clinicians' perceptions and beliefs was significantly associated with clinician accuracy (Table 6.9). Perception of the importance of "ecology" was not associated with clinician accuracy. The group of clinicians who considered "current caries" as "definitely very important" while assessing future caries development had a lower sensitivity and lower combined Se+Sp than clinicians who considered the "current disease" as somewhat less important. However, this difference was not statistically significant. In contrast, clinicians, who considered "past caries" as definitely important, had a higher sensitivity and higher overall accuracy, but the difference was not statistically significant compared with clinicians who considered "past caries" as somewhat less important.

Table 6.9: Accuracy by clinicians' perceptions and beliefs of clinical caries risk factors

Perception on the importance of …scales	n	Sensitivity mean (95%CI)	Specificity mean (95%CI)	Se+Sp mean (95%CI)
Ecology				
Less importance (scale<median)	58	47.7 (43.4–51.9)	84.1 (82.1–86.2)	131.8 (128.9–134.7)
More importance (scale≥median)	54	48.4 (44.7–52.0)	85.4 (83.5–87.4)	133.8 (131.4–136.3)
Plaque				
Less importance (scale<median)	45	47.5 (43.1–51.9)	84.9 (82.9–86.9)	132.4 (129.3–135.5)
More importance (scale≥median)	67	48.4 (44.7–52.0)	84.7 (82.7–86.6)	133.0 (130.6–135.4)
Current caries				
Less importance (scale<median)	40	50.5 (46.2–54.8)	84.2 (82.1–86.3)	134.7 (131.9–137.5)
More importance (scale≥median)	72	46.6 (42.9–50.3)	85.1 (83.2–87.0)	131.7 (129.2–134.2)
Past caries				
Less importance (scale<median)	31	44.7 (39.1–50.3)	86.7 (84.3–89.0)	131.3 (127.1–135.6)
More importance (scale≥median)	81	49.3 (46.1–52.5)	84.0 (82.3–85.8)	133.3 (131.3–135.4)

CI: Confidence Intervals. Within columns, subgroups are significantly different when their 95%CIs do not overlap

Sensitivity, specificity and overall accuracy were almost identical for the groups of clinicians by perceived importance of diet (Table 6.10). Sensitivity and combined Se+Sp were higher among those who perceived "socioeconomic status" as highly important compared with those who perceived it as less important. However, this difference was not statistically significant. Clinicians who perceived "fluoride exposure" as highly important also had a non-significant higher sensitivity.

Table 6.10: Accuracy by clinicians' perceptions and beliefs of non-clinical caries risk factors

Perception on the importance of …scales	n	Sensitivity mean (95%CI)	Specificity mean (95%CI)	Se+Sp mean (95%CI)
Diet				
Less (scale<median)	45	48.2 (43.7–52.7)	84.5 (82.3–86.7)	132.7 (129.5–135.9)
More (scale≥median)	67	47.9 (44.3-–51.5)	84.9 (83.1–86.8)	132.8 (130.5–135.2)
Socioeconomic status				
Less (scale<median)	47	45.8 (41.4–50.3)	86.4 (84.5–88.2)	129.5 (126.3–132.7)
More (scale≥median)	65	52.4 (48.0–56.8)	81.4 (78.3–84.4)	133.0 (129.1–137.0)
Fluoride exposure				
Less (scale<median)	55	46.2 (42.5–50.0)	85.9 (84.3–87.6)	132.2 (129.5–134.8)
More (scale≥median)	57	49.7 (45.6–53.9)	83.6 (81.4–85.9)	133.4 (130.7–136.1)
Dental behaviours				
Less (scale<median)	53	50.8 (45.8–55.8)	83.0 (79.7–86.3)	132.1 (127.4–136.7)
More (scale≥median)	59	48.8 (44.6–53.0)	83.7 (81.3–86.1)	131.1 (128.3–134.0)

CI: Confidence Intervals. Within columns, subgroups are significantly different when their 95%CIs do not overlap

The clinicians' accuracy was compared by clinicians reported levels of confidence in various clinical procedures related with caries management and prevention (Table 6.11). Clinicians' level of confidence in identifying the cause of caries, diagnosing caries, or treating caries was not associated with level of caries risk assessment accuracy. Clinicians who were reportedly were "not confident at all" in predicting caries or preventing future caries, had an overall accuracy (Se+Sp) lower than that of the group with a higher level of confidence in predicting and preventing caries. However, the differences were not statistically significant and there was only small number of clinician reported that they are not "confident at all" in predicting caries (n=4).

Table 6.11: Clinician accuracy by reported level of confidence in clinical situations

Clinician confidence in …	n	Sensitivity Mean (95%CI)	Specificity mean (95%CI)	Se+Sp mean (95%CI)
Identifying the cause of caries				
Very confident	39	47.6 (45.2–56.8)	84.6 (76.7–85.7)	132.2 (129.2–135.1)
Somewhat confident	71	48.9 (45.0–52.8)	84.7 (83.0–86.4)	133.7 (130.9–136.4)
Not confident at all	2	50.3 (-54.7–155.2)	84.4 (53.9–114.9)	134.6 (60.0–209.1)
Diagnosing caries				
Very confident	78	47.9 (46.1–53.8)	84.8 (80.3–85.4)	132.6 (127.3–133.9)
Somewhat confident	34	49.2 (43.3–55.1)	84.8 (82.0–87.6)	134.0 (130.0–138.0)
Not confident at all		N/A	N/A	N/A
Treating caries				
Very confident	85	48.3 (45.5-51.1)	84.6 (83.0–86.1)	132.9 (131.0–134.7)
Somewhat confident	27	47.1(39.3 - 54.9)	85.4 (82.2–88.6)	132.5 (127.0–138.1)
Not confident at all		N/A	N/A	N/A
Predicting future caries				
Very confident	19	46.6 (40.4–52.8)	85.7 (82.2–89.1)	132.2 (128.2–136.3)
Somewhat confident	89	48.3 (46.6–54.2)	84.7 (80.6–85.4)	133.0 (128.4–134.7)
Not confident at all	4	48.1 (37.7–58.5)	81.6 (74.3–88.8)	129.7 (125.1–134.3)
Preventing future caries				
Very confident	12	51.0 (41.4–60.6)	82.3 (76.1–88.5)	133.3 (128.3–138.3)
Somewhat confident	87	48.4 (46.8–54.2)	85.1 (80.9–85.7)	133.5 (128.7–135.0)
Not confident at all	13	42.8 (33.8–51.8)	85.0 (81.4–88.6)	127.8 (121.4–134.3)

CI: Confidence Intervals. Within columns, subgroups are significantly different when their 95%CIs do not overlap
N/A: Not available

The estimated accuracy was compared by clinician demographic and education characteristics (Table 6.12). Male clinicians had slightly lower accuracy, but the difference was not statistically significant. The youngest age group and the oldest age group had better sensitivity and slightly better overall Se+Sp than the other clinicians. However, the differences were not significant. There was no significant difference in accuracy by clinician country of birth or type of degree.

Table 6.12: Accuracy by clinician characteristics

Clinician characteristics	n	Sensitivity mean (95%CI)	Specificity mean (95%CI)	Se+Sp mean (95%CI)
Sex				
Male	11	44.4 (29.8–58.9)	84.3 (75.4–93.2)	122.7 (108.3–137.2)
Female	99	50.2 (47.1–53.3)	83.8 (82.4–85.3)	133.2 (130.9–135.5)
Age group				
≤30 years	15	55.0 (47.3–62.7)	80.4 (73.6–87.2)	132.1 (127.6–136.6)
31–40 years	26	46.3 (38.4–54.3)	83.3 (79.6–86.9)	129.6 (123.5–135.7)
41–50 years	43	47.6 (43.2–52.1)	84.6 (81.9–87.4)	131.2 (126.3–136.1)
51+ years	21	52.4 (44.6–60.2)	84.1 (79.6–88.5)	134.1 (128.5–139.8)
Born in Australia				
Yes	89	49.2 (45.8–52.6)	84.0 (82.4–85.6)	132.3 (130.0–134.5)
No	21	50.8 (42.4–59.1)	83.5 (78.6–88.3)	130.3 (120.8–139.9)
Type of degree				
Dentist	15	50.9 (38.6–63.2)	80.6 (71.5–89.7)	126.9 (115.2–138.7)
Certificate of DT	60	49.0 (45.6–52.5)	84.3 (82.6–86.0)	133.4 (131.1–135.6)
Diploma of DT	37	50.1 (44.2–56.0)	83.5 (80.9–86.2)	131.5 (127.6–135.3)

CI: Confidence Intervals. Within columns, subgroups are significantly different when their 95%CIs do not overlap

Clinicians with less than 20 years experience had lower overall accuracy Se+Sp than clinicians with more than 20 years experience (Table 6.13). Rural clinicians had higher sensitivity but lower specificity than clinicians who worked in metropolitan Adelaide. Hence, the Se+Sp were not different between these two groups. The busyness of clinicians or their working status was not associated with accuracy. Working alone or working with more than two clinicians in the same session was linked with slightly lower accuracy than working in a group of two or more clinicians. However, this difference was not statistically significant.

Table 6.13: Accuracy by clinician working conditions

Working conditions	n	Sensitivity mean (95%CI)	Specificity mean (95%CI)	Se+Sp mean (95%CI)
Work status				
Full-time	44	50.6 (45.6–55.5)	83.0 (80.1–86.0)	131.6 (126.5–136.6)
Part-time	64	48.9 (44.6–53.1)	84.4 (82.5–86.3)	132.0 (129.0–135.0)
Practice duration				
<10 years	25	51.2 (45.5–56.9)	79.3 (73.6–85.1)	128.9 (122.3–135.4)
10–20 years	19	47.7 (35.8–59.7)	84.9 (80.9–88.8)	128.4 (120.4–136.3)
20–30 years	49	49.6 (45.1–54.1)	85.2 (82.9 –87.4)	133.8 (130.4–137.3)
>30 years	16	49.8 (42.6–57.0)	83.5 (78.7–88.3)	133.3 (128.8–137.9)
Practice location				
Urban	63	47.8 (43.9–51.6)	84.5 (81.6–87.5)	130.9 (127.3–134.4)
Rural	49	52.0 (46.7–57.4)	81.9 (79.4–84.5)	132.5 (128.4–136.5)
Working hours spent chairside with patients per day				
Less than 4 hours	31	51.7 (42.1–61.3)	83.0 (78.6–87.3)	130.7 (124.0–137.4)
4–6 hours	54	44.6 (35.6–53.7)	86.5 (82.1–90.9)	131.1 (125.6–136.7)
More than 6 hours	27	50.2 (46.6–53.9)	82.9 (80.3–85.4)	131.9 (128.6–135.2)
Number of other clinicians				
None	19	48.4 (42.8–54.1)	81.1 (76.1–86.1)	129.6 (126.1–133.1)
1–2 clinicians	16	52.1 (46.8–57.4)	84.0 (81.6–86.3)	133.7 (130.0–137.4)
More than 2 clinicians	77	46.5 (41.4–51.5)	84.8 (80.9–88.7)	129.6 (122.3–136.9)

CI: Confidence Intervals. Within columns, subgroups are significantly different when their 95%CIs do not overlap

6.3.2.1.2 Clinician accuracy and children factors

The level of clinician accuracy was associated with characteristics of the children examined (Table 6.14). Sensitivity was greater for clinicians who examined a relatively large percentage of children who were: Indigenous, classified in the high risk category at baseline, and who had higher mean dmfs at baseline compared to clinicians who examined low percentages of those children. Clinicians who had seen a large number of patients in the high-risk category at baseline and higher mean dmfs or DMFS at baseline had significantly lower specificity. Overall accuracy (Se + Sp) was higher among clinicians with more Indigenous patients, high-risk patients and high mean dmfs than clinicians who saw fewer patients with these characteristics. However, these differences were not statistically significant. Children's sex, children with or without a healthcare card, children who resided in fluoridated areas or not, and average age of the children seen were not associated with clinician accuracy.

Table 6.14: Clinician accuracy by child characteristics

	n	Sensitivity mean (95%CI)	Specificity mean (95%CI)	Se+Sp mean (95%CI)
Per cent of female patients				
< 49%	51	46.9 (43.9–50.1)	85.7 (83.0–87.2)	132.7 (129. 1–136.3)
≥ 49%	61	49.0 (44.9–53.2)	84.0 (78.7– 85.1)	132.9 (126.8 –134.4)
Per cent of patients born overseas				
< 4%	60	45.3 (42.0–48.9)	87.1(85.4 – 88.8) *	132.4 (129.8–135.0)
≥ 4%	52	50.4 (46. 2–54.5)	80.5 (77.4–83.6)	130.9 (126.7–135.2)
Per cent of patients who had a healthcare card				
< 18%	64	49.5 (45.2–53.8)	83.4 (81.1–85.6)	130.9 (127.9–134.0)
≥ 18%	48	50.0 (45.1–54.9)	83.4 (79. 8 – 87.0)	132.4 (127.8 -137.1)
Per cent of patients who were Indigenous				
< 3%	81	47.7 (43.8–51.6) *	84.4 (81.9–86.9)	130.6 (127.4–33.8)
≥ 3%	31	55.1 (50.0–60.3)	80. 1 (77.4–82.8)	135.2 (130.8–139.6)
Per cent of patients who were high-risk at baseline				
< 25%	71	40.6 (37.9– 43. 4) *	89.4 (88. 5– 90.4) *	129.5 (127.1–131.9)
≥ 25%	41	63.4 (58.8–68.1)	74.1 (70.7– 77.5)	134.7 (129.7–140.1)
Per cent of patients who lived in non-fluoridated area				
< 25%	80	47.9 (44.4–51.3)	84.7 (82.3–87.1)	131.4 (128.3–34.4)
≥ 25%	32	54.0 (47.1–60.9)	80.3 (76.9–83.7)	132.0 (126.7–137.4)
Mean dmfs of children (range: 0.4–6.7)				
< 2.7 surfaces	72	43.9 (40.5–47.2) *	87.7 (86.8 – 89.7) *	131.5 (129.1–133.9)
≥ 2.7 surfaces	40	55.5 (51.2–59.7.2)	79. 6 (77.7 – 81.8)	135.0 (132.1–38.7)
Mean DMFS of children (range: 0.3–1.4)				
< 0.8 surfaces	81	46.2 (42.9– 49.5)	86.1 (84.6– 87.6) *	132. 3 (130.1–134.5)
≥ 0.8 surfaces	31	52.7 (47.5– 57.9)	81.3 (78.3– 84.3)	134.0 (130.3–137.7)
Per cent of children with (dmfs + DMFS =0) at baseline				
< 47%		54.1 (50.7–57.5) *	81.1 (79.2–83.0) *	135.2 (133.0–137.4)
≥ 47%		41.7 (37.8–45.6)	88.6 (87.0–90.1)	130.3 (127.3–133.3)
Mean age of child (range: 7.5–12.4)				
< 9 years old	61	51.3 (47.0 –55. 6)	81.8 (78.6–84.9)	132.3 (128.4 –136.2)
≥ 9 years old	51	47.9 (43.1–52.8)	85.2 (82. 9–87.6)	130.9 (127.3–134.6)

N: Number of clinicians
CI: Confidence Intervals. Within columns, subgroups are significantly different when their 95%CIs do not overlap
* Significant difference

6.3.2.1.3 Summary of findings regarding clinician accuracy at clinician level

According to bivariate analyses presented in this chapter, there were only a few variables significantly associated with clinicians' accuracy. Clinician related factors such as "Bitewing taken per every ten children" and "Stressful events and family circumstances" were associated with sensitivity. Child's country of birth, Indigenous status and deciduous dmfs were also significantly associated with sensitivity. Use transillumination light to detect caries and assessing tooth crowding were associated with higher specificity. Child's country of birth, Indigenous status and deciduous dmfs were also significantly associated with both sensitivity and specificity.

Table 6.15: Summary of bivariate association between clinician- and child-related factors and clinician accuracy

	Sensitivity	Specificity	Se+Sp
Clinician characteristics			
Sex	NS	NS	NS
Age	NS	NS	NS
Country of birth	NS	NS	NS
Type of degree	NS	NS	NS
Working condition			
Work status	NS	NS	NS
Practice duration	NS	NS	NS
Practice location	NS	NS	NS
Working hours per day	NS	NS	NS
Number of clinician work with	NS	NS	NS
Clinical practices			
Average number of bitewings taken every 10 children	*	NS	*
Brush teeth before examination	NS	NS	NS
Clean debris before examination	NS	NS	NS
Floss proximal surface before examination	NS	NS	NS
Use blunt probe to detect caries	NS	NS	NS
Use transillumination light to detect caries	NS	*	NS
Assess tooth alignment	NS	NS	NS
Assess tooth crowding	NS	*	NS
Look for signs of dental fluorosis	NS	NS	NS
Child behaviours	NS	NS	NS
Stressful events and family circumstances	*	NS	*
Perceptions and beliefs of clinical factors			
Ecology	NS	NS	NS
Plaque	NS	NS	NS
Current disease	NS	NS	NS
Past caries	NS	NS	NS

Table 6.15: *(continued)*

	Sensitivity	Specificity	Se+Sp
Perception of non-clinical factors			
Diet	NS	NS	NS
Socioeconomic status	NS	NS	NS
Fluoride exposure	NS	NS	NS
Dental behaviour	NS	NS	NS
Clinician' confidence			
Identifying the cause of caries	NS	NS	NS
Diagnosing caries	NS	NS	NS
Treating caries	NS	NS	NS
Predicting future caries	NS	NS	NS
Preventing future caries	NS	NS	NS
Child factors			
Sex	NS	NS	NS
Country of birth	*	*	NS
Healthcare card	NS	NS	NS
Indigenous status	*	*	NS
Fluoridated water area	NS	NS	NS
Child dmfs	**	*	NS
Child DMFS	NS	**	NS
Child age	NS	NS	NS

* Significance with p<0.05; ** Significance with p<0.001

NS: Not significant

6.3.2.2 Multivariate analysis

Before developing a multivariate model, correlation between variables was checked for multicollinearity. Correlation among variables which were available to enter in the generalised linear regression models were tested (Table 6.16). All correlations were weak (≤ 0.3).

Table 6.16: Correlation matrix among variables in the multivariate regression models

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Average number of bitewings (1)	1.0						
Collecting child stress and circumstances (2)	0.2	1.0					
Use transillumination (3)	0.3	0.3	1.0				
Assess tooth crowding (4)	0.1	0.1	0.3	1.0			
% children born overseas per clinician (5)	-0.1	0.1	0.1	0.3	1.0		
% Indigenous children per clinician (6)	-0.1	0.1	0.1	0.0	-0.2	1.0	
Child mean dmfs+DMFS (7)	0.1	0.1	0.2	0.1	0.1	-0.1	1.0

6.3.2.2.1 Clinician-level multivariate model of factors associated with clinicians' sensitivity

Several clinician-related factors such as the "average number of bitewings taken every ten children", "stressful events and family circumstances" subscale, "assessing tooth crowding" and clinicians' sex were statistically significant explanatory variables in the linear regression model for sensitivity (Table 6.17). Other factors such as "use of transillumination" to detect caries and clinician age were not significant in the presence of all other factors in the model.

Clinicians who took fewer bitewing radiographs per 10 children had a significantly lower likelihood of having high sensitivity compared to clinicians took more bitewing radiographs per 10 children. Clinicians who reported that it was less important to collect information on "stressful events and family circumstances" or who reported that it was less important to "assess tooth crowding", had a lower sensitivity than their colleagues.

Being a male clinician was associated with a significantly higher likelihood of having a lower sensitivity score compared to being a female clinician.

When adding child factors into clinician-level multivariate regression model (Model 2), clinicians who took fewer bitewing radiographs and who reportedly thought that it was less important to collect information on "stressful events and family circumstances" had a lower sensitivity than their colleges.

Children's level of caries experience was the largest contributing factor for the model.

Table 6.17: Clinician-level multivariate model of factors associated with clinicians' sensitivity

	Model 1		Model 2	
	Estimate (se)	**P-value**	**Estimate (se)**	**P-value**
Intercept	**61.6**	**<0.001**	**52.2**	**0.003**
Average number of bitewings taken every 10 children				
Less (< than 4)	-8.0	0.004	-6.4	0.009
More (more or equal to 4)	ref		ref	
Child stressful life events and family circumstances				
Less (scale<median)	-6.7	0.015	-5.8	0.017
More (scale≥median)	ref		ref	
Use of transillumination to detect caries				
Less (scale<median)	-1.9	0.542	-2.9	0.281
More (scale≥median)	ref		ref	
Assess tooth crowding				
Less (scale<median)	-22.8	0.021	-15.6	0.075
More (scale≥median)	ref		ref	
Clinician's sex				
Male	-10.8	0.015	-6.3	0.157
Female	ref		ref	
Clinician's age in years	-0.1	0.662	0.1	0.573
Child factors (in Model 2 only)				
% children born overseas examined per clinician	-	-	0.6	0.140
% Indigenous children examined per clinician	-	-	-0.2	0.463
Child mean age[a]	-	-	-4.2	0.067
Child mean dmfs+DMFS[a]*	-	-	7.5*	<0.001

* Statistically significant

Ref: Reference category

[a]Child mean age and child mean dmfs+DMFS were grand mean centered

6.3.2.2.2 Clinician-level multivariate model of factors associated with clinicians' specificity

"Assessing tooth crowding" and clinicians' sex were contributing factors to the linear regression model for the specificity score (Table 6.18 – Model 1). "Average number of bitewings taken per ten children", collecting" stressfull events and family circumstances", "use transillumination to detect caries" and clinician age were not significant in the presence of all other factors in the model.

Clinicians who reported less frequently conducting tooth crowding assessment had a higher likelihood of having higher specificity than their colleagues. Being a male clinician was associated with a significantly higher likelihood of having a higher specificity score compared to being a female clinician.

Child factors were associated with clinician specificity (Table 6.18 – Model 2). Clinicians who had seen children with greater caries experience had significantly lower specificity than their colleagues who examined children with a low level of caries. Child caries (dmfs+DMFS) was the main factor to account for most explanation in the model. Having older child patients was associated with a significantly higher likelihood of having a higher specificity score compared to clinicians having younger patients.

No clinician related factor was associated with specificity.

Table 6.18: Clinician-level multivariate model of factors associated with clinicians' specificity

	Model 1		Model 2	
	Estimate (se)	**P-value**	**Estimate (se)**	**P-value**
Intercept	**77. 6**	**<.0001**	**83.6**	**<.0001**
Average number of bitewings taken every 10 children				
Less (< than 4)	2.1	0.164	1.0	0.374
More (more or equal to 4)	ref		ref	
Child stressful life events and family circumstances				
Less (scale<median)	1.9	0.181	1.1	0.346
More (scale≥median)	ref		ref	
Use of transillumination to detect caries				
Less (scale<median)	0.2	0.928	0.5	0.672
More (scale≥median)	ref		ref	
Assess tooth crowding				
Less (scale<median)	12.2	0.021	7.6	0.067
More (scale≥median)	ref		ref	
Clinician's sex				
Male	5.5	0.022	3.0	0.156
Female	ref		ref	
Clinician's age in years	0.1	0.233	0.0	0.981
Child factors (in Model 2 only)				
% children born overseas examined per clinician	-	-	-0.2	0.298
% Indigenous children examined per clinician	-	-	0.0	0.859
Child mean age[a]	-	-	2.4	0.030
Child mean dmfs+DMFS[a]	-	-	-4.7	<.0001

* Statistically significant

Ref: Reference category

[a]Child mean age and child mean dmfs+DMFS were grand mean centered

6.3.2.2.3 Clinician-level multivariate model of factors associated with clinicians' combined sensitivity and specificity

Items "Average number of bitewing taken per 10 children" and collecting "stressful events and family circumstances" were contributing factors to the linear regression model for overall accuracy (combined Se+Sp).

Items "Use transillumination to detect caries", "assessing tooth crowding" scale, clinicians sex and clinicians age were not significant in the presence of all other factors in the model.

Clinicians who reported less frequently collecting "stressful events and family circumstances" or reportedly less frequent bitewing radiographs for children had a lower overall accuracy than their colleagues.

In Model 2 (Table 6.19), "average number of bitewings taken per 10 children" and collecting "stressful events and family circumstances" and children's mean DMFS+dmfs were the main contributing factors to the linear regression model for overall accuracy (combined Se+Sp).

Table 6.19: Clinician level multivariate model of factors associated with clinician's combined Se+Sp

	Model 1		Model 2	
	Estimate (se)	P-value	Estimate (se)	P-value
Intercept	**139.1**	**<.0001**	**137.4**	**<.0001**
Average number of bitewings taken every 10 children				
Less (< than 4)	-6.0	0.002	-5.4	0.004
More (more or equal to 4)	ref		ref	
Child stressful life events and family circumstances				
Less (scale<median)	-4.8	0.010	-4.7	0.010
More (scale≥median)	ref		ref	
Use of transillumination to detect caries				
Less (scale<median)	-1.7	0.402	-2.4	0.249
More (scale≥median)	ref		ref	
Assess tooth crowding				
Less (scale<median)	-10.6	0.105	-8.0	0.230
More (scale≥median)	ref		ref	
Clinician's sex				
Male	-5.4	0.069	-3.3	0.327
Female	ref		ref	
Clinician's age in years	0.0	0.764	0.1	0.467
Child factors (in Model 2 only)				
% children born overseas examined per clinician	-	-	0.4	0.195
% Indigenous children examined per clinician	-	-	-0.1	0.393
Child mean age[a]	-	-	-1.8	0.291
Child mean dmfs+DMFS[a]*	-	-	2.8	0.010

* Statistically significant

Ref: Reference category

[a]Child mean age and child mean dmfs+DMFS were grand mean centered

6.3.3 Child level analysis

6.3.3.1 Multivariate analysis (child level data)

Child-related socio-demographic factors were independent factors in the multivariate binomial regression model for sensitivity score (Table 6.20 – Model 1). Sensitivity was significantly lower if clinicians examined only Australian-born children than the sensitivity of clinicians who examined children born overseas. It was lower for children who were caries free at baseline compared to children who had caries at baseline. Caries experience at baseline was the largest contributing factor to the model. Sensitivity was significantly greater for Indigenous children than for non-Indigenous children.

When adding clinician overall accuracy in the model, child baseline caries experience remained the largest contributory factor in explaining clinician's accuracy (Table 6.20 – Model 2).

Table 6.20: Child level multivariate binomial regression model for sensitivity by child factors

	Model 1		Model 2	
	Estimate	**P**	**Estimate**	**P**
Intercept	63.9	<0.0001	74.4	<.0001
Child's sex				
Male	1.4	0.07	1.3	0.10
Female	ref		ref	
Child's country of birth				
Australia	-7.7	0.00	-7.7	0.00
Overseas	ref		ref	
Child's residence				
Fluoridated area	-2.1	0.02	-1.0	0.18
Non-fluoridated area	ref		ref	
Child's card status				
Non card holder	0.5	0.62	0.8	0.45
Card holder	ref		ref	
Child's baseline caries experience				
DMFS + dmfs=0	-50.5	<0.0001	-43.1	<.0001
DMFS + dmfs>0	ref		ref	
Child's Indigenous status				
Yes	8.0	0.00	7.2	0.01
No	ref		ref	
Clinician's overall accuracy				
Low	-	-	-22.6	<.0001
Medium	-	-	-11.8	<.0001
High	-	-	ref	

Multivariate model using PROC GENMOD with identity link.

Intercept is estimated sensitivity score when all factors equal zero.

Ref: reference category

The similar models score is presented in Table 6.21 for specificity. Child's sex, country of birth, residence, card status, baseline caries experience and Indigenous status were significant predictors for the specificity score. Once again, child caries experience at baseline was the main factor that explained the variation in clinician's specificity.

Table 6.21: Child level multivariate binomial regression for specificity by child socio-demographic factors

	Model 1		Model 2	
	Estimate	**P**	**Estimate**	**P**
Intercept	68.9	<0.0001	66.8	<.0001
Sex			ref	
Male	-0.5	0.01	-0.6	0.00
Female	ref		ref	
Country of birth				
Australia	2.7	0.00	2.5	0.00
Overseas	ref		ref	
Resided in				
Fluoridated water	-0.2	0.48	-0.5	0.08
Non-fluoridated water	ref		ref	
Card status				
Non card holder	0.7	0.00	1.0	<.0001
Card holder	ref			
Baseline caries experience			ref	
DMFS + dmfs=0	25.9	<0.0001	25.7	<.0001
DMFS + dmfs>0	ref			
Indigenous			ref	
Yes	-3.6	0.01	-3.7	0.01
No	ref		ref	
Clinician's overall accuracy				
Low	-	-	3.4	<.0001
Medium	-	-	2.4	<.0001
High	-	-	ref	

Multivariate model using PROC GENMOD with identity link.
Intercept is estimated specificity score when all factors equal zero.
Ref: reference category

The estimates of the above four multivariate models (Table 6.20 & Table 6.21) were used to illustrate two contrasting situations (Table 6.22). In situation 1, clinicians were assumed to be examining only children with most favourable conditions such as children who were born in Australia, non-cardholders and resided in fluoridated areas. Situation 2 was when clinicians were assumed to be predicting caries risk for children with least favourable conditions such as children born overseas, cardholders and residing in non-fluoridated areas. In each situation, estimated clinician accuracy was computed among a group of caries-free children at baseline and a group of children with caries.

The difference between sensitivity scores observed among most favourable and least favourable children was around 13 units in either the caries free group or the group with caries (6.79 compared with 19.9 and 57.3 compared with 70.5 respectively). There was some six-unit difference in overall accuracy when predicting risk among children of the most favourable group and the least favourable group after adjusting for child caries experience level at baseline (104.79 vs 110.64 and 129.44 vs 135.29). That magnitude of difference was notably larger when comparing scores observed among the caries free group and the group with caries at baseline (Sensitivity: 6.79 vs 57.36 for the most favourable group and 19.93 vs 70.50 for the least favourable group; overall accuracy: 104.79 vs 129.44 for the most favourable group and 110.64 vs 135.29 for the least favourable group).

Table 6.22: Estimated clinician accuracy by child socio-demographic characteristics

Clinician overall accuracy classification	Estimated accuracy scores[a]					
	Among children DMFS + dmfs=0			Among children DMFS + dmfs>0		
	Se	Sp	Se+Sp	Se	Sp	Se+Sp
	Most favourable child group[b]					
Low	1.57	98.99	100.56	49.23	73.29	122.53
Moderate	8.68	98.13	106.81	56.34	72.43	128.77
High	22.69	95.71	118.40	70.35	70.01	140.36
Total	**6.79**	**97.99**	**104.79**	**57.36**	**72.08**	**129.44**
Clinician overall accuracy classification	**Least favourable child group[c]**					
Low	8.22	95.09	103.31	55.88	69.39	125.27
Moderate	15.33	94.23	109.56	62.99	68.53	131.52
High	29.99	92.23	122.22	77.00	66.11	143.11
Total	**19.93**	**90.71**	**110.64**	**70.50**	**64.79**	**135.29**

[a] Estimated accuracy scores using multivariate model (Proc Genmod)
Two most contrasted situations were selected for illustrative purposes
[b] Most favourable children were born in Australia, were non-cardholders, and resided in fluoridated areas
[c] Least favourable children were born overseas, were cardholders, and resided in non-fluoridated areas

Sensitivity observed among children who were examined by clinicians who were less likely to collect information on "stressful events and family circumstances" were significantly lower than that among children who were examined by clinicians with frequent collection of "stressful events and family circumstances" (Table 6.23). Similarly, taking fewer bitewing radiographs for children was associated with lower sensitivity compared with taking more bitewing radiographs.

Child caries experience was the main factor that explained a large proportion of variation in clinicians' sensitivity.

Table 6.23: Child's level multivariate model for sensitivity by child and clinician-related factors

	Model 3	
	Estimate	**p**
Intercept	57.46	<0.0001
Sex		
Boys	1.65	0.0224
Girls	Ref	
Country of birth		
Australia	-7.95	<.0001
Overseas	ref	
Resided in		
Fluoridated areas	-2.82	0.0111
Non-fluoridated areas	ref	
Card status		
Non card holder	-1.74	0.0604
Card holder	ref	
Indigenous		
Yes	6.47	0.0052
No	ref	
Child's age		
5–7	16.57	<.0001
8–12	5.03	0.0004
13–15	ref	
Baseline caries experience		
DMFS + dmfs=0	-41.37	<.0001
DMFS + dmfs>0	ref	
Child stressful life events and family circumstances		
Less	-3.58	<.0001
More	ref	
Take bitewing radiographs		
Less	-3.78	<.0001
More	ref	

Multivariate model using PROC GENMOD with identity link.

Intercept is estimated sensitivity score when all factors equal zero.

Ref: reference category

A child's baseline caries experience was again the main factor associated with clinician specificity in caries risk assessment. Clinicians who examined children without caries experience had a specificity score 25 units higher than that of clinicians who examined children with caries experience at baseline (Table 6.24). Collecting more information on "stressful events and family circumstances" was not associated with the specificity score.

Table 6.24: Child level multivariate model for specificity by child and clinician-related factors

	Model 3	
	Estimate	**P**
Intercept	69.34	<0.0001
Sex		
Male	-0.48	0.0035
Female	ref	
Country of birth		
Australia	2.37	0.0018
Overseas	ref	
Resided in		
Fluoridated areas	-0.12	0.6048
Non-fluoridated areas	ref	
Card status		
Non card holder	1.19	<.0001
Card holder	ref	
Indigenous		
Yes	-3.44	0.0109
No	ref	
Age		
5–7 years	-2.81	<.0001
8–12 years	-0.43	0.0123
13–15 years	ref	
Baseline caries experience		
DMFS + dmfs=0	25.61	<.0001
DMFS + dmfs>0	ref	
Collect information on child stressful life events and family circumstances		
Less	0.13	0.4311
More	ref	
Take bitewing radiographs		
Less	0.96	<.0001
More	ref	

Multivariate model using PROC GENMOD with identity link.
Intercept is estimated specificity score when all factors equal zero.
Ref: reference category

The estimates of the above-presented two models (Table 6.23 & Table 6.24) were used to illustrate two contrasting scenarios (Table 6.25). These two scenarios were stratified by child baseline caries experience. In the first scenario, clinician accuracy was estimated among children who were examined by clinicians who less frequently collected information on "stressful events and family circumstances" and also who took less bitewing radiographs in their routine practice. In the second scenario, the accuracy was estimated among children who were examined by clinicians who more frequently collected that information. Estimated clinician accuracy among clinicians who were concerned about "stressful events and family circumstances" (Group B) achieved higher accuracy scores in both stratification analyses than their colleagues (Group A) (107.61 and 102.25 among children without caries; 131.86 and 126.49 among children with caries).

Table 6.25: Estimated clinician accuracy by clinician-related factors

Clinician-related factors	Estimated accuracy scores[a]					
	Among children without caries			Among children with caries		
	Se	Sp	Se+Sp	Se	Sp	Se+Sp
Group A	4.03	98.21	102.25	54.49	72.00	126.49
Group B	10.65	96.96	107.61	61.12	70.75	131.86
Difference between groups A and B			**5.36**			**5.36**

a Estimated accuracy scores using multivariate model (PROC GENMOD)

Group A: Group of clinicians who less frequently collected information on child stressful events and family circumstances, took less bitewing Xrays

Group B: Group of clinicians who more frequently collected information on child stressful events and family circumstances, frequently took bitewing Xrays

Similarly, Table 6.26 was used to illustrate another four scenarios. The differences in overall accuracy between clinicians who examined most favourable children and clinicians who examined least favourable children were only two units in both children without caries experience and children with caries experience (Table 6.26). The differences in overall accuracy among the group of clinicians who less often collected information on child stressful events and family circumstances, who took less bitewing X-rays, and the group of clinicians who frequently collected information on child stressful events and family circumstances, were not large (5.64 unit) in both the children with caries group and the children without caries group.

Table 6.26: Estimated clinician accuracy using both clinician and child characteristics

	Estimated accuracy scores[a]					
	Among children without caries			Among children with caries		
	Se	Sp	Se+Sp	Se	Sp	Se+Sp
	Most favourable children[b]					
Group A[d]	4.08	98.52	102.61	54.07	72.68	126.75
Group B[e]	11.06	97.19	108.25	61.05	71.34	132.39
Difference between groups A and B			**5.64**			**5.64**
	Least favourable children[c]					
Group A[d]	9.69	94.94	104.63	59.67	69.10	128.77
Group B[e]	16.66	93.61	110.27	66.65	67.76	134.41
Difference between groups A and B			**5.64**			**5.64**

a Estimated accuracy scores using multivariate model (PROC GENMOD)

Four of the most contrasted situations were selected for illustrative purposes

b Most favourable children were born in Australia, were non-cardholders, and resided in fluoridated areas

c Least favourable children were born overseas, were cardholders, and resided in non-fluoridated areas

d Group of clinicians who collected less information on child stressful events and family circumstances, took less bitewing X-rays

e Group of clinicians who frequently collected information on child stressful events and family circumstances, frequently took bitewing X-rays

The clinician overall accuracy was associated with the caries experience status of children seen by the clinicians (Table 6.27). In the low-accuracy clinician group, the overall estimated accuracy (Se+Sp) increased from 101 in children who had no caries at baseline to 120 in children who had caries. A similar difference was observed for the moderate- and high-accuracy clinician group (24.51 and 23.96 respectively).

In the children who had no caries at baseline, clinicians could correctly predict a small proportion of children who would later develop caries (sensitivity from 3 to 16). However, the specificity score was almost perfect in this group of children. The overall accuracy in the group without caries at baseline was notably lower than that observed among children who had caries at baseline (Table 6.27). The sensitivity scores were much higher in this latter group of children at the expense of lower specificity scores. Overall, the differences in accuracy scores between the groups of children with or without caries at baseline were greater than the differences between the clinicians themselves.

Table 6.27: Estimated clinician accuracy by child's caries experience at baseline

Clinician overall accuracy classification	Clinician accuracy scores[a]						Change from c to d
	Baseline (dmfs + DMFS)=0			Baseline (dmfs + DMFS)>0			
	Se	Sp	Se+Sp[c]	Se	Sp	Se+Sp[d]	
Low accuracy group (n=21)	3.06	98.12	101.18	39.02	80.83	119.85	**18.67**
Moderate accuracy group (n=71)	6.57	98.00	104.57	58.82	70.26	129.08	**24.51**
High accuracy group (n=20)	15.93	96.38	112.31	71.24	65.03	136.27	**23.96**
Magnitude of change[b]			**11.31**			**16.15**	

a Estimated accuracy scores using multivariate model (PROC GENMOD)

b Change from the group with low accuracy to the group with high accuracy

Children's age was another factor that predicts clinician accuracy. Clinician overall accuracy (Se+Sp) decreased by 10 units moving from predicting caries risk in the youngest age group to children aged 13–15 years old (Table 6.28). The estimated overall clinician accuracy decreased by approximately 10 units among all three clinician accuracy groups. However, it need to be noted that the experience of caries in permanent dentition is less than in deciduous teeth.

Table 6.28: Clinician accuracy by children age groups

	Estimated accuracy scores [a]		
	Se	**Sp**	**Se+Sp**
Clinician overall accuracy classification	**Age group 5–7 years old**		
Low	36.58	88.46	125.04
Moderate	54.37	81.83	136.2
High	70.19	76.91	147.1
Total	**53.57**	**82.38**	**135.95**
Clinician overall accuracy classification	**Age group 8–12 years old**		
Low	23.83	90.86	114.69
Moderate	44.28	84.56	128.84
High	53.49	81.95	135.44
Total	**42.19**	**85.36**	**127.55**
Clinician overall accuracy classification	**Age group 13–15 years old**		
Low	22.46	95.16	117.62
Moderate	34.65	90.79	125.44
High	54.97	88.00	142.97
Total	**35.38**	**91.17**	**126.55**

a Estimated accuracy scores using multivariate model (PROC GENMOD)

6.3.4 Multivariate predictive models

6.3.4.1 Overall multivariate predictive models

Binary logistic regression was used to predict odds of a high rate using clinician risk assignment at baseline only (Table 6.29). Children who were classified as high risk of developing caries had 15 times the odds of having a high rate of caries compared to low risk children.

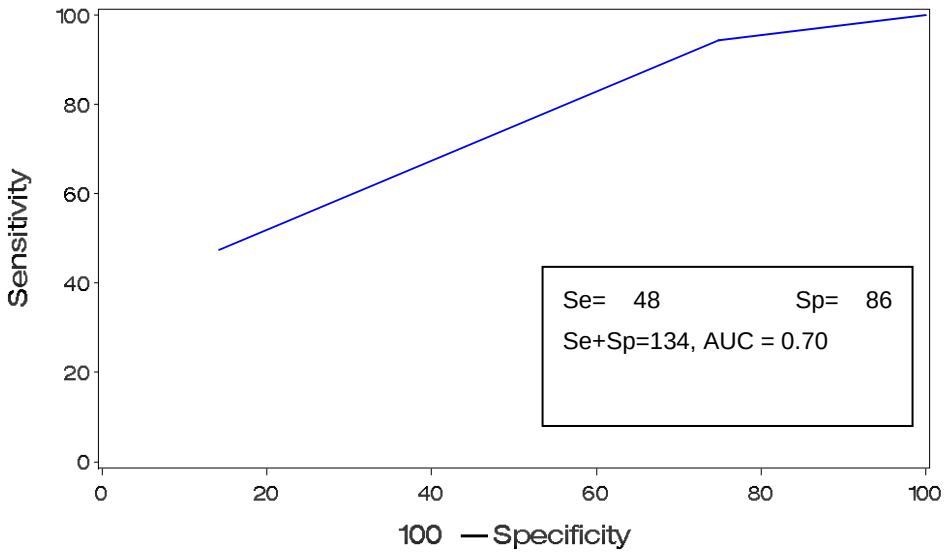
Table 6.29: Model 1: predicting odds of high rate using clinical judgement only

Predictor variable	OR	95%CI
Risk status assigned by clinician at baseline		
High risk	14.7	13.6–15.8
Medium risk	3.4	3.2–3.7
Low risk	ref	

Logistic regression model for having high rate of caries (incidence density of 1.2 or higher)

The ROC curve for Model 1 yielded the AUC of 0.70 and the overall accuracy of 134 (Figure 6.2).

Figure 6.2: ROC curve for Model 1: predictive accuracy using clinician judgment only



The clinician assigned risk status and caries experience at baseline were independently associated with the odds of developing a high rate of caries during the follow-up (Table 6.30). Being in the high-risk group at baseline and having more than 5 surfaces with caries experience had significantly higher odds of developing a high rate of caries compared to the low risk group and caries free group.

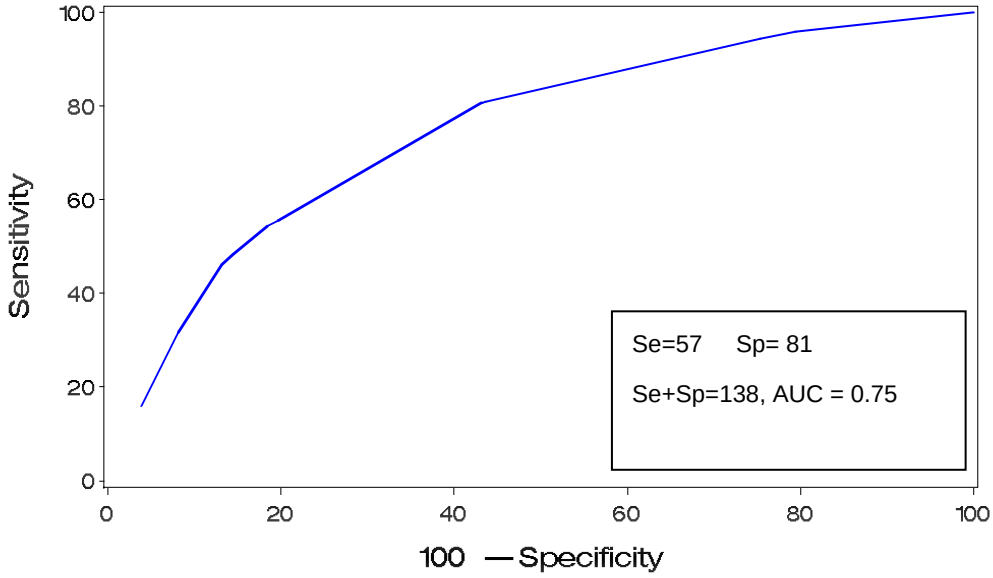
Table 6.30: Model 2: predicting odds of high rate using clinician judgment and caries experience

Predictor variable	OR	95%CI
Risk status assigned by clinician at baseline		
High risk	6.5	6.0–7.1
Medium risk	2.5	2.3–2.7
Low risk	ref	
Total number of carious surfaces		
dmfs+DMFS>10	3.5	3.2–3.8
5<dmfs+DMFS<=10	3.2	2.9–3.4
0<dmfs+DMFS<=5	2.4	2.3–2.6
dmfs+DMFS=0	ref	

Logistic regression model for having high rate of caries (incidence density of 1.2 or higher)

Model 2 yielded the AUC of 0.75 and combined Se+Sp of 138 (Figure 6.3). These values are higher than that of the Model 1 where only clinician-assigned risk status was used.

Figure 6.3: ROC curve for Model 2: predictive accuracy using clinician judgment and caries experience



In Model 3, clinician judgment, caries experience and child' age were independent predictors for having a high rate of caries development (Table 6.31). Being in a younger age group was associated with higher odds of developing a high rate of caries compared to the older age group.

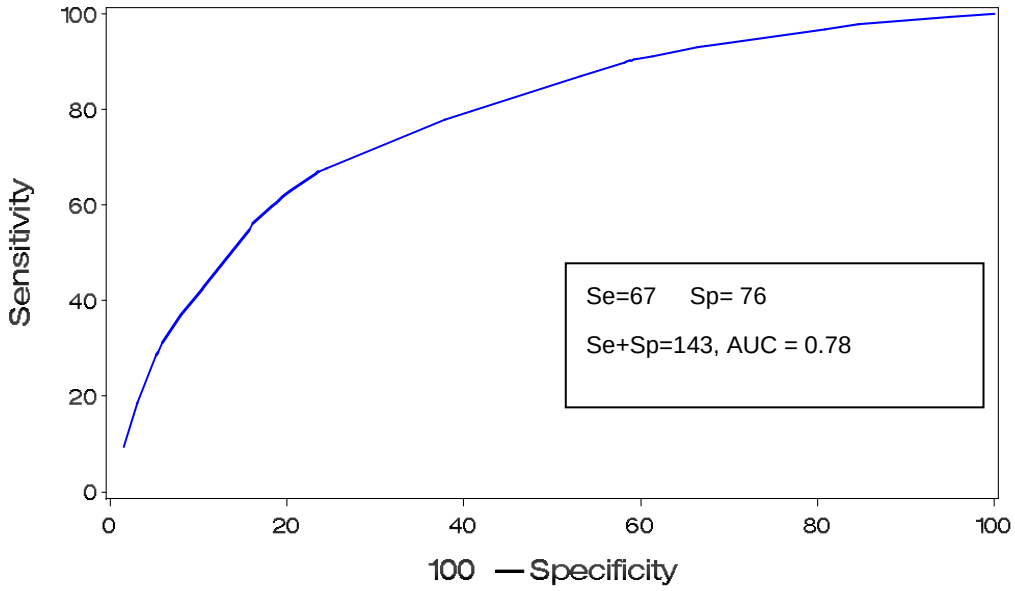
Table 6.31: Model 3: Predicting odds of high rate using clinician judgment, caries experience and child' age

Predictor variable	OR	95%CI
Risk status assigned by clinician at baseline		
High risk	4.2	3.9 – 4.6
Medium risk	1.9	1.8–2.1
Low risk	ref	
Total number of carious surfaces		
dmfs+DMFS>10	4.7	4.3–5.1
5<dmfs+DMFS≤10	4.4	4.1–4.7
0<dmfs+DMFS≤5	3.1	2.9–3.3
dmfs+DMFS=0	ref	
Child age group		
5–7	3.2	2.9–3.4
8–12	1.2	1.2–1.3
13+	ref	

Logistic regression model for having high rate of caries (incidence density of 1.2 or higher)

By adding clinician judgement, past caries experience and children age to the model, it yielded an AUC of 0.78 and specificity + sensitivity of 143 (Figure 6.4). These values were higher than that in the other two models.

Figure 6.4: Model 3: predicting high risk using clinician judgment, caries experience and child' age



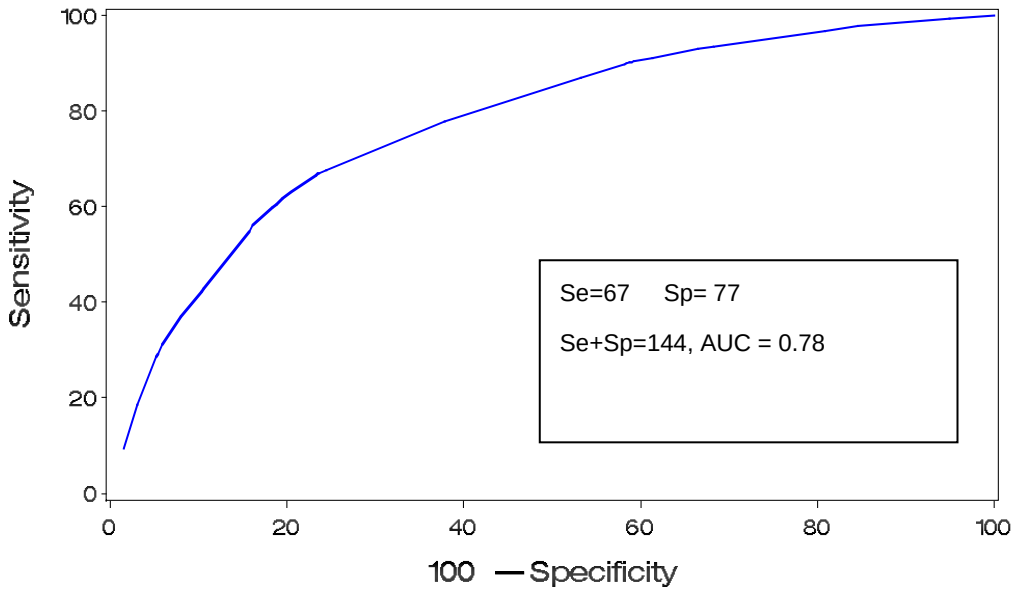
Model 4 indicated that in addition to the above-mentioned three factors, a number of sociodemographic factors were significant in predicting high caries rate (Table 6.32). The model yielded a similar AUC as Model 3. The specificity score and the combined Se+Sp score increased by 1 unit.

Table 6.32: Model 4: Predicting odds of high rate using clinician judgment, caries experience, child' age and child social factors

Predictor variable	OR	95%CI
Risk status assigned by clinician at baseline		
High risk	4.8	4.4–5.4
Medium risk	2.1	1.9–2.3
Low risk	ref	
Total number of carious surfaces		
dmfs+DMFS>10	4.0	3.6–4.5
5<dmfs+DMFS≤10	4.0	3.7–4.4
0<dmfs+DMFS≤5	3.2	3.0–3.4
dmfs+DMFS=0	ref	
Child age group		
5–7	3.3	3.0–3.5
8–12	1.3	1.2–1.4
13+	ref	
Indigenous status		
Indigenous	1.1	1.0–1.3
Non-Indigenous	ref	
Country of birth		
Overseas born	1.1	1.0–1.2
Australia born	ref	
Healthcare card holder status		
Card holder	1.0	1.0–1.1
Non-cardholder	ref	
Water fluoridation status		
Non-fluoridated water	1.2	1.2–1.3
Borderline	1.4	1.3–1.5
Fluoridated water	ref	

Logistic regression model for having high rate of caries (incidence density of 1.2 or higher)

Figure 6.5: Model 4: predicting high risk using clinician judgment, caries experience and child' age



When comparing the four models, Model 3 which included clinician judgement, child caries experience and child's age as predictor's variables and Model 4, which added children's socio-demographic characteristics, yielded the best combined sensitivity and specificity and had the best AUC. The AUC of Model 3 and Model 4 are significantly larger compared to Model 1 which used clinician judgement only and Model 2 which used clinician judgement and caries experience. However, when comparing Model 3 and Model 4, the AUC were identical and Model 4 increased Se+Sp by only 1 unit (Table 6.33).

Table 6.33: Comparison of Area Under Curve (AUC) and accuracy (Se+Sp) of four models

	AUC	95%CI	Se+Sp
Model 1: clinician judgement	0.70	0.70–0.71	133
Model 2: clinician judgement dmfs+DMFS	0.75	0.74–0.75	138
Model 3: clinician judgement dmfs+DMFS age	0.78	0.77–0.78	143
Model 4: clinician judgement dmfs+DMFS age social factors	0.78	0.77–0.78	144

6.3.4.2 Multivariate prediction model among children with no caries experience at baseline

Among children who had no recorded dental caries experience at baseline, risk status was still associated with significantly higher odds of having high rate of new caries during the followup (Table 6.34). Having been assigned high risk status was associated with three times the odds having high rate of new caries compared with having low risk status. Being in the youngest age group was associated with significantly higher odds of having high rate of caries compared with the oldest age group. Current residence in non-fluoridated areas was also associated with significantly higher odds of having high rate of caries, after adjusting for other factors in the model.

Table 6.34: Predicting odds of high rate using clinician judgment, child' age and child social factors among children with no caries at baseline

Predictor variable	OR	95%CI
Risk status assigned by clinician at baseline		
High risk	3.0	2.2–4.0
Medium risk	1.8	1.3–2.3
Low risk	ref	
Child age group		
5–7	3.8	3.0–4.8
8–12	1.1	0.9–1.4
13+	ref	
Indigenous status		
Indigenous	1.3	0.9–2.0
Non-Indigenous	ref	
Country of birth		
Overseas born	1.2	0.9–1.3
Australia born	ref	
Healthcare card holder status		
Card holder	1.1	0.9–1.3
Non-cardholder	ref	
Water fluoridation status		
Non-fluoridated water	1.3	1.1–1.6
Borderline	1.3	1.0–1.7
Fluoridated water	ref	

Logistic regression model for having high rate of caries (incidence density of 1.2 or higher)

6.4 Summary of findings

6.4.1 Factors at clinician level

Collecting information on stressful events and family circumstances and taking bitewing radiographs for children predicts clinicians' accuracy. However, after adjusting for child variables such as caries experience, the level of variance explained by these two clinician-level variables was lower. This phenomenon suggested that the characteristics of children, rather than clinician behaviour, could have more influence on the level of accuracy.

The findings indicated that collecting information on child stressful events and family circumstances improved the accuracy as indicated in the multivariate regression models. While that finding was not strongly reflected in the predictive Model 4, it was possible that knowledge of the social factors was already incorporated in the clinicians' judgement. This implies that understanding children' social circumstances could potentially play a role in predicting future development of caries.

However, children's past level of disease was the strongest factor affecting the level of caries risk assessment accuracy. As we can see from Table 6.27, the sensitivity scores of clinicians who examined children with no caries experience were low while their specificity scores were high. In contrast, the clinicians who examined children with a higher level of disease had significantly higher sensitivity scores and lower specificity scores compared with those who did not.

Many clinician characteristics and behaviours were not associated with accuracy of caries risk assessment in this study. Further, some clinicians' behaviours and characteristics such as clinician sex and "assessing tooth crowding" that were associated with sensitivity and specificity scores in bivariate analysis were not significant after adjusting for child mean dmfs and DMFS. This suggested that the characteristics of children examined could have a large influence on clinicians' accuracy in caries risk assessment. However, it was important to note that the number of clinician who "assess tooth crowding" was small (N=4). Therefore, the

difference in CRA's accuracy might not be detectable. Further study with a large clinician population would be required.

6.4.2 Factors at child level

The study indicated that variation in prediction was better explained by child-related factors than clinician-related factors. Child baseline caries experience and child age explained a large proportion of the variance between clinicians' accuracy estimates. Similar findings were reported in the clinician level of analysis.

6.4.3 Implications of the findings

The study reported that the highest overall combined sensitivity and specificity was 135 for children and clinicians with the following characteristics: Group of clinicians who frequently collected information on child stressful events and family circumstances, frequently took bitewing X-rays and among children who had caries experience at baseline. Greater sensitivity found with bitewing X-ray could be confounded by a larger proportion of high-risk children receiving bitewings. This level was still lower than the suggested accuracy level required for a public health screening/diagnostic test of 160. As the accuracy level was more dependent on child-related factors than clinician-related factors, there is a potential to improve caries risk assessment by seeking other child-related factors.

Overall, the observed clinician accuracy was low among children with no caries experience. According to the Child Dental Health Survey in Australia, around 48% of children attending school dental services in Australia had no caries experience. Improving accuracy of caries risk assessment in those children would improve the overall level of accuracy. As children with no caries experience do not require time consuming restorative treatment, there would be time for clinicians to explore other factors that may assist in assigning risk status to those children. Such additional information could include observation of early carious lesions, presence or absence of fluorosis and other discolorations, and querying about stressful events and family circumstances. However, this study has already measured these factors and could not find an association (presence of fluorosis and the accuracy of caries prediction or early carious lesion and the accuracy of caries risk assessment) or found only modest affect (querying about stressful events and family circumstances and the accuracy of

caries risk assessment). These results suggested that there were two separate populations of caries-free and caries-active children that would make a case for a dichotomous approach to risk assessment. This issue was also discussed in the literature ((Milsom et al. 2008).

The stratified multivariate analysis among children with no caries experience present at baseline indicated that, in addition to clinician's judgement about risk status, other factors may be useful to improve the accuracy of risk assessment. Those factors are being youngest age group and residence in non-fluoridated areas. This finding may have practical implication in developing practice guidelines for the relevant areas and age groups.

Clinicians in this study reported that past caries experience is the primary factor that is used for caries risk assessment. This finding was also reported by Saemundsson et al (Saemundsson et al. 1997). Therefore, it was highly likely that child caries experience was already incorporated in clinicians' decision making when assigning a risk status for a child. However, adding child caries experience into a caries prediction model could still significantly improve the accuracy level as measured by the AUC compared to that of the model using clinician judgement alone. This finding was important in developing a computer-assisted program to further improve the accuracy of risk assessment. Children's age also played an important role in the caries risk prediction model. The model with child age and child caries experience along with clinician judgement yielded the higher level of accuracy and better combined sensitivity and specificity. However, it was difficult to justify why age was good predictor as age might confound the association between caries experience and other factors.

Chapter 7. Discussion

In this chapter, the key findings will be outlined, and the credibility, novelty and implication of the findings will be discussed.

7.1 Key results

This study of caries risk assessment in South Australian children rejected the null hypotheses for all four of its study aims: caries rates were strongly associated with clinician's classification of caries risk, although individual clinicians varied markedly in their accuracy of risk prediction. Yet, the more profound influences on accuracy of risk prediction were seen in the characteristics of children themselves, in particular, their baseline caries experience. In fact, among children with no dental caries at their baseline exam, clinicians' risk prediction was barely more accurate in predicting caries onset than prediction by chance.

The findings of the study are discussed below.

7.1.1 Factors influencing the observed accuracy in caries risk assessment

The study clearly indicated that baseline caries experience was the strongest predictor for the observed accuracy level. Caries risk assessment performed among children with high level of baseline caries was significantly more accurate compared with that observed among children with a low level of baseline caries. This finding was concordant with other available reports (Alanen et al. 1994). Caries experience at baseline remained strongly significant in the multivariate models adjusting for other child- and clinician-related factors. This suggested that variation between clinicians in their accuracy levels depended on oral health of the children they saw to some extent.

The current study showed that among clinician-related factors, collecting child stressful life events and family circumstances was a statistically significant predictor of higher level of accuracy in caries risk assessment (Table 6.19 and Table 6.23). However, as for all clinician-measured factors, the magnitude of its effect on accuracy was much smaller than the effect of child-characteristics. Those clinicians who more frequently collected child stressful life events and family circumstances

might be more thorough in their examination or they might build a good rapport to the child's care giver so they obtained the better information that helped in their decision making. This finding suggested that further education and instruction of clinicians in collecting such information would benefit dental care provision.

7.1.2 Clinicians and their routine practice and perception of caries risk assessment

Little variation was observed between clinicians in terms of reported routine practice and perception of caries risk assessment. This was expected as the clinicians in the South Australian School Dental Service received uniform practice guidelines. However, this observed consistency between the clinicians was important in evaluating their accuracy level in predicting caries.

There was variation between clinicians in the perceived importance of child socioeconomic status. This difference discriminated clinicians with better level of accuracy. Those clinicians who more frequently performed interviewing about child socioeconomic status had a better sensitivity score compared with those who less frequently did so. This finding was in concordance with the theory of socioeconomic determinants of oral health. It indicates to a necessity to further educate clinicians in understanding of socioeconomic determinants of the oral conditions.

7.1.3 Clinician's caries risk prediction accuracy

7.1.3.1 Overall accuracy in the caries risk prediction of the South Australian school dental service

In this study, the accuracy of the caries risk assessment in South Australian School Dental Service was assessed in a primary care environment. Clinicians conducted caries risk assessment as a routine practice prior to dental care provision. The main advantage of this environment was that it reflected the real life conditions of the clinical dental care where performance of certain procedures may differ from an evaluation in research setting. Evaluation of the accuracy of caries risk assessment in real life conditions provides a more realistic assessment of its performance. However, a larger variation between clinicians in performing this procedure compared with that in a research setting was expected. Also, relatively less strict requirements in real life conditions might lead to lower level of observed accuracy.

The accuracy level of caries risk assessment in this current study, expressed as combined sensitivity and specificity, was around 134 (Se=48; Sp=86). Variation between clinicians was considerable with the "best clinician" achieving a score of 160 (Se=67; Sp=93) while the "worse clinician" having a score of 100 (Se=0 Sp=100). The difference in sensitivity scores was significantly larger than that in specificity scores. From a population perspective, this variation might lead to a considerable number of "false negative" children who would have missed out timely preventive care. In particular, sensitivity scores were below 50% which is no better than chance alone. This led to a large number of false negative children (7,831 children) and to a large number of false positive (8,051 children) in a total study population of over 70,000 children. These results were consistent with reported level of accuracy in other studies.

On average, the clinicians' accuracy did not reach the level of combined accuracy of 160 as suggested in the literature (Stamm et al. 1991). However, the purpose of caries risk assessment in the SA School Dental Services was not the same as screening/diagnostic children who would then receive care as in a true population screening/diagnostic program. The suggested level of 160 combined Se+Sp was developed for such population screening/diagnostic programs. Children in the SA SDS clinics are all under active dental care programs. They were assessed for risk of developing caries in order to receive appropriate care.

The level of accuracy was similar to that reported in a Finnish study (Alanen et al. 1994), which was conducted in similar primary care environment (children aged 5–17 year old by dentists and dental hygienists working in a healthcare centre). The current study therefore confirms that clinicians in a "real life" environment are able to achieve a level of accuracy with combined sensitivity and specificity of about 135. The components of clinicians' accuracy were similar in both studies, with Se=44 and Sp=90 in Finish study and Se= 48 and Sp=86 in the current study.

In the North Carolina study (Stamm et al. 1988; Disney et al. 1992), the best combination of combined sensitivity and specificity reached 150 with Se=60 and Sp=85. Clinicians in the current study had lower accuracy, especially lower sensitivity. However, conditions in the current study were different to that in the North Carolina study, where a strict research protocol was applied. Clinicians in the North Carolina study were specifically trained for the purpose of the research. In the

current study, clinicians practiced CRA as a routine part of their daily clinical practise that involved provision of preventive and restorative treatment in addition to diagnosis and risk assessment. Clinicians in SA had a heavy workload and they had limited clinical time assigned to complete each examination. Therefore, it was expected that the caries risk assessment process would have lower accuracy level compared to that observed in the North Carolina study.

A study evaluating predictive accuracy of caries risk assessment performed during routine clinical practice among young adult patients also reported similar level of the observed accuracy. The observed sensitivity score in this current study was lower compared with that in the study by Bader and co-workers (48 versus 57 respectively) (Bader et al. 2008). However, caries risk assessment in this current study was performed among children in different stages of dentition.

Bader and co-workers (Bader et al. 2008) also examined the predictive validity of statistical models that combined clinicians' subject judgements with clinical indicators of oral disease. In their statistical model that included clinician subjective assessment in addition to clinical indicators, sensitivity was greater than a model that used clinical indicators alone. The current study found a similar effect. Sensitivity increased from 48 to 57 when baseline caries experience (dmfs+DMFS) and clinician judgement were used (Figure 6.2 and Figure 6.3).

Another finding of this study was the observed level of accuracy in predicting caries risk differed according to children's level of caries experience at the baseline examination. In the children with no caries experience at baseline, the sensitivity was low (Se=6.6) and specificity was high (Sp=98; Se+Sp=104.6) (Table 4.8). On the other hand, the observed sensitivity score was higher (Se=56.8) in the children with caries experience at baseline although specificity score was lower (Sp=71.5; Se+Sp=128.3).

It is evidenced that baseline caries was strongly associated with caries development during the follow-up as well as with the clinicians' prediction of caries risk at the baseline examination. Therefore, the caries experience at the baseline examination was expected to act as a confounding factor or an effect modifier for the association between clinicians' prediction of caries risk and the actual development of caries after the follow-up period. A stratified analysis was conducted to examine this effect by evaluating the accuracy observed among children who had and who did not have

caries at the baseline examination. It was clear that the presence of baseline caries exerted both confounding effect and effect modification on the overall accuracy. The overall estimated accuracy level did not truly reflect the average of the accuracy levels estimated in the stratified analysis (Table 4.8). This finding indicates a strong need to perform caries risk for children who had no caries differently as compared with for children who have had caries. This important implication will be discussed in more details in Section 7.3 below.

There exist a strong link between past caries experience and risk of having new caries (Steiner et al. 1992; Grindefjord et al. 1996; Vanobbergen et al. 2001; Li and Wang 2002; Skeie et al. 2006). It was clear from the current study that clinicians based their caries risk assessment mainly on evidence of past caries experience. While this practice was conceptually correct, the finding did not offer much prospect for further improvement in caries risk assessment. In another words, the findings indicated that caries risk assessment is less satisfactory for children who have no experience of caries at an examination. The proportion of caries-free children who were correctly classified as having high risk was very low although it was offset by an almost perfect specificity score. However, the proportion of true high-risk children among the caries-free children at baseline was low. Therefore, improving sensitivity of caries risk assessment among those caries-free children may not be efficient, if it occurs at the cost of reduced specificity. A small expected improvement would be offset by an increased expense of dental services as well as possible side effects of those preventive services.

It is well accepted that precise assessment of future caries risk is difficult. This was evident in this current study. The fact that children in the low risk group developed significantly fewer carious lesions than children in high risk group (Table 3.11) revealed that risk assessment at the group level was far more accurate than would have been expected based on chance. In the current study, the sensitivity, which expresses percentage of children who were correctly picked as high risk of developing caries in the future, was 56.8 with the group of children who had caries experience at baseline examination. However, with group of children who had no caries experience at baseline examination, the accuracy was low (Se=6.6). This low prevalence of the disease had made it more difficult to predict the development of

caries. Procedures in caries risk assessment are not well developed to predict caries in children with no or a low level of previous disease.

Therefore, it is important to define approaches applicable for children who have no caries. Possible approaches can range from ceasing caries risk assessment in the caries-free children to better defining the clinical guidance available for collecting more useful information before making clinical decisions.

The results of this research suggested that the latter approach can prove successful. It would be recommended for clinicians to check other evidence than past caries experience that would indicate a risk of developing caries in near future. For example, white spot lesions were reported associating with future caries in several studies. While the proportion of white spot lesions is low however, white spot lesions are still a good caries risk predictor (Nuttall and Deery 2002). The presence of white spot lesions in young children's mouths is considered a good indicator to predict future caries development. Clinical guidance needs to be developed to assist clinicians to observe white spot lesions before making decisions on caries risk.

7.1.4 Magnitude of effect of clinician and child factors on clinician accuracy

Clinician level of accuracy was found associated with the characteristics of children they had seen. For example, the best achieved accuracy of clinicians was only 112 among children who are in most favourable group (living in fluoridated areas, non-Indigenous, non-cardholder) and have no caries experience at baseline. This level was significantly lower than that observed among children in the least favourable group. Among children with no caries experience at baseline, the specificity was almost perfect (sp ranged from 96-98) while the sensitivity were very low to low accuracy group of clinician in the three groups by accuracy levels (combined sensitivity and specificity) (se ranged from 3–16) (Table 6.27). From a population perspective, when assessing risk among children with no baseline caries experience, improving sensitivity is the only option. However, the study's results showed that even with more accurate clinicians the sensitivity was far below 50% or 'chance alone'. Therefore, different approaches need to be identified for use among those children.

7.1.5 Caries rate among South Australian children

In general, caries experience was relatively low in this study population. Caries experience at baseline was slightly higher than the statewide findings for an earlier period (Armfield et al. 2004). For example, 49.0 % of children age six in this study had deciduous caries compared to 44.1% of the child population in South Australia in 2000. The South Australian child population had a prevalence of permanent caries of 33.5% at age 12 years in 2001, whereas this study sample had caries prevalence of 38.5% at age 12 years. It should be noted that data for this study was collected during the period from 2002 to 2005. There was a report of an increasing trend of caries in children in the earlier part of the decade (Armfield, 2010).

The relative low prevalence of caries in this study population was a reason for a caries risk assessment approach in delivering care. When caries is no longer a universal condition, it becomes more important to identify those who would be at higher risk of developing new caries in order to apply appropriate preventive services. While this provided a rationale for this study, the low prevalence of caries might have complicated the performance of caries risk assessment, the target of this study. As the study's findings indicated, clinicians' performance (measured by sensitivity) was significantly lower among children who had no caries experience.

7.2 Overview – strengths and limitations

7.2.1 Strengths of the study

1) **The study population**

This study was designed as a population-based longitudinal study with complex data collection processes. This study design was appropriate for the aims of the study in evaluating the relationship between clinician accuracy in predicting caries risk for SA SDS children. The number of children included in this study was large and it was considered as representative for the child population in South Australia. Because the sample was representative of the child population treated in a real-world setting, the results provided an opportunity to evaluate the actual caries risk assessment which can potentially be different to observations in a small-scale research setting. Estimates reported in this study were considered to be close to the population parameters.

2) **Information on clinicians**

Clinician accuracy in caries risk assessment was assessed in this study using both child- and clinician-related factors. This approach is unusual in research on caries risk assessment but necessary to reflect the conceptual framework of the caries risk assessment process. Outcomes of dental care delivery depend on both patient and provider. The individual-related factors determine the caries experience and caries risk profile of a patient prior to and after a clinical examination when a level of risk was assigned by a treating clinician. Knowledge and beliefs of the clinician are also important factors for a precise diagnosis and prognosis of the carious process. Interdependence exists between the child-related and clinician-related factors in affecting caries development during the follow-up period. That expected interdependence was evaluated and controlled for in this study.

3) Information on children

A major strength of the study was its use of information about child socio-demographic factors. The factors that were included in the analysis were almost all child socio-demographic information available to the clinicians at clinical examination. Evaluating the effect of those factors mimics the situation faced by the clinicians in the decision making process during the examination. Hence, the information was considered useful in evaluating the caries risk assessment process.

4) Measurement of caries rate

Caries rate was measured in this study using an incidence density estimate. This is a complex measure of caries development. The use of incidence density helped to adjust for different recall periods and different number of teeth present in each child. The resulting measurement of tooth surface-time at risk was considered appropriate and useful indicator in assessing longitudinal caries development. The use of incidence density was important to achieve the main objective of evaluating accuracy in caries risk assessment.

5) Measurement of accuracy of caries risk assessment

Using the combined caries of deciduous and permanent dentition as gold standard to calculate clinician accuracy was another feature of study as the majority children attending the SA SDS were children aged 5-12 presenting with a mixed dentition. This approach reflected the actual situation that the clinicians are faced with in

clinical practice. However, this approach has some associated issues. Caries experience is associated with age. Also, caries experience measured by the dmf/DMF index shows lower level of severity in the permanent dentition than in the primary dentition. On the other hand, clinicians often pay more attention in predicting caries in permanent dentition than caries in deciduous dentition. This might lead to an underestimate the actual clinician accuracy to some extent.

Sensitivity and specificity were used as measurements of clinician accuracy in assessing risk of developing caries in children. These indices have been used in numerous studies in different populations for varying purposes. Sensitivity and specificity has been one of the most widely used indices for assessing the accuracy of tests including high risk screening/diagnostic among children. Sensitivity and specificity have also been used to evaluate the accuracy of a predictive model. These indices have a wide range of values; therefore, they were suitable for achieving the specific objectives of this study. In SA SDS children were assigned to one of three levels of risk as low, medium or high. In order to calculate sensitivity and specificity, low and medium risks were aggregated to create 2x2 tables. This aggregation might have reduced informativeness of the data. However, the main focus of the caries risk assessment practice is on preventing high level of caries development. In another word, predicting high risk children has higher priority over differentiating between low and medium risk. Measures of association for 3x3 tables as an index of validity (for example, weighted kappa) were considered. However, Se+Sp using the 2x2 table are more widely used for clinical decision making. Previous caries risk prediction studies have usually used Se+Sp. Therefore, this approach was used in this study to enable comparison with previous studies.

6) Data analysis

Data analysis to achieve the study objectives was complex. The analysis was developed progressively from biavariate to multivariate analyses as is standard practice. The study objectives were tested from different perspectives to ensure consistency of the findings. Different datasets were used to answer different sub-questions during the process of hypothesis testing. Stratification was also used to evaluate study findings in different population groups.

7.2.2 Limitations of the study design and population

1) Uncalibrated examiners

There may be criticism that the dental caries data were collected by a large number of uncalibrated examiners (dentists and dental therapists) in the School Dental Service. Therefore, inter-examiner variation was expected. However, those examiners were similarly trained and had centrally regulated practice guidelines and used a uniform manual. Therefore, systematic biases were unlikely. Also, a similar approach in caries data collection was used in the Child Fluoride Study 1991/1992 (Slade et al. 1995; Slade et al. 1996; Slade et al. 1996), which had been considered as a pivotal study in children oral health (NHMRC 1999). The methodologies used in this study were similar to those of the Child Fluoride Study, with some modifications aimed at improving the reliability of the data. Also, analyses were based on the presence/absence of cavitated caries lesion (either filled or not), which is reliable (Evans et al. 1995).

On the other hand, using the data collected by clinicians in routine clinical practice can provide a more realistic assessment of the effect of caries risk assessment.

2) Factors associated with the study design

There was an unavoidable methodological problem that comes about because patients' treatment was tailored according to their level of risk. For example, children judged to be at high risk are more likely to receive preventive care and to have relatively shorter recall intervals than low-risk children. If the preventive care was efficacious, it was possible that a certain proportion of caries would be prevented among the children in the high risk group. If the observed rate of caries among those high-risk children fell below 1.2 carious lesions per 100-surface-years because of preventive care, they would be considered as false positives. Overall, providing care based on baseline risk status could lead to underestimation of the sensitivity scores and overall accuracy of caries risk assessment.

This issue was addressed in analyses using stratification according to provision of preventive care. For example, sensitivity (54) among children who received new fissure sealants during study period was higher than sensitivity (46) among children who did not receive fissure sealants. However, specificity among children who received fissure sealants was lower than among children who did not receive fissure

sealants. Sensitivity and specificity changed in the opposite directions. Therefore, overall accuracy (Se+Sp) of caries risk assessment were similar among these two groups of children. This suggested that there was probably only a small degree of underestimation due to this risk-based-treatment strategy. However, the results may, therefore, not be directly comparable with some other caries prediction studies where preventive services were not provided or not related to level of predicted risk. However, the study results reflected the actual situation in routine clinical practice.

Another limitation was that children's risk classification may have been based on factors other than caries such as due to orthodontic treatment or having certain medical conditions. A study conducted in South Australian children in 1995/1996 reported that majority of children (60%) were assigned a risk status for caries, other 20% were assigned at risk based on poor oral hygiene (Polster A 2003). In this study, risk status was used to assess clinician accuracy in predicting future caries development. Hence, this assumption might also underestimate clinician accuracy. This study included a large number of children creating potential for statistically significant findings even when the effects were small in magnitude. For that reason, emphasis was placed on the direction and magnitude of difference. Statistical significance observed in the analysis did not have high level of importance in comparisons between groups.

Clinician-related factors were derived from the survey of a representative sample of the South Australian SDS clinicians. There were over one hundred of participants in that survey. This sample size might be considered under-powered to detect statistical difference between clinicians. Despite that, statistical by significant difference were achieved in the main inferential statistics of the study.

3) Data analysis

A small group of clinicians examined a large number of children that were used in the analysis. Therefore, there was a strong clustering effect of child-related factors within clinicians. Controlling for this clustering effect was needed. Multilevel analysis is a new technique to control for clustering effects. However, it was not possible to perform multilevel analysis in this study for a number of reasons. First, children in the study might be seen by the same or different examiners during the follow-up period. Controlling for that cross-over effect was not in the scope of this study. Second, the outcome variables of the study, sensitivity and specificity, were

calculated for clinicians using child caries experience. Therefore, it was not possible to develop multilevel models for sensitivity and specificity. Nevertheless, the analysis was performed at both clinician and child levels as an alternative to control for the clustering effect. The analysis using the combined dataset was generated with robust standard error estimation to control for the interdependence of the observations.

Clinicians practised in the School Dental Services under uniform clinical policies and procedures. They also had similarities in many aspects of their training and experience. This made it difficult to identify clinician-related factors that might be associated with accuracy of risk prediction. Many of the clinical procedures were uniformly reported, or with very little variation. That produced skewed distributions for most of the items concerning clinicians' clinical practices (Table 5.3). For example, almost all clinicians reportedly dried teeth and used a blunt probe as an aid in diagnosing carious lesions. Furthermore, almost all clinicians received continuing professional education in Adelaide by SADS. Most of dental therapists worked for SADS only.

There is a common problem of dental caries data in children that are often highly skewed. Caries is confined to a minority of children who bear most of the burden of the disease. This might create problems for statistical analysis. However, most of parametric statistical analyses are reasonably robust and are not substantially affected when the assumption of data being normally distributed is slightly violated (Munro 1994). Further, the sample size of the study was large enough to increase the normality of the distribution of means, according to the central limit theorem (Munro 1994). The model summaries of the linear regression models reported in the study showed that residuals were normally distributed; hence, those models were applicable to test the study hypothesis.

4) Short-term caries outcomes

The follow-up period ranging from six months to 24 months was used in this study. It was possible that this follow-up time was too short for some children to develop new caries. However, the amount of caries developed during the study period was large. Furthermore, this period was used to simulate the recall period used in the South Australian School Dental Service.

7.3 Caries risk assessment strategy within School Dental Service

The risk assessment strategy has been considered as having some limitations. The available risk assessment models have low accuracy in identifying high risk subjects (Powell 1998; Zero et al. 2001). The current study also reported a relatively low observed accuracy in predicting new caries development. Furthermore, it has been recognised that an effective high-risk strategy would reduce the mean DMFS for the whole population by a mean of only one surface (Poulsen and Scheutz 1999). Even if high-risk subjects were accurately predicted, the existing in-office preventive measures may not be sufficient to prevent new disease (Hausen et al. 2000). On the other hand, Bachelor and Sheiham (2002) found that 50% of new lesions came from the predicted low-risk group in a screening/diagnostic program. That was an indication of the low accuracy of such simple screening/diagnostic programs.

The situation may differ in South Australia, where children were already covered by a comprehensive dental care program. All children had a right to have some level of treatments, prevention or oral health education regardless of their socioeconomic status and their predicted risk level. Therefore, assigning risk status for children served as the first step of a priority setting approach for more appropriate levels of care. The South Australian child population's oral health has benefited from the existing population strategy such as water fluoridation, widespread use of fluoridated toothpaste and access to dental care. The effectiveness of the population strategies should be maximised. The high-risk strategy can be implemented in addition to strong and successful population strategies or in the other word an evidence-based population approach must remain the cornerstone of prevention (Milsom and Tickle 2010). On the other hand, limited resources for dental care in South Australia create a need for a risk assessment strategy and its recall system for better resource allocation. It also should be noted that over-treatment of children who are at very low risk of having caries might not be necessary or beneficial (Milsom and Tickle 2010).

It has been emphasised by the findings of the current study that the caries risk assessment approach would achieve a small higher accuracy level if its "clinically-visible determinants" were supplemented by broader information on upstream

determinants of oral health. Understanding children's circumstances was found to improve combined sensitivity and specificity of caries risk assessment. Such information may also determine a better outcome of the risk assessment-related preventive measures. The findings support the suggested integration of targeted health promotion with prevention at a more upstream level to deliver better outcomes (Watt 2007).

This study agrees with all the studies gone before that we cannot predict caries very well and that there is a large difference between caries-free and caries-active populations. It also suggests that it might be time for researchers to minimise the search for more information on how to predict caries, as caries risk prediction is only for clinical management, and to pay more attention to research and providing an evidence based approach to population prevention strategies according to caries-free and caries-active status. An explicit decision about CRA should be made in the future: CRA is a population oral health prevention strategy or CRA is a clinical monitoring strategy (Brocklehurst et al. 2011).

7.4 Implications of study finding

7.4.1 Implication for research

While the study findings have contributed to the understanding of the caries risk assessment by clinicians in real life conditions and to the understanding of factors influencing the caries risk assessment process, further research could address some of the limitations as well as address new research questions raised.

The study indicated the importance of understanding non-clinical child-related factors by the service providers in predicting caries risk. There has been evidence of a link between child oral health and family factors (Mattila et al. 2000). However, research to understand how this effect influences clinician decision is required. Qualitative research investigating clinician behaviours may address this question.

Despite extensive research on the efficacy of the existing preventive measures, it was surprising to observe a significant amount of new caries in the high-risk children who received more of those services. This phenomenon needs to be understood in order to improve the effectiveness of the dental care provided to children. Research evaluating the community effectiveness of the existing efficacious preventive

measures can address this issue. Furthermore, the study findings indicated that an unproportionately high amount of intervention such as fissure sealants was used for low-risk children. Understanding factors leading to the actual use of preventive measures in the population will be beneficial for resource allocation and limiting unnecessary over treatment.

In this study age was also a factor that influenced the accuracy of CRA. This result was supported in many other studies. Numerous risk indicators should be considered when planning caries prevention procedures, including risk ages, teeth and surfaces at risk, time at risk, medical risks and social risks (Bader et al. 1986, Virtanen et al. 1996, Vehkalahti et al. 1997, Meurman 1997, Powell 1998, Härkänen et al 2002). CRA and preventive care should be initiated before the first phase of tooth eruption and during maturation of the enamel, in order to prevent the children from becoming high-risk cases in adolescence. The results from this study also suggest that CRA and preventive care should be focused on early childhood, to prevent the adherence of cariogenic bacteria to the newly erupted primary molars and then create a "biologically friendly" environment for the permanent dentition and also influence parents' attitudes towards the effectiveness of dental care in improving oral the health of small children. This is also supported by study in England by Bachelor et al (2002). To maximise the effectiveness of CRA further research is needed on what kind of intervention is suitable for what age.

7.4.2 Implications for population oral health

This section deals with the public health implications of the findings. These are discussed in relation to appropriateness of care and the development of guidelines in clinical practice.

Several major findings of this study can have public health implications. There is a need to develop a better caries risk assessment approach for children who had no caries differently as compared with for children who have had caries. The study's findings have indicated to a number of factors that can be used to improve the accuracy of caries risk assessment among the children with no caries experience at the time of examination. The younger age group and residence in non-fluoridated areas are the additional factors that assist improving caries risk assessment. This finding has practical implication in developing clinical guidelines for such age group

and staff working in non-fluoridated areas. This "proof of evidence" supports the call for further research to improve caries risk assessment among children with no presence of decay.

The study findings provided evidence to support caries risk assessment practice in delivering care for children in an environment of universal care. It was obvious that certain groups in the child population, mostly those in low socioeconomic position, would develop more caries than others. This unevenness in oral health needs to be addressed in order to improve the overall oral health of the population. This is important in the situation where dental resources are limited. The study findings indicate the need for clinicians to develop better understanding of circumstances related to the patients other than clinical dental factors alone. This supports the call for integration of general and dental care.

Another finding of the study was that even when caries risk was reasonably accurately predicted and high risk children were provided with more intensive care, certain groups of high-risk children still developed significantly amount of disease. This paradoxical finding indicated that the existing preventive practices, mostly clinical procedures, might not be adequate to address the problem. This inadequacy points to the need of a broader range of measures integrating clinical procedures with measures targeting family and social circumstances. More attention is required to identify other factors intervention for which may further reduce the risk of developing caries. The current concept of caries as a multifactorial, condition may play a significant role in addressing this issue. The study indicated that understanding child-related non-clinical factors in the family, school or community might have a modest effect in better predicting caries.

In the light of the current knowledge and findings of the study, the importance of continuing education for clinicians is further emphasised. Any such continuing education must be focused on developing a preventive orientation for clinicians. A patient-centred approach is also required and this is aided by the information that should be collected as part of CRA.

One of immediate implications of the study findings can be development and implementation of an algorithm to assist clinicians to better predict caries risk for children. The development of such a model has been described in Chapter 6 of this study. The study findings indicate that incorporating clinician best judgement (one of

the main factors in caries risk assessment) with other child-related factors using a computer-assisted program can further improve the accuracy of caries risk assessment. Implementation of such a program can be made possible in the South Australian School Dental Service by the universal use of a computerised patient management system. Such a system has become the norm in public dental services in Australia. It is especially relevant in a public health care system where resource scarcity is a significant problem. Therefore, risk assessment remains a suitable approach in resource allocation.

This study indicated that dental caries is still widespread among South Australian children and it has a measurable impact on the perception of oral health and oral health-related quality of life of the children (Do and Spencer 2007). Dental caries is still a dental public health problem in the study population. The prevention of dental caries in children continues to be on the agenda of the dental public health in Australia.

Caries risk assessment was mostly performed by dental therapists in SA SDS. The level of accuracy in predicting caries risk for SA children among dental therapists was similar to that performed by dentists in other studies. This study's findings have provided evidence to support the use of dental therapists in caries risk assessment for children. Further research should investigate the effect of such substitution on the dental care system as suggested by Baelum and others (Baelum et al. 2007).

7.4.3 Implications for dental practitioners

A useful risk assessment program should be one with high sensitivity and specificity (Stamm et al., 1998). However, with the trade-off between sensitivity and specificity, it may be impractical for both to be achieved simultaneously. Cariogram, a computerized program which was developed in Sweden, even with biological test, showed a sensitivity/specificity (73%/60%) among children age 9-10 (Petersson, 2010). Another caries risk assessment cariogram among preschool children in Sweden could only achieve a sensitivity of 46% and specificity of 88% (Holgerson, 2009). This indicated that efforts to try to develop an accurate CRA tool in any population and of any age, the result was not as good as expected.

The difficulty in individual assessment of future caries risk is widely accepted. This was evident in this current study. However, at the group level risk assessment is

much stronger. The fact that children in the low risk group developed significantly fewer new carious lesions than children in high risk group (Table 3.14) revealed that risk assessment at the group level was far more accurate than would have been expected by chance alone.

The study findings indicate that CRA can only be useful in children who already had some level of disease. This limitation of a purely high risk strategy in preventing dental caries has been discussed (Batchelor, 2002). Hausen (1997) concluded that the whole population approach should still be adopted as services are unable to provide adequate individual protection to those at the greatest risk and that dental caries remains a common disease. Batchelor (2002) concluded that caries preventive strategies should be based on a population approach. Therefore, from a dental care program perspective, caries risk assessment can better be used as a method to allocate resources proportional to expected level of risk. This approach may be useful when dental resources are scarce, similar to that observed in the South Australian Dental Services. While caries risk assessment is still useful, it is important to note the difficulty in improving CRA accuracy among children with no caries experience.

Fontana (2006) concluded that the assessment of all risk factors not only allows for a more accurate assessment of risk of developing a disease, but it also helps identifying potential factors associated with the disease experience in a particular patient. The caries risk assessment and clinical examination provide an overview of unfavourable exposures to potential caries risk/protective factors such as plaque, frequency of sugar intake, and exposure fluoride. This approach encourages management strategies developed specifically for the patient. Therefore, caries risk assessment is also useful in the clinical management of caries by helping dental professionals to evaluate the degree of the patient's risk of developing caries to determine the intensity of the treatment and frequency of recall appointments or treatments (Tinanoff and Douglass 2001). CRA also helps identify the main etiologic agents that contribute to the disease or that, because of their recent onset, may contribute to future disease, to determine the type of treatment and aid in restorative treatment decisions (for example, wether to intervene, cavity designs, choice of dental materials). Without a CRA program clinicians may only focus on performing clinical procedures without exploring the factors associated with their patients' caries pattern. Fontana (2006) also stated the CRA can also improve the reliability of the

prognosis of the planned treatment and assess the efficacy of the proposed management and preventive treatment plan at recall visits. CRA can be a tool to assist clinicians in allocating their time to understand factors affecting individual child's caries experience and may help setting up an effective treatment plan.

Chapter 8. Summary and conclusions

Findings from this study support five main conclusions:

1. Accuracy of caries risk assessment performed in SA children by SADS clinicians was comparable to that reported for dentists in research settings. This is empirical evidence that clinicians with appropriate training can perform caries risk assessment with a reasonable level of accuracy. While the study supports the use of CRA in school dental service patients with caries experience, accuracy in children with no caries experience was little better than chance alone.

2. A number of factors at the clinician level were found associated with clinician's performance of caries risk assessment in practice. Improving clinician factors in order to understand children's stressful life events and family circumstances can improve the accuracy of CRA by approximately four percent (5 units of Se+Sp).

3. However, the study has indicated that to a large extent, the accuracy of caries risk assessment depended on the children's level of past caries experience. This finding indicated that among children with no caries experience, the current practice of caries risk assessment is not adequate in predicting caries development. This is of importance because the majority of children in Australia have a low level of caries. More research needs to be done among this group in order to improve caries risk assessment.

4. The study has indicated that there were large children's caries rates. Current preventive care provided in the SDS is not adequate to prevent a large amount of the disease, even when risk is correctly identified. Children who were classified as high-risk still developed significant amounts of caries even

with a shorter recall interval and more preventive treatments. Research is needed to improve the effectiveness of preventive care provided in SADS.

5. Incorporating clinician's judgement with other predictive factors using computerised algorithm can improve the accuracy of caries risk assessment in this study population.

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Appendix 1: Caries risk assessment guideline

NOTE:
This appendix is included on pages 236-239 of the print copy of the thesis held in the University of Adelaide Library.

Appendix 2: survey instrument

Questionnaire to clinicians

South Australian Dental Service

ARCPOH
Australian Research Centre for POPULATION ORAL HEALTH

THE UNIVERSITY OF ADELAIDE
AUSTRALIA

CARIES RISK ASSESSMENT for South Australian Children

QUESTIONNAIRE FOR DENTAL CLINICIANS 2004

AUSTRALIAN RESEARCH CENTRE FOR POPULATION ORAL HEALTH
DENTAL SCHOOL
THE UNIVERSITY OF ADELAIDE
SOUTH AUSTRALIA 5005

TELEPHONE 8303 4611
FACSIMILE 8303 4858

YOUR ROUTINE CLINICAL PRACTICE

For the following questions, please read each row and tick ONE box that best describes your usual practice.

Q1 When you conduct an initial or recall examination, how often do you …?

	Always	Usually	Some-times	Rarely	Never
1a. Ask a child to brush his/her teeth before the examination?	☐1	☐2	☑3	☐4	☐5
1b. Clean debris and calculus before examination?	☐1	☐2	☐3	☑4	☐5
1c. Clean approximal surfaces with dental floss before examination?	☐1	☐2	☐3	☐4	☑5
1d. Isolate teeth with cotton rolls during examination?	☐1	☐2	☐3	☑4	☐5
1e. Dry teeth with compressed air during examination?	☑1	☐2	☐3	☐4	☐5
1f. Use a blunt probe to detect caries in a questionable area?	☐1	☑2	☐3	☐4	☐5
1g. Use transillumination or reflected light for caries diagnosis?	☑1	☐2	☐3	☐4	☐5
1h. Use disclosing solutions or tablets to detect caries?	☐1	☐2	☐3	☐4	☑5
1i. Assess the child's orthodontic (Angle) classification?	☐1	☑2	☐3	☐4	☐5
1j. Assess tooth alignment in the dental arch?	☑1	☐2	☐3	☐4	☐5
1k. Assess teeth for crowding?	☑1	☐2	☐3	☐4	☐5
1l. Look for signs of dental fluorosis?	☑1	☐2	☐3	☐4	☐5

Q2 During an initial or recall examination, how often do you ask a CHILD OR HIS/HER PARENTS/CAREGIVERS information about ...?	Always	Usually	Some-times	Rarely	Never
2a. Child's frequency of brushing?	☐1	☑2	☐3	☐4	☐5
2b. Whether or not the child uses fluoridated toothpaste?	☐1	☑2	☐3	☐4	☐5
2c. Whether the toothpaste is low concentration or standard fluoridated toothpaste?	☐1	☐2	☑3	☐4	☐5
2d. Amount of toothpaste placed on his/her toothbrush?	☐1	☐2	☑3	☐4	☐5
2e. Method of clearing toothpaste from child's mouth after brushing *(rinsing or spitting)*?	☐1	☐2	☑3	☐4	☐5
2f. Type of drinking water that child usually drinks *(tap water, bottled water or tank water)*?	☐1	☐2	☐3	☑4	☐5
2g. Child's frequency and quantity of sugar intake?	☐1	☐2	☑3	☐4	☐5
2h. Child's stressful life events?	☐1	☐2	☐3	☑4	☐5
2i. Child's general coping in school *(eg academic, social coping)*?	☐1	☐2	☐3	☐4	☑5

Q3 How important do you think the role of saliva is in preventing caries?	Definitely important	Probably important	Neutral	Probably not important	Definitely not important
	☑1	☐2	☐3	☐4	☐5

Q4 Based on your clinical experience and judgment, how important is each of the following in assessing children's risk of dental caries? (PLEASE TICK ONE BOX FOR EACH ROW)

	Definitely important	*Probably important*	*Neutral*	*Probably not important*	*Definitely not important*	*Don't know*
Section A: Child's caries experience						
A1. Number of new cavities between recalls	☑ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6
A2. Past caries	☑ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6
A3. Decalcified "white spot" lesions	☐ 1	☑ 2	☐ 3	☐ 4	☐ 5	☐ 6
A4. The size or surface area of carious lesions	☑ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6
A5. The extent or depth of carious lesions	☑ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6
Section B: Tooth morphology						
B1. Deep pits and fissures	☐ 1	☑ 2	☐ 3	☐ 4	☐ 5	☐ 6
B2. Dental occlusion (Angle class)	☐ 1	☐ 2	☑ 3	☐ 4	☐ 5	☐ 6
B3. Tooth alignment in the dental arch	☐ 1	☑ 2	☐ 3	☐ 4	☐ 5	☐ 6
B4. Tooth crowding	☐ 1	☑ 2	☐ 3	☐ 4	☐ 5	☐ 6
Section C: Socio-demographic status						
C1. Non-English-speaking background	☐ 1	☐ 2	☑ 3	☐ 4	☐ 5	☐ 6
C2. Family's income	☑ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6
C3. Residence in rural areas	☑ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6
C4. Family composition, eg sole parent	☐ 1	☐ 2	☐ 3	☑ 4	☐ 5	☐ 6
C5. Parents' education	☐ 1	☑ 2	☐ 3	☐ 4	☐ 5	☐ 6
C6. Parents' occupation	☐ 1	☐ 2	☑ 3	☐ 4	☐ 5	☐ 6
C7. Country of birth of child	☑ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6

Section D: Behavioural factors	Definitely important	Probably important	Neutral	Probably not important	Not Important	Don't know
D1. Presence of plaque on teeth	☑ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6
D2. Presence of gingivitis	☑ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6
D3. General personal hygiene	☐ 1	☐ 2	☑ 3	☐ 4	☐ 5	☐ 6
D4. Tooth-brushing habits	☑ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6
D5. Flossing habits	☐ 1	☐ 2	☑ 3	☐ 4	☐ 5	☐ 6
D6. Frequency of dental check-ups	☐ 1	☐ 2	☑ 3	☐ 4	☐ 5	☐ 6
D7. Diet high in fermentable carbohydrate	☑ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6
D8. Frequent sweet snacks between meals	☑ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6
D9. Frequent intake of drinks containing sugars	☐ 1	☑ 2	☐ 3	☐ 4	☐ 5	☐ 6
D10. Frequent intake of sweet drinks or snacks prior to going to bed	☑ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6
Section E: Fluoride history						
E1. Use of fluoridated tap water as main source of drinking water	☑ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6
E2. History of topical fluoride applications	☐ 1	☐ 2	☐ 3	☑ 4	☐ 5	☐ 6
E3. Past use of fluoride supplements	☐ 1	☐ 2	☐ 3	☑ 4	☐ 5	☐ 6
E4. At least twice daily use of fluoride toothpaste	☑ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6
E5. Presence of fluorosis	☑ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6
Section F: Other factors						
F1. Child's general health, eg diabetes	☑ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6
F2. Regular use of medication with sugar base	☐ 1	☑ 2	☐ 3	☐ 4	☐ 5	☐ 6

	Definitely important	Probably important	Neutral	Probably not important	Definitely not important	Don't know
F3. Presence of caries in mother	☐1	☐2	☐3	☑4	☐5	☐6
F4. Presence of caries in sibling	☐1	☐2	☐3	☑4	☐5	☐6
F5. Child's saliva flow rate	☑1	☐2	☐3	☐4	☐5	☐6
F6. Unstimulated salivary pH	☐1	☐2	☐3	☐4	☐5	☑6
F7. Stimulated salivary pH	☐1	☐2	☐3	☐4	☐5	☑6
F8. *Mutans streptococci* count	☐1	☐2	☐3	☐4	☐5	☑6
F9. Presence of enamel hypoplasia	☑1	☐2	☐3	☐4	☐5	☐6

Additional factors: Based on your own clinical experience, please **write down** any additional factor(s) that you think should be added to the above list.

Please tick the box that best describes the importance of these factors.

Section G: Additional factors	Definitely important	Probably important	Neutral	Probably not important	Definitely not important	Don't know
G1. "SOCIO ECONOMIC" FACTORS	☑1	☐2	☐3	☐4	☐5	☐6
G2.	☐1	☐2	☐3	☐4	☐5	☐6
G3.	☐1	☐2	☐3	☐4	☐5	☐6
G4	☐1	☐2	☐3	☐4	☐5	☐6

Q4a **Based on your own knowledge, experience and judgment, please choose three factors that you consider to be the most important for predicting caries from the factors listed above.** **(PLEASE WRITE QUESTION NUMBER)**	Most important factor	Second most important factor	Third most important factor
	eg E1.	eg G3.	eg F3.
	A2.	A4	E1.

Q4b Which three factors do you most frequently use when assigning caries risk status in School Dental Service clinics? (PLEASE WRITE QUESTION NUMBER)

Most frequently used factor	*Second most frequently used factor*	*Third most frequently used factor*
eg E2.	eg A7.	eg F4.
A 1	A 2	A 4

Please indicate your main reason for using those factors in Q4b by ticking ONE box that best describes your reason for choosing each factor.

☑1 I find it is quite accurate	☑1 I find it is quite accurate	☑1 I find it is quite accurate
☐2 Based on evidence from literature	☐2 Based on evidence from literature	☐2 Based on evidence from literature
☑3 I find it is easy to obtain this information	☑3 I find it is easy to obtain this information	☑3 I find it is easy to obtain this information
☐4 Based on SADS's guidelines for caries risk assessment	☐4 Based on SADS's guidelines for caries risk assessment	☐4 Based on SADS's guidelines for caries risk assessment
☐5 Based on SADS's continuing education lectures/seminars	☐5 Based on SADS's continuing education lectures/seminars	☐5 Based on SADS's continuing education lectures/seminars
☐6 Other *(please specify)* ----------	☐6 Other *(please specify)* ----------	☐6 Other *(please specify)* ----------

Q5 If you have difficulty in deciding between two levels of risk for patients, what are you most likely to do?
(PLEASE TICK ONE BOX ONLY)

- ☐1 Search for more information about risk assessment
- ☐2 Assign the child to the lower risk category
- ☐3 Discuss with other colleagues
- ☐4 Recall/review patient before deciding a level of risk
- ☑5 Assign the child to the higher risk category
- ☐6 Other *(please specify)*----------

Q6 On average, for every ten children examined, how many bitewings would you take for diagnosing caries? (PLEASE WRITE THE NUMBER IN BOX) [.5]

Q7 How do you rate your current knowledge of caries risk assessment?

Very up-to-date	*Adequate*	*Need some update*	*Totally Out- of- date*
☐1	☑2	☐3	☐4

Q8 Would you like extra training in caries risk assessment?	Yes	No	Don't know
	☐1	☑2	☐3

Q9 Do you attend the continuing education courses which SADS organises?	Yes	Sometimes	No
	☑1	☐2	☐3

If NO, is it because **(PLEASE TICK THE MAIN REASON FOR NOT ATTENDING)**	☐1 Have no time ☐2 The courses usually provide no new information ☐3 The location of the course is too far away ☐4 Other *(please specify)* _____

Q10 Based on your experience, how confident are you in …?

	Very confident	Somewhat confident	Not confident at all
10a. Identifying the cause of caries?	☐1	☑2	☐3
10b. Diagnosing caries?	☑1	☐2	☐3
10c. Treating caries?	☑1	☐2	☐3
10d. Predicting future caries?	☐1	☑2	☐3
10e. Preventing future caries?	☐1	☐2	☑3

Q11 Please indicate your level of agreement with the following statements by ticking ONE box for each row.

Do you think that SADS's caries risk assessment program (or Personalised Dental Care) for children …?

	Strongly agree	Agree	Not sure	Disagree	Strongly disagree
11a. Is cost-effective?	☐1	☐2	☑3	☐4	☐5
11b. Prevents caries?	☐1	☐2	☐3	☑4	☐5
11c. Encourages children to improve their oral hygiene?	☐1	☐2	☐3	☑4	☐5
11d. Is useful for all children?	☐1	☐2	☐3	☑4	☐5

	Strongly agree	Agree	Not sure	Disagree	Strongly disagree
11e. Is an accurate system?	☐1	☐2	☑3	☐4	☐5
11f. Provides appropriate services for the needs of children?	☐1	☐2	☐3	☑4	☐5
11g. Creates the right priorities for the SDS?	☐1	☐2	☑3	☐4	☐5
11h. Establishes a fairer SDS?	☐1	☐2	☐3	☑4	☐5

WORKING CONDITIONS

Q12 Please answer the following in terms of your clinic time using a typical or average day or week as indicated.

	Location (SADS clinic)	Hours you spend chairside with patients (on average)	
		AM	PM
Mon		4	3½
Tue		4	3½
Wed		4	3½
Thu		4	3½
Fri			

Q13 How many weeks did you work over the last 12 months? 41. weeks

Q14 How many other dentists/dental therapists work with you at the above locations?

	Number of clinicians	
	AM	PM
Mon	4 - 5	4 - 5
Tue	4 - 5	4 - 5
Wed	4 - 5	4 - 5
Thu	1	1
Fri		

Q15 Please indicate how comfortable you feel seeking a second opinion to discuss clinical cases. (PLEASE TICK ONE BOX ONLY)	Very comfortable	Comfortable	Neutral	Uncom-fortable	Very uncom-fortable
	☑1	☐2	☐3	☐4	☐5

Q16 Please tick ONE box which best indicates your level of agreement with each statement about your job satisfaction.

	Strongly agree	*Agree*	*Not sure*	*Disagree*	*Strongly disagree*
16a. My dental colleagues are a source of professional stimulation.	☑ 1	☐ 2	☐ 3	☐ 4	☐ 5
16b. I get along with my dental colleagues.	☐ 1	☑ 2	☐ 3	☐ 4	☐ 5
16c. I feel a sense of belonging to the community where I practise.	☑ 1	☐ 2	☐ 3	☐ 4	☐ 5
16d. I feel respected by the community that I work in.	☑ 1	☐ 2	☐ 3	☐ 4	☐ 5
16e. I have too much administrative work to do.	☑ 1	☐ 2	☐ 3	☐ 4	☐ 5
16f. Dental supplies are available when I need them.	☑ 1	☐ 2	☐ 3	☐ 4	☐ 5
16g. I have sufficient space to see my patients.	☐ 1	☑ 2	☐ 3	☐ 4	☐ 5
16h. I have adequate equipment for office procedures.	☐ 1	☑ 2	☐ 3	☐ 4	☐ 5
16i. There are not enough support staff to aid in my work.	☐ 1	☐ 2	☐ 3	☑ 4	☐ 5
16j. I am not well compensated given my training and experience.	☐ 1	☑ 2	☐ 3	☐ 4	☐ 5
16k. The work load required is a burden to me.	☐ 1	☐ 2	☐ 3	☑ 4	☐ 5
16l. Time pressure keeps me from developing good patient relationships.	☐ 1	☐ 2	☐ 3	☑ 4	☐ 5
16m. Overall, I am pleased with my work	☑ 1	☐ 2	☐ 3	☐ 4	☐ 5
16n. Overall, I am satisfied with my current practice.	☐ 1	☑ 2	☐ 3	☐ 4	☐ 5
16o. My total compensation package is fair.	☐ 1	☐ 2	☑ 3	☐ 4	☐ 5
16p. My current work situation is a major source of frustration.	☐ 1	☐ 2	☐ 3	☑ 4	☐ 5

	Strongly agree	Agree	Not sure	Disagree	Strongly disagree
16q. In general my dental career has not met my expectations	☐1	☐2	☐3	☑4	☐5
16r. If I were to start my career over again, I would choose my current area and type of practice	☐1	☑2	☐3	☐4	☐5

GENERAL INFORMATION

Q17 Operator ID Number	_____ *(Please note that it is important to place Operator ID No. for data linkage to EXACT system, but it will not be used to identify any person answering this questionnaire.)*
Q18 Sex	Male ☐
Q19 Country of birth	Australia ☑1 Other country ☐2
Q20 Year of birth	

Q21 Please indicate what dental qualification(s) you have obtained.

Year of completion	Name of qualification	State/territory where qualification obtained

Q22 Other qualifications	Yes ☐1	*Please specify* _____
	No ☑2	
Q23 Year of graduation	_	
Q24 School of graduation	_	

Q25 Please indicate your current work status.

Full-time work in dentistry ☐1	Part-time ☑2	Casual ☐3

Additional comments or questions.

Thank you for your cooperation and time in filling out this questionnaire.

Please check to ensure the completeness of the questionnaire and return in the enclosed reply-paid envelope to:

Caries Risk Assessment Study

ARCPOH, Dental School

The University of Adelaide

SA 5005

If you have any questions about the study, please feel free to call Dr Diep Ha during business hours on 8303 4611.

Office use:

Date arrived: .....

Clinician data dictionary

Name	Type	Width	Decimal	label	value
PATID	String	14	0	patient ID	
CLINIC	String	20	0	Clinic name	
SITEID	Numeric	3	2	Clinic name	
SCHOOL	Numeric	3	2	School Code	
DOB	Date	10	0	Date of birth	
SEX	String	1	0	Gender of child	
RISK	String	11	0	Risk classification	
POSTCODE	Numeric	4	2	Residential postcode	
ABORIGIN	String	14	0	Aboriginality status	
LANGUAGE	String	9	0	Language spoken at home	
COB	String	11	0	Country of birth	
INSURANC	String	4	0	Health care insurance	
CARDTYPE	String	25	0	Health care concession card status	
FIRSTEXM	Date	10	0	First examination	
LASTEXAM	Date	10	0	Last examination	
DateExam	Date	10	0	Date of current examination	
TimeExam	String	10	0	Time of current examination	
User	String	5	0	Provider ID	

T18_0	Numeric	2	1	tooth 18_tooth level	1:Sound; 2:Decayed; 3:Filled; 4:Extracted – Pathology (counts as Missing in DMF index); 5:Extracted – Orthodontic (Not included in DMF index); 6: Unerupted/Exfoliated; 7:(Not Used); 8:Precavitated lesion (D1); 9:Fissure Sealed (Permanent teeth only);
T18_1	Numeric	1	0	tooth 18_occlusal surface	As above
T18_2	Numeric	1	0	tooth 18_Buccal surface	As above
T18_3	Numeric	1	0	tooth 18_mesial surface	As above
T18_4	Numeric	1	0	tooth 18_Distal surface	As above
T18_5	Numeric	1	0	tooth 18_palatal surface	As above
T17_0	Numeric	1	0	tooth 17_tooth level	As above
T17_1	Numeric	1	0	tooth 17_occlusal surface	As above
T17_2	Numeric	1	0	tooth 17_Buccal surface	As above
T17_3	Numeric	1	0	tooth 17_mesial surface	As above
T17_4	Numeric	1	0	tooth 17_Distal surface	As above
T17_5	Numeric	1	0	tooth 17_palatal surface	As above
T16_0	Numeric	1	0	tooth 16_tooth level	As above
T16_1	Numeric	1	0	tooth 16_occlusal surface	As above
T16_2	Numeric	1	0	tooth 16_Buccal surface	As above
T16_3	Numeric	1	0	tooth 16_mesial surface	As above
T16_4	Numeric	1	0	tooth 16_Distal surface	As above

T16_5	Numeric	1	0	tooth 16_palatal surface	As above
T15_0	Numeric	1	0	tooth 15_tooth level	As above
T15_1	Numeric	1	0	tooth 15_occlusal surface	As above
T15_2	Numeric	1	0	tooth 15_Buccal surface	As above
T15_3	Numeric	1	0	tooth 15_mesial surface	As above
T15_4	Numeric	1	0	tooth 15_Distal surface	As above
T15_5	Numeric	1	0	tooth 15_palatal surface	As above
T14_0	Numeric	1	0	tooth 14_tooth level	As above
T14_1	Numeric	1	0	tooth 14_occlusal surface	As above
T14_2	Numeric	1	0	tooth 14_Buccal surface	As above
T14_3	Numeric	1	0	tooth 14_mesial surface	As above
T14_4	Numeric	1	0	tooth 14_Distal surface	As above
T14_5	Numeric	1	0	tooth 14_palatal surface	As above
T13_0	Numeric	1	0	tooth 13_tooth level	As above
T13_1	Numeric	1	0	tooth 13_incisal edge	As above
T13_2	Numeric	1	0	tooth 13_Buccal surface	As above
T13_3	Numeric	1	0	tooth 13_mesial surface	As above
T13_4	Numeric	1	0	tooth 13_Distal surface	As above
T13_5	Numeric	1	0	tooth 13_palatal surface	As above
T12_0	Numeric	1	0	tooth 12_tooth level	As above
T12_1	Numeric	1	0	tooth 12_incisal edge	As above

T12_2	Numeric	1	0	tooth 12_Buccal surface	As above
T12_3	Numeric	1	0	tooth 12_mesial surface	As above
T12_4	Numeric	1	0	tooth 12_Distal surface	As above
T12_5	Numeric	1	0	tooth 12_palatal surface	As above
T11_0	Numeric	1	0	tooth 11_tooth level	As above
T11_1	Numeric	1	0	tooth 11_incisal edge	As above
T11_2	Numeric	1	0	tooth 11_Buccal surface	As above
T11_3	Numeric	1	0	tooth 11_mesial surface	As above
T11_4	Numeric	1	0	tooth 11_Distal surface	As above
T11_5	Numeric	1	0	tooth 11_palatal surface	As above
T21_0	Numeric	1	0	tooth 21_tooth level	As above
T21_1	Numeric	1	0	tooth 21_incisal edge	As above
T21_2	Numeric	1	0	tooth 21_Buccal surface	As above
T21_3	Numeric	1	0	tooth 21_mesial surface	As above
T21_4	Numeric	1	0	tooth 21_Distal surface	As above
T21_5	Numeric	1	0	tooth 21_palatal surface	As above
T22_0	Numeric	1	0	tooth 22_tooth level	As above
T22_1	Numeric	1	0	tooth 22_incisal edge	As above
T22_2	Numeric	1	0	tooth 22_Buccal surface	As above
T22_3	Numeric	1	0	tooth 22_mesial surface	As above
T22_4	Numeric	1	0	tooth 22_Distal surface	As above

T22_5	Numeric	1	0	tooth 22_palatal surface	As above
T23_0	Numeric	1	0	tooth 23_tooth level	As above
T23_1	Numeric	1	0	tooth 23_incisal edge	As above
T23_2	Numeric	1	0	tooth 23_Buccal surface	As above
T23_3	Numeric	1	0	tooth 23_mesial surface	As above
T23_4	Numeric	1	0	tooth 23_Distal surface	As above
T23_5	Numeric	1	0	tooth 23_palatal surface	As above
T24_0	Numeric	1	0	tooth 24_tooth level	As above
T24_1	Numeric	1	0	tooth 24_occlusal surface	As above
T24_2	Numeric	1	0	tooth 24_Buccal surface	As above
T24_3	Numeric	1	0	tooth 24_mesial surface	As above
T24_4	Numeric	1	0	tooth 24_Distal surface	As above
T24_5	Numeric	1	0	tooth 24_palatal surface	As above
T25_0	Numeric	1	0	tooth 25_tooth level	As above
T25_1	Numeric	1	0	tooth 25_occlusal surface	As above
T25_2	Numeric	1	0	tooth 25_Buccal surface	As above
T25_3	Numeric	1	0	tooth 25_mesial surface	As above
T25_4	Numeric	1	0	tooth 25_Distal surface	As above
T25_5	Numeric	1	0	tooth 25_palatal surface	As above
T26_0	Numeric	1	0	tooth 26_tooth level	As above
T26_1	Numeric	1	0	tooth 26_occlusal surface	As above

T26_2	Numeric	1	0	tooth 26_Buccal surface	As above
T26_3	Numeric	1	0	tooth 26_mesial surface	As above
T26_4	Numeric	1	0	tooth 26_Distal surface	As above
T26_5	Numeric	1	0	tooth 26_palatal surface	As above
T27_0	Numeric	1	0	tooth 27_tooth level	As above
T27_1	Numeric	1	0	tooth 27_occlusal surface	As above
T27_2	Numeric	1	0	tooth 27_Buccal surface	As above
T27_3	Numeric	1	0	tooth 27_mesial surface	As above
T27_4	Numeric	1	0	tooth 27_Distal surface	As above
T27_5	Numeric	1	0	tooth 27_palatal surface	As above
T28_0	Numeric	1	0	tooth 28_tooth level	As above
T28_1	Numeric	1	0	tooth 28_occlusal surface	As above
T28_2	Numeric	1	0	tooth 28_Buccal surface	As above
T28_3	Numeric	1	0	tooth 28_mesial surface	As above
T28_4	Numeric	1	0	tooth 28_Distal surface	As above
T28_5	Numeric	1	0	tooth 28_palatal surface	As above
T48_0	Numeric	1	0	tooth 48_tooth level	As above
T48_1	Numeric	1	0	tooth 48_occlusal surface	As above
T48_2	Numeric	1	0	tooth 48_Buccal surface	As above
T48_3	Numeric	1	0	tooth 48_mesial surface	As above
T48_4	Numeric	1	0	tooth 48_Distal surface	As above

T48_5	Numeric	1	0	tooth 48_lingual surface	As above
T47_0	Numeric	1	0	tooth 47_tooth level	As above
T47_1	Numeric	1	0	tooth 47_occlusal surface	As above
T47_2	Numeric	1	0	tooth 47_Buccal surface	As above
T47_3	Numeric	1	0	tooth 47_mesial surface	As above
T47_4	Numeric	1	0	tooth 47_Distal surface	As above
T47_5	Numeric	1	0	tooth 47_lingual surface	As above
T46_0	Numeric	1	0	tooth 46_tooth level	As above
T46_1	Numeric	1	0	tooth 46_occlusal surface	As above
T46_2	Numeric	1	0	tooth 46_Buccal surface	As above
T46_3	Numeric	1	0	tooth 46_mesial surface	As above
T46_4	Numeric	1	0	tooth 46_Distal surface	As above
T46_5	Numeric	1	0	tooth 46_lingual surface	As above
T45_0	Numeric	1	0	tooth 45_tooth level	As above
T45_1	Numeric	1	0	tooth 45_occlusal surface	As above
T45_2	Numeric	1	0	tooth 45_Buccal surface	As above
T45_3	Numeric	1	0	tooth 45_mesial surface	As above
T45_4	Numeric	1	0	tooth 45_Distal surface	As above
T45_5	Numeric	1	0	tooth 45_lingual surface	As above
T44_0	Numeric	1	0	tooth 44_tooth level	As above
T44_1	Numeric	1	0	tooth 44_occlusal surface	As above

T44_2	Numeric	1	0	tooth 44_Buccal surface	As above
T44_3	Numeric	1	0	tooth 44_mesial surface	As above
T44_4	Numeric	1	0	tooth 44_Distal surface	As above
T44_5	Numeric	1	0	tooth 44_lingual surface	As above
T43_0	Numeric	1	0	tooth 43_tooth level	As above
T43_1	Numeric	1	0	tooth 43_incisal edge	As above
T43_2	Numeric	1	0	tooth 43_Buccal surface	As above
T43_3	Numeric	1	0	tooth 43_mesial surface	As above
T43_4	Numeric	1	0	tooth 43_Distal surface	As above
T43_5	Numeric	1	0	tooth 43_lingual surface	As above
T42_0	Numeric	1	0	tooth 42_tooth level	As above
T42_1	Numeric	1	0	tooth 42_incisal edge	As above
T42_2	Numeric	1	0	tooth 42_Buccal surface	As above
T42_3	Numeric	1	0	tooth 42_mesial surface	As above
T42_4	Numeric	1	0	tooth 42_Distal surface	As above
T42_5	Numeric	1	0	tooth 42_lingual surface	As above
T41_0	Numeric	1	0	tooth 41_tooth level	As above
T41_1	Numeric	1	0	tooth 41_incisal edge	As above
T41_2	Numeric	1	0	tooth 41_Buccal surface	As above
T41_3	Numeric	1	0	tooth 41_mesial surface	As above
T41_4	Numeric	1	0	tooth 41_Distal surface	As above

T41_5	Numeric	1	0	tooth 41_lingual surface	As above
T31_0	Numeric	1	0	tooth 31_tooth level	As above
T31_1	Numeric	1	0	tooth 31_incisal edge	As above
T31_2	Numeric	1	0	tooth 31_Buccal surface	As above
T31_3	Numeric	1	0	tooth 31_mesial surface	As above
T31_4	Numeric	1	0	tooth 31_Distal surface	As above
T31_5	Numeric	1	0	tooth 31_lingual surface	As above
T32_0	Numeric	1	0	tooth 32_tooth level	As above
T32_1	Numeric	1	0	tooth 32_incisal edge	As above
T32_2	Numeric	1	0	tooth 32_Buccal surface	As above
T32_3	Numeric	1	0	tooth 32_mesial surface	As above
T32_4	Numeric	1	0	tooth 32_Distal surface	As above
T32_5	Numeric	1	0	tooth 32_lingualsurface	As above
T33_0	Numeric	1	0	tooth 33_tooth level	As above
T33_1	Numeric	1	0	tooth 33_incisal edge	As above
T33_2	Numeric	1	0	tooth 33_Buccal surface	As above
T33_3	Numeric	1	0	tooth 33_mesial surface	As above
T33_4	Numeric	1	0	tooth 33_Distal surface	As above
T33_5	Numeric	1	0	tooth 33_lingual surface	As above
T34_0	Numeric	1	0	tooth 34_tooth level	As above
T34_1	Numeric	1	0	tooth 34_occlusal surface	As above

T34_2	Numeric	1	0	tooth 34_Buccal surface	As above
T34_3	Numeric	1	0	tooth 34_mesial surface	As above
T34_4	Numeric	1	0	tooth 34_Distal surface	As above
T34_5	Numeric	1	0	tooth 34_lingual surface	As above
T35_0	Numeric	1	0	tooth 35_tooth level	As above
T35_1	Numeric	1	0	tooth 35_occlusal surface	As above
T35_2	Numeric	1	0	tooth 35_Buccal surface	As above
T35_3	Numeric	1	0	tooth 35_mesial surface	As above
T35_4	Numeric	1	0	tooth 35_Distal surface	As above
T35_5	Numeric	1	0	tooth 35_lingual surface	As above
T36_0	Numeric	1	0	tooth 36_tooth level	As above
T36_1	Numeric	1	0	tooth 36_occlusal surface	As above
T36_2	Numeric	1	0	tooth 36_Buccal surface	As above
T36_3	Numeric	1	0	tooth 36_mesial surface	As above
T36_4	Numeric	1	0	tooth36_Distal surface	As above
T36_5	Numeric	1	0	tooth 36_lingual surface	As above
T37_0	Numeric	1	0	tooth 37_tooth level	As above
T37_1	Numeric	1	0	tooth 37_occlusal surface	As above
T37_2	Numeric	1	0	tooth 37_Buccal surface	As above
T37_3	Numeric	1	0	tooth 37_mesial surface	As above
T37_4	Numeric	1	0	tooth 37_Distal surface	As above

T37_5	Numeric	1	0	tooth 37_lingual surface	As above
T38_0	Numeric	1	0	tooth 38_tooth level	As above
T38_1	Numeric	1	0	tooth 38_occlusal surface	As above
T38_2	Numeric	1	0	tooth 38_Buccal surface	As above
T38_3	Numeric	1	0	tooth 38_mesial surface	As above
T38_4	Numeric	1	0	tooth 38_Distal surface	As above
T38_5	Numeric	1	0	tooth 38_palatal surface	As above
T55_0	Numeric	1	0	tooth 55_tooth level	As above
T55_1	Numeric	1	0	tooth 55_occlusal surface	As above
T55_2	Numeric	1	0	tooth 55_Buccal surface	As above
T55_3	Numeric	1	0	tooth 55_mesial surface	As above
T55_4	Numeric	1	0	tooth 55_Distal surface	As above
T55_5	Numeric	1	0	tooth 55_palatal surface	As above
T54_0	Numeric	1	0	tooth 54_tooth level	As above
T54_1	Numeric	1	0	tooth 54_occlusal surface	As above
T54_2	Numeric	1	0	tooth 54_Buccal surface	As above
T54_3	Numeric	1	0	tooth 54_mesial surface	As above
T54_4	Numeric	1	0	tooth 54_Distal surface	As above
T54_5	Numeric	1	0	tooth 54_palatal surface	As above
T53_0	Numeric	1	0	tooth 53_tooth level	As above
T53_1	Numeric	1	0	tooth 53_incisal edge	As above

T53_2	Numeric	1	0	tooth 53_Buccal surface	As above
T53_3	Numeric	1	0	tooth 53_mesial surface	As above
T53_4	Numeric	1	0	tooth 53_Distal surface	As above
T53_5	Numeric	1	0	tooth 53_palatal surface	As above
T52_0	Numeric	1	0	tooth 52_tooth level	As above
T52_1	Numeric	1	0	tooth 52_incisal edge	As above
T52_2	Numeric	1	0	tooth 52_Buccal surface	As above
T52_3	Numeric	1	0	tooth 52_mesial surface	As above
T52_4	Numeric	1	0	tooth 52_Distal surface	As above
T52_5	Numeric	1	0	tooth 52_palatal surface	As above
T51_0	Numeric	1	0	tooth 51_tooth level	As above
T51_1	Numeric	1	0	tooth 51_incisal edge	As above
T51_2	Numeric	1	0	tooth 51_Buccal surface	As above
T51_3	Numeric	1	0	tooth 51_mesial surface	As above
T51_4	Numeric	1	0	tooth 51_Distal surface	As above
T51_5	Numeric	1	0	tooth 51_palatal surface	As above
T61_0	Numeric	1	0	tooth 61_tooth level	As above
T61_1	Numeric	1	0	tooth 61_incisal edge	As above
T61_2	Numeric	1	0	tooth 61_Buccal surface	As above
T61_3	Numeric	1	0	tooth 61_mesial surface	As above
T61_4	Numeric	1	0	tooth 61_Distal surface	As above

T61_5	Numeric	1	0	tooth 61_palatal surface	As above
T62_0	Numeric	1	0	tooth 62_tooth level	As above
T62_1	Numeric	1	0	tooth 62_incisal edge	As above
T62_2	Numeric	1	0	tooth 62_Buccal surface	As above
T62_3	Numeric	1	0	tooth 62_mesial surface	As above
T62_4	Numeric	1	0	tooth 62_Distal surface	As above
T62_5	Numeric	1	0	tooth 62_palatal surface	As above
T63_0	Numeric	1	0	tooth 63_tooth level	As above
T63_1	Numeric	1	0	tooth 63_incisal edge	As above
T63_2	Numeric	1	0	tooth 63_Buccal surface	As above
T63_3	Numeric	1	0	tooth 63_mesial surface	As above
T63_4	Numeric	1	0	tooth 63_Distal surface	As above
T63_5	Numeric	1	0	tooth 63_palatal surface	As above
T64_0	Numeric	1	0	tooth 64_tooth level	As above
T64_1	Numeric	1	0	tooth 64_occlusal surface	As above
T64_2	Numeric	1	0	tooth 64_Buccal surface	As above
T64_3	Numeric	1	0	tooth 64_mesial surface	As above
T64_4	Numeric	1	0	tooth 64_Distal surface	As above
T64_5	Numeric	1	0	tooth 64_palatal surface	As above
T65_0	Numeric	1	0	tooth 65_tooth level	As above
T65_1	Numeric	1	0	tooth 65_occlusal surface	As above

T65_2	Numeric	1	0	tooth 65_Buccal surface	As above
T65_3	Numeric	1	0	tooth 65_mesial surface	As above
T65_4	Numeric	1	0	tooth 65_Distal surface	As above
T65_5	Numeric	1	0	tooth 65_palatal surface	As above
T85_0	Numeric	1	0	tooth 85_tooth level	As above
T85_1	Numeric	1	0	tooth 85_occlusal surface	As above
T85_2	Numeric	1	0	tooth 85_Buccal surface	As above
T85_3	Numeric	1	0	tooth 85_mesial surface	As above
T85_4	Numeric	1	0	tooth 85_Distal surface	As above
T85_5	Numeric	1	0	tooth 85_lingual surface	As above
T84_0	Numeric	1	0	tooth 84_tooth level	As above
T84_1	Numeric	1	0	tooth 84_occlusal surface	As above
T84_2	Numeric	1	0	tooth 84_Buccal surface	As above
T84_3	Numeric	1	0	tooth 84_mesial surface	As above
T84_4	Numeric	1	0	tooth 84_Distal surface	As above
T84_5	Numeric	1	0	tooth 84_lingual surface	As above
T83_0	Numeric	1	0	tooth83_tooth level	As above
T83_1	Numeric	1	0	tooth 83_incisal edge	As above
T83_2	Numeric	1	0	tooth 83_Buccal surface	As above
T83_3	Numeric	1	0	tooth 83_mesial surface	As above
T83_4	Numeric	1	0	tooth 83_Distal surface	As above

T83_5	Numeric	1	0	tooth 83_lingual surface	As above
T82_0	Numeric	1	0	tooth 82_tooth level	As above
T82_1	Numeric	1	0	tooth 82_incisal edge	As above
T82_2	Numeric	1	0	tooth 82_Buccal surface	As above
T82_3	Numeric	1	0	tooth 82_mesial surface	As above
T82_4	Numeric	1	0	tooth 82_Distal surface	As above
T82_5	Numeric	1	0	tooth 82_lingual surface	As above
T81_0	Numeric	1	0	tooth 81_tooth level	As above
T81_1	Numeric	1	0	tooth 81_incisal edge	As above
T81_2	Numeric	1	0	tooth 81_Buccal surface	As above
T81_3	Numeric	1	0	tooth 81_mesial surface	As above
T81_4	Numeric	1	0	tooth 81_Distal surface	As above
T81_5	Numeric	1	0	tooth 81_lingual surface	As above
T71_0	Numeric	1	0	tooth 71_tooth level	As above
T71_1	Numeric	1	0	tooth 71_incisal edge	As above
T71_2	Numeric	1	0	tooth 71_Buccal surface	As above
T71_3	Numeric	1	0	tooth 71_mesial surface	As above
T71_4	Numeric	1	0	tooth 71_Distal surface	As above
T71_5	Numeric	1	0	tooth 71_lingual surface	As above
T72_0	Numeric	1	0	tooth 72_tooth level	As above
T72_1	Numeric	1	0	tooth 72_incisal edge	As above

T72_2	Numeric	1	0	tooth 72_Buccal surface	As above
T72_3	Numeric	1	0	tooth 72_mesial surface	As above
T72_4	Numeric	1	0	tooth 72_Distal surface	As above
T72_5	Numeric	1	0	tooth 72_lingualsurface	As above
T73_0	Numeric	1	0	tooth 73_tooth level	As above
T73_1	Numeric	1	0	tooth 73_incisal edge	As above
T73_2	Numeric	1	0	tooth 73_Buccal surface	As above
T73_3	Numeric	1	0	tooth 73_mesial surface	As above
T73_4	Numeric	1	0	tooth 73_Distal surface	As above
T73_5	Numeric	1	0	tooth 73_lingual surface	As above
T74_0	Numeric	1	0	tooth 74_tooth level	As above
T74_1	Numeric	1	0	tooth 74_occlusal surface	As above
T74_2	Numeric	1	0	tooth 74_Buccal surface	As above
T74_3	Numeric	1	0	tooth 74_mesial surface	As above
T74_4	Numeric	1	0	tooth 74_Distal surface	As above
T74_5	Numeric	1	0	tooth 74_lingual surface	As above
T75_0	Numeric	1	0	tooth 75_tooth level	As above
T75_1	Numeric	1	0	tooth 75_occlusal surface	As above
T75_2	Numeric	1	0	tooth 75_Buccal surface	As above
T75_3	Numeric	1	0	tooth 75_mesial surface	As above
T75_4	Numeric	1	0	tooth 75_Distal surface	As above

T75_5	Numeric	1	0	tooth 75_lingual surface	As above
COC	Numeric	5	2	Course of care number	None
CoCType	String	7	0	Course of care type	None