Effect of dental caries and treatment strategies on oral and general health in children
van Gemert-Schriks, M.C.M.

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Effect of dental caries and treatment strategies on oral and general health in children

Martine C.M. van Gemert-Schriks
Effect of dental caries and treatment strategies on oral and general health in children

Martine Christine Maria van Gemert-Schriks
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aan de Universiteit van Amsterdam
op gezag van de Rector Magnificus
prof. dr. D.C. van den Boom
ten overstaan van een door het college voor promoties
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in het openbaar te verdedigen in de Aula der Universiteit
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Martine Christine Maria Schriks

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Prof. dr. L.C. Martens

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(Academisch Centrum Tandheelkunde Amsterdam, ACTA)
Voor papa en mama
Anansi – de Slimste
Meester Superspin Anansi zat te piekeren: Stel je voor dat er iemand bestaat die slimmer is dan ik... Dat kon hij niet hebben, dus besloot hij de wereld in te trekken en alle Slimheid op te kopen. Inderdaad ontmoette hij hier en daar iemand die een heel speciale slimheid bezat, maar niemand lukte het om van Anansi's slimmigheid te winnen. Anansi troggelde alle Slimheid en Slimmigheidjes van iedereen af en borg ze op in zijn kalebas-mandje. Toen hij thuiskwam, begon hij weer te piekeren: Waar moet ik alles verstoppren? Boven in de katoenboom kakantri, bedacht hij. Hij hing zijn kalebasje aan een draadje om zijn nek en begon te klimmen. Maar de kalebas danste op zijn buik en zat hem dusdanig in de weg dat hij maar niet hogerop kwam. Steeds als hij halverwege de stam van de boom was, gleed hij weer terug. En terwijl hij zo aan het modderen was, hoorde hij opeens de stem van zijn zoontje van zeven jaar: “Pa, waarom heb je die kalebas op je buik gehangen? Waarom doe je hem niet op je rug, als een rugzak, dan klim je in een wip naar boven!”
Anansi schrok geweldig. “Verdraaid nog aan toe, hoe komt die jongen erop? De hele wereld heb ik afgereisd en mijn eigen vlees en bloed blijkt slimmer dan ik!” Woedend gooide Anansi de kalebas op de grond. Die brak in vele stukken en alle Slimheid en Slimmigheidjes vlogen weg, de wereld in. Maar vergis je niet...een groot aantal is bij Anansi gebleven en slimheid is erfelijk, zoals iedereen weet.

Anansi is een mythische spin uit volksverhalen uit West-Afrika en de Caraiben. Anansi wordt gezien als symbool van de zon. Zoals de zon in de hemel staat te stralen, zo zit de spin in z'n web met z'n poten als stralen van de zon. En zoals de zon op- en ondergaat, zo stijgt en zakt de spin aan z'n draad. Kenmerkend voor de Anansi-Tori (zoals de verhalen in Suriname genoemd worden) is dat Anansi zijn tegenstanders steeds te slim af is. Anansi zal altijd overleven, in welke cultuur hij ook terecht komt. Hoe groot en hoe machtig die andere cultuur ook is, uiteindelijk is de spin slim genoeg om zich erin te verweven.

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Introduction
Introduction

Caries prevalence
Despite great improvements, dental caries is still one of the most prevalent infectious diseases of the world as it affects 60-90% of the school-aged children and the vast majority of adults [64, 86]. The development of the caries problem has taken various pathways in different countries and communities. In recent decades, a substantial decline in dental caries prevalence has been noted in the majority of industrialized countries due to a number of public health measures, including effective use of fluoride, changing lifestyles and living conditions [46, 57, 62, 66, 67]. This decrease in caries prevalence, however, seemed to have reached its plateau in some of the industrialized countries, and stabilized, turned to an increase or changed into a pattern of polarisation, with more of the disease occurring in a smaller proportion of the population [17, 30, 33, 72]. With regard to these different patterns in caries prevalence, it must be emphasized that dental caries as a disease in children has never, and nowhere, been eradicated, but only controlled to a certain degree [62, 63].

The burden of oral diseases, including dental caries, is particularly high for disadvantaged and poor population groups in both developing and developed countries. Although caries prevalence used to be much lower than in the industrialized countries [7, 69, 85], an increase is observed in developing countries, particularly as a result of urbanisation, growing sugar consumption and inadequate exposure to fluoride [16, 38, 51, 57, 64, 66, 86]. Access to oral care is often limited and the priority of dental health care is generally low due to the existence of major problems in communicable diseases, environmental hazards, and nutritional inadequacies. Although oral diseases are a major public health problem, oral health care in these countries is often highly underrepresented within the total health care system.

Oral health goals
The World Health Organisation (WHO) aims at achieving an acceptable level of oral health for all people. In 1982, the WHO, in collaboration with the International Dental Federation (FDI), has formulated six goals for oral health to be achieved by the year 2000 [37]. One of the most important goals was that the mean number of decayed, missing or filled teeth (DMFT) should not exceed 3.0 at the age of 12 years and that 50 per cent of the 5- to 6-year-olds should be caries free. Despite great improvements in the oral health status of populations across the world, these goals appeared not to be feasible to every country [59]. Nonetheless, the oral health goals have stimulated awareness of the importance of oral health in general [35]. Recently the WHO formulated a new document containing new goals, objectives and targets to be achieved by the year 2020 [62, 63]. More emphasis is placed on the appreciation that an acceptable level of oral
health should be interpreted differently by each country in the light of its social and economic characteristics, health status and morbidity patterns of its population and state of development of its health system [57, 66]. Therefore, the goals and objectives in this new document are more population-based and their formulation is guided by the principles of disease prevention and health promotion. The targets are constructed without absolute values and are not intended to be prescriptive. The framework is primarily designed to encourage health policy-makers at regional, national and local levels to set standards for oral health in consideration of local realities, i.e. the epidemiology of oral diseases and the socio-environmental conditions [53, 62, 63].

Oral Health Care

In order to achieve the new goals, oral health care should be more integrated within Primary Health Care (PHC) programs. Originally, within the framework of PHC, oral health care programs were not included. However, in the last decade, a number of PHC models, with oral health integrated at various phases of implementation, were developed [9, 54, 73, 81]. The speed of integration remains low and unsteady despite the epidemic dimension of oral diseases, the suggested oral-systemic link of some chronic diseases, and the increased demand and need for prevention based health care [53].

The global Oral Health Program (OHP) is currently one of the priority programs of the WHO. Based on the common-risk factor approach, the OHP puts emphasis on oral health promotion and disease prevention with focus on disadvantaged population groups in developed and developing countries and gives priority to the integration of oral health within general health programs [60-65]. Essential to this, however, is the establishment of priorities in oral health care. The WHO Collaborating Centre for Oral Health Care and Future Scenarios in Nijmegen, established by the WHO in 1996, was charged with the task of compiling a report on the establishment of these priorities. This resulted in the Basic Package of Oral Care (BPOC). The BPOC represented a fusion of concepts and approaches that were considered to be effective, acceptable, feasible and affordable for most disadvantaged communities [27]. The BPOC aimed at integrating basic oral care into the existing primary health care systems and at increasing the level of preventive and curative oral treatment. The essential components of BPOC are: Oral Urgent Treatment (OUT), Affordable Fluoride Toothpaste and Atraumatic Restorative Treatment (ART).

Though aiming at integration, the report did not present a strategy for implementation of oral care within PHC while each local situation demands tailor-made solutions with respect to available funds, personnel and services. Each country or community should develop its own BPOC, based on perceived needs and existing environmental conditions. Within the concept of BPOC, in case of pain, extraction of the perpetrating tooth (OUT) is indicated and otherwise, cavitated teeth are suggested to be restored by means of ART. ART is a minimal invasive treatment method whereby soft, demineralised carious tooth tissue is removed using hand instruments only, followed by restoration of the tooth with an adhesive restorative
material, often glass-ionomer cement. Because neither electricity nor running water is required for this treatment approach, ART can be applied in almost any setting [25, 26]. However, the report does not elaborate the question whether or to what extent invasive dental treatment of the primary dentition is indicated. For example, leaving primary teeth unrestored is not included in the BPOC. This highly minimal invasive treatment option should not be left out of sight when current literature is addressed [41, 42, 50, 76]. Before tailor-made BPOC’s can be introduced and before oral health care can be implemented in primary health care programs, it is necessary to open the discussion concerning the question to what extend and how the primary dentition should be treated. Further, the supposed effects of dental decay on the general health of the patient should be elucidated whereas these play a key role whenever it concerns the establishment of the priority of oral health care within the general health care programs.

Dental treatment of the primary dentition

Dental treatment of the primary dentition is currently under debate among dental professionals. There is a lot of discussion about the best treatment strategy that should be applied to the diseased deciduous dentition [24, 39, 42, 50, 68, 76]. The lack of consensus on indications for restoration and extraction of diseased deciduous teeth exists due to constantly changing definitions and extensive scientific achievements. New knowledge of caries progression rates has led to substantial modification of restorative intervention thresholds and further handling of the disease. New diagnostic tools for caries lesion detection, caries risk assessment and focussed preventive treatments have decreased the need for early restorative interventions [12, 21, 22, 58, 84]. Overall, dentists are encouraged to prefer a more conservative and biological approach rather than an invasive approach. Regardless of the strategy that is preferred or applied, the purpose of dental treatment should be unambiguous and comprises four items: prevention of new dental decay, arrestment of existing carious lesions, prevention of pain and discomfort for children, and prevention of early loss of deciduous teeth.

These clinical aims cannot always be met at the same time and their relative priority might vary under different circumstances. The possible side effects of a certain dental treatment can be to such an extent that other strategies are preferred. For example, when the often cited space changes induced by premature loss of a primary molar are expected to occur but cannot be treated adequately with orthodontic equipment, more conservative methods might be preferred. Treatment decisions are not only guided by clinical considerations but also by attendance patterns, parent’s wishes, behavioural skills, socio-economic background, available budgets, adequate material and qualifications of the personnel [34, 36, 70, 77-80].

Though a strategy can not be decided upon unanimously, the overall assumption exists that treatment of dental decay in the primary dentition is necessary with regard to the expected
effects of oral diseases on the patient’s general health and well-being [23]. However, the true impact or extent of these effects has not been properly addressed as yet.

**Impact of oral disease**

Dental caries, and the associated pain and infection, may have a number of detrimental effects. Interference with nutrition, loss of sleep, behavioural disturbance, and poor aesthetics [23] are only a few possibly occurring symptoms that can give rise to physical, social and psychological effects that influences the day-to-day living of the patient [28, 45, 48, 49, 75, 82, 83].

An improvement of the quality of life of children would definitely request for a central role of dental treatment within a health care system. However, due to a lack of consistency in the definition and measurement of the construct “quality of life”, literature shows a fragmented vision of its relation with oral health [49, 56].

Assessment of systemic effects of oral diseases from a purely biomedical point of view has been described less ambiguously. Particularly from the field of periodontology, an association has been described between certain systemic conditions, such as cardiovascular diseases, respiratory diseases, diabetes mellitus, low birth weight and preterm birth, and periodontal diseases [8, 18, 28, 29, 43, 44, 52]. Several pathways are suggested to explain this association [28, 43]. Bacteraemia, bacterial endotoxins, cytokines, and other inflammatory mediators could play a direct or indirect role. Diet may be an additional mediator for several of these outcomes. However, there are several common risk factors for oral and systemic diseases that might play a confounding role in the analysis of their relation. Therefore, a careful interpretation is required.

Though numerous studies have investigated the relation between periodontal and systemic disease, systemic effects of dental caries have not been equally investigated on a biomedical level. However, similar outcomes may be expected. Dental caries is, just as periodontitis, a chronic infectious disease. It has been well established that immune factors play an essential role in the etiology of chronic multifactorial diseases [6, 15, 65, 74]. Moreover, systemic responses to *Streptococcus Mutans* and infected dental pulps have been described [31, 32, 40]. It thus might be suggested that dental caries may induce a systemic immune response that may especially occur when caries progresses into pulpal inflammation [19, 71].

One of the difficulties that are encountered when establishing the effects of dental decay on general health is the lack of a suitable tool to diagnose physical health properly. Health is a multidimensional concept which renders its measurement challenging and prone for deficiencies.
Assessment of children’s height and weight is well established as a valid clinical indicator for their general health and well being [11, 14]. Studies concluded that infectious diseases can interfere with body growth [10, 13, 47]. Therefore, given the fact that dental caries is one of the most prevalent infectious diseases worldwide [62], it can be hypothesized that the possible systemic effects of dental caries could be reflected in a deviant growth pattern. Indeed, an association between rampant caries and body growth was described in the literature [1-5, 20, 55, 75]. The aetiology of the relation between dental caries and body growth could be explained by the fact that toothache and infection alter eating and sleeping habits, dietary intake and physiological processes that are essential for normal growth [1, 5, 75].

**Rationale and aim of the study**

The literature relating oral disease to increased risk of systemic diseases provides additional motivation for achieving and maintaining good oral health. If body growth in children is indeed adversely affected by dental decay, the global increase in caries prevalence should raise major concerns, especially in those countries where access to oral health services is limited and where dental health care is of low priority. However, the evidence regarding the oral-systemic associations is not unanimous, and the associations may or may not be causal. Further exploration of the oral-systemic relationship, including a systemic immune response to dental caries, is therefore indicated in order to establish the priority of oral health care within the general health care programs.

The aim of this thesis was to establish the relation between dental caries and general health in children of a defined population in Suriname. Primary outcome measures are systemic immune response and body growth.

The results of this study could play a decisive role in the question if and how oral care should be implemented in primary health care programs. In other words: what dental treatment should minimally be performed in order to prevent adverse influences of the dental decay on the general health of the patient.
Outline of the thesis

Chapter 1
The first chapter comprises an epidemiological survey that was carried out in Suriname. Before the entire project could be launched, it was important to determine the oral health status of the children, living throughout the area where the research was planned to be performed. The interior of Suriname was chosen as the goal area for the project, based on the need for dental care that was expressed by the Director of the Medical Mission and on the positive attitude of the Government, regarding the current study. The epidemiological survey concerned four different areas in the Suriname rainforest. The intervention study-project was, mainly for practical reasons, conducted in only two of these regions.

Chapter 2
Different dental treatment strategies were performed in the current study. Two of these strategies included Atraumatic Restorative Treatment (ART), whereas this was, given the outreach circumstances, the restorative treatment of choice. Chapter 2 outlines the suitability of this restorative treatment strategy for the target population. ART claims to be atraumatic for both patient and the tooth in question. A preliminary study in Indonesia was performed to compare the discomfort that was experienced during ART with the discomfort that was experienced during dental treatment with other minimal invasive restorative methods whereby rotary instruments were used.

Chapter 3
In chapter three, the survival of the ART restorations, performed during the course of this study in Suriname, is described. The success of different treatment modalities, that include ART (chapter 4), should be evaluated in the light of these survival rates. Because ART is non-electricity dependent and has relatively low maintenance costs, it is ascribed as the preferred restorative treatment method in countries or areas that contend with tight budgets for primary (oral) health services. However, although the costs are low, the effect of any treatment must be acceptable and reliable in order to enable its indication.

Chapter 4
In chapter four, the effect of four different dental treatment strategies on the oral health of the study population, is established. The results of this part of the project are important and should be considered in any situation where due to situational, economical, psychological or practical circumstances, choices have to be made regarding the most suitable treatment option with optimal prognosis under the given conditions.
Chapter 5
The effects of dental decay and dental treatment are supposed to go beyond the oral cavity. Chapter five discusses the oral-systemic relationship focusing on the body growth of the Surinam children that participated in this project. Assessment of children’s height and weight is generally established as an indicator for their general health and well being.

Chapter 6
In chapter six a pilot study is described where three systemic factors, acute phase proteins associated with chronic infections, and antibodies to *Mutans Streptococci* were associated to dental caries. The study was performed in Indonesia and the results were applied to the Surinam project.

Chapter 7
Chapter seven discusses the relationship between caries, the formation of abscesses and fistulae, and the concentration of acute phase proteins and other systemically induced immune factors. The hypothesis that caries treatment improves general health and results in reduced levels of acute phase proteins CRP and AGP is tested. Since study population lives in the inlands of Surinam, it is expected that they can suffer from other infectious diseases due to parasites. To control for these events, the concentration of serum neopterin is tested. The genetic sensibility regarding for abscesses or fistulae formation as a result of severe caries, is also explored.

General Discussion
In the general discussion, the separate parts of the overall project are evaluated in the light of the existing literature and translated into clinical implications that can be applied or should at least be considered in daily dental and primary health care practices.
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Caries prevalence in Suriname schoolchildren

M.C.M. van Gemert-Schriks
W.E. van Amerongen
J.M. ten Cate

Community Dental Health 2008, in press
Abstract

The present study aims at obtaining more insight in the current oral health status of children living throughout the Interior of Suriname in order to be able to plan or define the need for dental care in the future to obtain an oral health situation that meets the oral health goals of the WHO.

Materials and methods:
In this cross sectional study, dental caries was recorded according to the criteria of the WHO. Decayed, missing and filled (DMF)-teeth (T) and surfaces (S) indices for caries prevalence were used. A total of 951 children from four different regions and between 5-15 years of age, was examined. There was an approximately equal distribution of boys and girls.

Results:
The mean dmfs in the youngest children (5-7.5 yrs) was 11.81 (±11.19) and the mean dmft 5.16 (±3.93). Regional, racial and gender differences were found regarding the caries prevalence of these children. Caries prevalence in the middle age category (7.5-10 years) was lower compared to the youngest children; a mean dmfs of 5.37 (±6.42) and a mean DMFS of 0.84 (±1.30) were observed. A mean DMFS of 2.31 (±4.97) was recorded in the oldest children.

Conclusions:
The results of this study indicate that caries prevalence in young children in the Interior of Surinam is high according to the criteria of the WHO. Children in older age groups seem to experience low to moderate caries levels.
Introduction

Dental caries is one of the most prevalent infectious diseases of the world. The development of the caries problem has taken various pathways in different parts of the world. A substantial decline in dental caries prevalence has been noted in recent decades in the majority of industrialized countries, mostly attributed to the regular use of fluoride, improved oral hygiene and a prudent diet (Marthaler et al., 1996; Pakhomov, 1999; Pilot, 1988; Reich, 2001). Children from ethnic minority groups and low socio-economic backgrounds however, still experience high levels of dental disease in these nations (Jamieson et al., 2004; Reich, 2001). Recent studies have shown that the ongoing decrease in caries prevalence has reached its plateau in some industrialized countries and caries levels are stabilizing or even rising again (Gray and Davies-Slowik, 2001; Haugejorden and Birkeland, 2002; Speechley and Johnston, 1996).

Although caries prevalence in developing countries used to be much lower than in the developed countries (Sardo-Inferri, 1979; WHO 1996), an increase is observed. This is most obvious in those countries that are rapidly urbanizing and advancing socio-economically (Diehnelt and Kiyak, 2001; Jamieson et al., 2004; Pakhomov, 1999; Pilot, 1988; Miura et al., 1997). Dental health in these countries is often of low priority due to the existence of major problems in communicable diseases, environmental hazards, and nutritional inadequacies.

The World Health Organisation (WHO) aims at achieving an acceptable level of oral health for all people. In 1982, the WHO, in collaboration with the International Dental Federation (FDI), has formulated six oral health goals to be achieved by the year 2000 (FDI and WHO, 1982). One of the most important goals was that the mean number of decayed, missing or filled teeth (DMFT) should not exceed 3.0 at the age of 12 years and that 50 per cent of the 5- to 6-year-olds should be caries free. An acceptable level of oral health however, should be interpreted differently by each country in the light of its social and economic characteristics, health status and morbidity patterns of its population and state of development of its health system (Pakhomov, 1999; Pilot, 1988). Planning, organisation, administration, monitoring and evaluation of all types of health services, including oral health, must be based upon reliable and relevant data. Then, realistic separate goals per country or area can be set up leading to adequate and effective care.

Many countries lack national or regional epidemiological baseline surveys. One of these countries is Suriname. Suriname is a former Dutch colony and is situated on the northern coast of South America. Suriname is divided into urban, rural and interior areas, in terms of population and economic activity. The Interior, comprising about 80% of the country, is sparsely populated by tribal communities, around 50.000 people (12% of the total Surinam population), mainly Creole Bushnegroes (80%) and Amerindians (20%), who depend on hunting, fishing and agriculture.
This area lacks an adequate infrastructure, electricity and running water (Pan American Health Organisation (PAHO), 1998).

The Ministry of Health assigned the Medical Mission (MM) with the responsibility for all medical care in the Interior. The MM aims to develop an affordable health care system based on the needs of the community and the promotion of health care awareness. Health care, including dental health care, is rendered by health care workers of different educational level. Due to a lack of knowledge, technical skills, time and proper equipment, the only dental treatment performed is tooth extractions in case of urgent pain.

The MM does not have comprehensive information on the actual extent of the oral health problem, whereas adequate epidemiological data lack. Only a few national dental surveys were conducted in Suriname. The WHO Global Oral Data bank reported a DMFT of 4.9 in 12-year old Surinam children in 1978 (Guille, 1986) and of 2.7 in 1992 (Beltrán-Aguillar et al., 1999). A survey, carried out by the Youth Dental Service Foundation in 1995 in the districts Paramaribo and Wanica, found an average dmft of 6.05 and 13% sound teeth among 6-year-olds and an average DMFT of 5.6 among 12-year-olds. These results were consistent with a survey conducted on the same sample in 1990 (PAHO, 1998). These currently available studies do not report about the caries prevalence or treatment need for the children in the Interior. However, knowledge upon this population in particular would be of great importance when planning adequate oral health care in this underprivileged part of the country.

The present study aims at obtaining more insight in the current oral health status of children living throughout the Interior of Suriname in order to be able to plan or define the need for dental care in the future to obtain an oral health situation that meets the oral health goals of the WHO.

Materials and methods

The present study was carried out in the Interior of Suriname. Four different regions were included in the study: East Suriname, West Suriname, Brokopondo and Upper Suriname (Figure 1). The socio-economic status of the people living throughout these regions is comparable. People living in West Suriname are mainly from Amerindian origin, the other three regions are habited by Creole people. The study population consisted of primary school children of various ages. Because of the broad variation in age, the children were divided into three different age categories: children between 5 and 7.5 years, between 7.5 and 10 years and children between 10 and 15 years. This categorisation was based on the different phases of tooth exfoliation, taking into account that Negro children show an earlier eruption pattern than Caucasians (Stewart et al., 1982). The youngest category represented the first eruption phase, children in the middle age
group were in their second eruption phase and the eldest children had all their permanent teeth erupted. Twenty schools, selected from the database of the Medical Mission (MM), participated in the study. For practical reasons, only schools that were able to be travelled across within two days were included. Ethical clearance was obtained from the director of the Surinam Ministry of Health. No definite selection criteria were formulated for inclusion of the children although the children had to show a non contributory medical history.

Oral examination using a headlamp, mouth mirror and dental probe, took place in the classroom whilst the child was lying on a table. All children were examined by one of the authors, calibrated with a golden standard (kappa 0.89). This golden standard document was prepared by two experienced investigators after assessing 25 pictures of molars and premolars with and without dentine carious lesions.

Caries was recorded according to the criteria and recommendations of the WHO (1987). The prescribed decayed, missing and filled (DMF)-teeth (T) and surfaces (S) indices for caries prevalence were both used. For the power of the statistical analysis, dmfs (DMFS) rendered higher values and was therefore thought to be more adequate. However, in order to facilitate international comparisons and to overcome the difficulty in interpretation due to the disagreement about the number of surfaces to be ascribed to a tooth that is missing because of caries, the dmft (DMFT) values are included as well. WHO uses capitals for caries prevalence in the permanent dentition and lower case for the primary dentition. A tooth or tooth surface was considered ‘sound’ if it showed no evidence of treated or untreated dentine caries and ‘decayed’ if any lesion in a pit or fissure or

**Figure 1** Map of Suriname
on a smooth tooth surface, had a detectable softened floor, undermined enamel or softened wall. A tooth is considered present in the mouth when any part of it is visible or can be touched with the tip of the dental probe without unduly displacing soft tissue. If a permanent and a primary tooth occupy the same tooth space, the status of the permanent tooth only is recorded.

Statistical analyses were performed using SPSS for Windows, version 12.0.1. Non parametric statistics were used whereas the data upon the caries prevalence showed a skewed distribution. Mann Whitney U tests (MW) were applied when two groups were compared and Kruskwall Wallis tests (KW) were used to compare more groups. For the evaluation of the nominal data, cross tabs with Pearson Chi-square test were applied. All significant differences were detected at a 95% confidence level.

Results

A total of 951 children was examined. The mean age of the children was 8.03 years (±2.60, range 5.11–14.99 years). The main relevant socio–demographic characteristics of the sample are presented in table 1. There were significant differences in the representation of all age categories among the four regions (Pearson Chi-square, p<0.001). Children in the Brokopondo and Upper Suriname region were all in the youngest age category. Children that originated from the East and West Suriname region showed more variation in age but were on average older. Regarding the sample of the current study, there was an approximately equal distribution of boys and girls within the four regions and within the different age categories with Pearson Chi square tests showing no statistically significant differences. Regarding race, there were significant differences between the four regions (Pearson Chi-Square, p<0.001). Children from the West Suriname region were all from Amerindian origin, the other children were Creole Bushnegroes.

Table 1 Socio-demographic characteristics of the population

<table>
<thead>
<tr>
<th></th>
<th>East Suriname</th>
<th>West Suriname</th>
<th>Brokopondo</th>
<th>Upper Suriname</th>
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<tbody>
<tr>
<td>Gender</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Boys (%)</td>
<td>151 (51.9)</td>
<td>79 (46.7)</td>
<td>91 (43.8)</td>
<td>153 (54.1)</td>
</tr>
<tr>
<td>Girls (%)</td>
<td>140 (48.1)</td>
<td>90 (53.3)</td>
<td>117 (56.3)</td>
<td>130 (45.9)</td>
</tr>
<tr>
<td>Race</td>
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<td>--</td>
<td>208</td>
<td>283</td>
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<td>AmerIndian</td>
<td>--</td>
<td>169</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Mean age</td>
<td>10.39</td>
<td>9.54</td>
<td>6.17</td>
<td>6.06</td>
</tr>
<tr>
<td>(SD, range)</td>
<td>(2.21, 5.92-14.99)</td>
<td>(2.51, 5.25-14.98)</td>
<td>(0.49, 5.12-7.06)</td>
<td>(0.47, 5.11-7.09)</td>
</tr>
</tbody>
</table>
Caries prevalence of children in the 5-7.5 year age group (Table 2.)
The mean dmfs of the overall sample was 11.81 (±11.19, median 9.0) and the mean DMFS was 0.26 (±0.75, median 0.0). The mean dmft of the overall sample was 5.16 (±3.93, median 5.0) and the mean DMFT was 0.24 (±0.67, median 0.0). Only 17.2% of all participating children was clinically free of caries in the primary dentition and 86.3% was clinically free of caries in the permanent dentition.

Between the four different regions, statistically significant differences were observed regarding the caries prevalence in both primary and permanent dentition (KW, p<0.001). Post hoc Mann Whitney U tests showed that, regarding the primary dentition, children in the Eastern region had a significant lower dmfs than children from the West- (p=0.034), Brokopondo- (p=0.003) and Upper Suriname region (p<0.001). Children in the Upper Surinam region had a significant higher dmfs than children from the Western- (p=0.004) and Brokopondo region (p<0.001). Regarding the caries prevalence in the permanent dentition, children from the Western region showed a higher DMFS compared to the Eastern region (MW, p=0.006), Brokopondo and Upper Surinam region (MW, p<0.001). The difference in DMFS between children from the Eastern region and children from both the Brokopondo and Upper Surinam region was statistically significant as well (p=0.006, resp. p=0.026). Children in the eastern region had higher caries prevalence.

In both primary and permanent dentition, gender differences in caries prevalence were observed. Boys had a significantly higher mean dmfs (13.33, ±12.23, median 11.0) than girls (10.33, ±9.87, ±).

### Table 2 Caries prevalence for children in age category 5-7.5 years

<table>
<thead>
<tr>
<th>Region</th>
<th>East Suriname</th>
<th>West Suriname</th>
<th>Brokopondo</th>
<th>Upper Suriname</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>33</td>
<td>46</td>
<td>208</td>
<td>283</td>
<td>570</td>
</tr>
<tr>
<td>dmfs</td>
<td>5.12*</td>
<td>9.39</td>
<td>10.67</td>
<td>13.82*</td>
<td>11.81</td>
</tr>
<tr>
<td>SD, range</td>
<td>6.19, 0-23</td>
<td>10.12, 0-3</td>
<td>11.36, 0-67</td>
<td>11.23, 0-59</td>
<td>11.19, 0-67</td>
</tr>
<tr>
<td>median</td>
<td>3.00</td>
<td>7.50</td>
<td>8.00</td>
<td>12.00</td>
<td>9.00</td>
</tr>
<tr>
<td>dmft</td>
<td>2.18</td>
<td>4.00</td>
<td>4.67</td>
<td>6.05</td>
<td>5.16</td>
</tr>
<tr>
<td>SD, range</td>
<td>2.39, 0-8</td>
<td>3.44, 0-16</td>
<td>4.01, 0-18</td>
<td>3.82, 0-18</td>
<td>3.93, 0-18</td>
</tr>
<tr>
<td>median</td>
<td>1.00</td>
<td>3.50</td>
<td>8.00</td>
<td>6.00</td>
<td>5.00</td>
</tr>
<tr>
<td>% clinically caries free primary dentition</td>
<td>36.4</td>
<td>28.3</td>
<td>22.1</td>
<td>10.6</td>
<td>17.2</td>
</tr>
<tr>
<td>DMFS</td>
<td>0.57*</td>
<td>2.40*</td>
<td>0.19</td>
<td>0.26</td>
<td>0.26</td>
</tr>
<tr>
<td>SD, range</td>
<td>0.85, 0-2</td>
<td>1.14, 1-4</td>
<td>0.64, 0-5</td>
<td>0.75, 0-6</td>
<td>0.75, 0-6</td>
</tr>
<tr>
<td>median</td>
<td>0.00</td>
<td>2.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>DMFT</td>
<td>0.57</td>
<td>2.40</td>
<td>0.15</td>
<td>0.25</td>
<td>0.24</td>
</tr>
<tr>
<td>SD, range</td>
<td>0.85, 0-2</td>
<td>1.14, 1-4</td>
<td>0.50, 0-3</td>
<td>0.69, 0-4</td>
<td>0.67, 0-4</td>
</tr>
<tr>
<td>median</td>
<td>0.00</td>
<td>2.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>% clinically caries free permanent dentition</td>
<td>64.3</td>
<td>20.0</td>
<td>89.4</td>
<td>86.6</td>
<td>86.3</td>
</tr>
</tbody>
</table>

* significant at p = 0.05
median 8.0) in their primary dentition (p=0.004). Girls had a significantly higher DMFS than boys, i.e. 0.33 (±0.75, median 0.0) compared to 0.19 (±0.74, median 0.0) (p=0.006). Regarding race, a difference in DMFS was observed (MW, p<0.001). Children from Amerindian origin had a higher mean DMFS (2.40, ±1.14, median 2.0) compared to the Creole children (0.24, ±0.71, median 0.0).

### Caries prevalence of children in the 7.5-10 year age group (Table 3)

Children in this category origin from West and East Suriname only. Overall, a mean dmfs of 5.37 (±6.42, median 3.0) and a mean DMFS of 0.84 (±1.30, median 0.0) were observed. The mean dmft of the overall sample in this age category was 2.24 (±2.31, median 2.0) and the mean DMFT was 0.78 (±1.14, median 0.0). Within this age category, 35.1% of the children was clinically free of caries in the primary dentition compared to 59.3% in the permanent dentition.

No statistically significant differences in caries prevalence in either the primary or the permanent dentition between the two regions or races, nor between the two sexes were found.

<table>
<thead>
<tr>
<th>Table 3 Caries prevalence for children in age category 7.5-10 years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>N</td>
</tr>
<tr>
<td>dmfs</td>
</tr>
<tr>
<td>(SD, range, median)</td>
</tr>
<tr>
<td>dmft</td>
</tr>
<tr>
<td>(SD, range, median)</td>
</tr>
<tr>
<td>% clinically caries free primary dentition</td>
</tr>
<tr>
<td>DMFS</td>
</tr>
<tr>
<td>(SD, range, median)</td>
</tr>
<tr>
<td>DMFT</td>
</tr>
<tr>
<td>(SD, range)</td>
</tr>
<tr>
<td>% clinically caries free permanent dentition</td>
</tr>
</tbody>
</table>

### Caries prevalence of children in the 10-15 year age group (Table 4)

Children in this category origin from West and East Suriname only. The majority of the children in this age category had lost their primary teeth due to exfoliation, therefore, only the caries prevalence in the permanent dentition was evaluated. For this group, a mean DMFS of 2.31 (±4.97, median 0.0) and DMFT of 1.27 (±1.78, median 0.0) were calculated. Within this age category, 54.3% of the children appeared to be clinically free of dental caries in the permanent dentition. No statistically significant differences could be found regarding the caries prevalence in the permanent dentition between either the two regions and races or between the two sexes.
Table 4 Caries prevalence for children in age category 10-15 years

<table>
<thead>
<tr>
<th></th>
<th>East Suriname</th>
<th>West Suriname</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>173</td>
<td>69</td>
<td>242</td>
</tr>
<tr>
<td>DMFS</td>
<td>2.45</td>
<td>2.00</td>
<td>2.31</td>
</tr>
<tr>
<td>(SD, range, median)</td>
<td>(5.55, 0-51, 0.00)</td>
<td>(3.35, 0-15, 0.00)</td>
<td>(4.97, 0-51, 0.00)</td>
</tr>
<tr>
<td>DMFT</td>
<td>1.40</td>
<td>0.99</td>
<td>1.27</td>
</tr>
<tr>
<td>(SD, range, median)</td>
<td>(1.94, 0-8, 0.00)</td>
<td>(1.32, 0-4, 0.00)</td>
<td>(1.78, 0-8, 0.00)</td>
</tr>
<tr>
<td>% clinically caries free</td>
<td>53.3</td>
<td>56.5</td>
<td>54.3</td>
</tr>
</tbody>
</table>

Discussion

The results of this study indicate that caries prevalence in the deciduous dentition of young children in the Interior of Suriname is moderate to high according to the severity criteria of the WHO (Marthaler et al., 1990). Caries prevalence in the permanent dentition (DMFT) was moderate to very low.

In this study, the presence of dental caries was assessed by clinical examination only. No radiographs were taken. Unfortunately the latter was not possible in the absence of electricity and proper equipment. For this reason, the caries prevalence might be underestimated because proximal lesions that had not yet led to loss of tooth material were missed.

Regarding the variations in caries experience, it appears from this study that at a young age, children from Amerindian origin (West Surinam) experience far more caries in their permanent dentition compared to their Creole peers living throughout the other regions. This finding might be the result of a difference in eruption of the permanent teeth between the two races. More accurate research on this subject should be done in order to verify this hypothesis. Dietary differences are not likely to be responsible for these differences in caries prevalence while Creole and Amerindian people do not have substantial differences in their dietary habits nowadays. Overall, the diet in the Interior is changing from traditional diets and low sugar consumption towards more “westernized” diets containing sugary sweets and soft drinks. Among others, improvement of the infrastructure accounts for this change that, on its turn, is alarming while, at the moment, dental care is highly underrepresented in the primary health care programs for the people living throughout the Interior and an increase in caries prevalence might thus be expected.

From an epidemiological perspective, the survey was not ideal; the sample was not randomized and this limits the possibility to generalize from the data. The samples derived from the four different regions are difficult to compare and the differences between the regions cannot be analysed independently since the variables age and race were not equally distributed. However, the study should be regarded as a convenience sample. Although the WHO might not be able
to use the results for epidemiological purposes since it does not apply to the conditions of the so called Pathfinder Method (WHO, 1987), the results are indicative and can serve as a clinical baseline for further research. Part of this study population will be evaluated during subsequent years in order to establish possible trends in oral health which is important for long term planning and policy making.

Considering the current oral health status of these children with regard to the oral health goals that were aimed for by the WHO, one must conclude that these goals are not fully met in all age categories. The WHO states that the mean DMFT should not exceed 3.0 by the age of 12 years. According to the results of this study, this goal seems to be met for the children in the oldest age category. Furthermore, the WHO states that 50% of the 5-6 year olds should be free of dental caries in the primary dentition. Obviously, this goal is not met in this particular Surinam population.

Conclusion

Dental caries prevalence among young schoolchildren throughout some parts of the interior of Suriname is high. Far less than 50% of the children in this age group is clinically free of dental decay. Obviously there is a need for more dental care in these regions when WHO oral health goals aimed for. The current package of primary health care should thus be extended with a proper basic oral health care program.

As a baseline study, the presented data can be considered very useful. Data of this type provide a significant essential background for long-term strategic planning of dental services and for predicting future need for manpower, facilities and resources for dental care.

Acknowledgments

This study was supported by the Netherlands Institute of Dental Sciences (IOT), the Netherlands Foundation for the advancement of Tropical Research (WOTRO), the Foundation “De Drie Lichten” in The Netherlands and 3M-ESPE. The authors would like to thank Dr. I.H.A. Aartman for her critical reading and advices. Furthermore, they would like to thank the director of the Surinam Ministry of Health and the Medical Mission of Surinam for the intensive and enthusiastic cooperation, the provision of all facilities and the inspiring input.
References


M.C.M. Schriks
W.E. van Amerongen
Atraumatic Perspectives of ART: Psychological and physiological aspects of treatment with and without rotary instruments

Community Dentistry Oral Epidemiology 2003; 31: 15-20
Abstract

Atraumatic Restorative Treatment, ART, is a method of minimal caries intervention that uses only hand instruments. The aim of the present study was to explore a possible difference between the extent of discomfort experienced during dental treatment according to the ART approach and a method using rotary instruments.

Materials and methods:
The study was performed in Indonesia. 403 children were randomly divided in two groups. In each child one class-II restoration in a deciduous molar was made. One group received treatment, using rotary instruments (750 rpm). The other group was treated according to the ART approach. Glass ionomer cement was used for restoration in both groups. Discomfort scores were determined using both physiological measurements (heart rate) and behavioral observations (Venham) on specific moments during the treatment.

Results:
Venham scores showed a marked difference between the two groups on most time points. Heart rate measurements were different at deep excavation. Also, a clear relation between Venham scores and heart rate measurements could be found at all time points. Confounding could be shown for operating dentist, gender of the patient and initial anxiety, not for age. No effect modification could be shown.

Conclusion:
It can be concluded that children treated according to the ART approach using hand instruments alone, experience less discomfort than those treated using rotary instruments.
Introduction

A new approach for the treatment of dental caries, Atraumatic Restorative Treatment (ART), was introduced in 1985. ART is a minimal intervention technique, based on removing carious tooth tissue using hand instruments and restoring the cleaned cavity with an adhesive material, currently glass ionomer [1-3]. The choice for glass ionomer is based on its self-curing and caries preventive properties [4, 5]. The often cited low wear resistance of glass ionomers was not observed in the last generation of these restorative materials [6, 7]. This is because of the improvement in the physical composition of the material and the relatively small cavity preparations, whereby only the affected tooth tissue is removed and no mechanical retention has to be obtained [3, 8].

ART was initially intended to make preventive and curative oral care more available for the majority of people in economically deprived countries. Prior to the introduction of ART, tooth extraction was the only option for the treatment of dentinal caries due to the lack of sophisticated dental equipment, electricity and financial resources.

The straightforwardness and simplicity of ART and the relatively low cost compared to a treatment approach using rotary instruments, are attractive advantages of this new method.

In the last decade, several ART-studies have been carried out in a number of countries such as Thailand, Zimbabwe, Pakistan and China. These studies reported the survival of single-surface restorations in the permanent dentition and show good results on the short term, on average 88% after three years [9–11].

An interesting advantageous aspect of ART is its claim to be “atraumatic” towards the patient. Several studies have shown that dental anxiety is mainly associated with highly invasive procedures such as “drilling” and “injections” [12, 13]. Neither procedure is usually needed in the ART approach.

A 1995-study in Indonesia [14] compared ART to a modified ART-procedure using rotary instruments only to provide access to the cavity. After completion of the treatment subjects were asked if they had experienced any discomfort during treatment. Answers were given dichotomously (yes or no). The subjects in the ART-group indicated significantly less discomfort (6.3%) compared to the modified ART-group (12.4%).

In another study, ART was compared to a more usual treatment method that uses rotary instruments (MCP). Subjects were asked whether or not they felt pain during the treatment session. Subjects in the ART group reported significantly less pain; 19 % compared to 36% in the conventional group [8]. These studies both concerned one-surface restorations in the permanent dentition.
Discomfort is defined in this study as an occurrence of emotions felt during (dental) treatment, mainly caused by pain or anxiety. This implies that discomfort is a multidimensional construct, consisting of a behavioral, a cognitive and a physiological component [15, 16]. In order to get an impression of the extent of discomfort felt during dental treatment, measurements should model this multidimensional aspect. For the purpose of this study, both the physiological and the behavioral (psychological) aspect are considered to be representative indicators.

The aim of the present study is to explore a possible difference between the extent of discomfort experienced during dental treatment of multi-surface cavities in deciduous molars according to the ART approach and a method using rotary instruments.

Materials and methods

The target population for the current study was 6-year-old school children from deprived communities. Children from randomly selected elementary schools in various districts in Bandung, Indonesia were selected. In order to be included in the study each child needed to have at least one multisurface-cavity in a deciduous molar that was accessible to hand instruments as prescribed for the ART approach [17] and where no pulp exposure was expected. A signed parental consent form was received from each participant prior to the study’s commencement.

The study compared two treatment groups. Children in the control group were treated with rotary instruments. Excavation of the demineralized tooth material was carried out by means of stainless steel round burs in a hand piece (750 rpm), without water-cooling (Minimal Cavity Preparation, MCP). Children in the experimental group were treated according to the ART approach using only hand instruments i.e. hatchets and excavators. In both groups only the demineralized carious tooth tissue and unsupported enamel were removed. After cleaning the cavity, a matrix band and wooden wedges were applied. Cotton wool rolls were used to isolate the cleaned cavity from contamination with saliva and/or blood. After conditioning the dentin for 15 seconds, hand-mix glass ionomer (Chemflex, Dentsply/deTrey) was placed into the cavity in both groups. No local anesthesia was used in either group. Treatments were allocated randomly, the patients could be considered blinded. Four operators carried out the treatments: two 4th year dental students from the Netherlands (University of Groningen) and two Indonesian dentists from the Pedodontic Department of the University of Bandung, Java.

The extent of discomfort, as defined in the introduction, was assessed by measuring the behavioral (psychological) and the physiological aspect; represented by respectively a modified Venham score and the heart rate of the children at six fixed moments during dental treatment:
1) when the child entered the treatment room, 2) at the start of excavation, 3) at the moment of deepest excavation, 4) at the moment of application of the matrix band and wedges, 5) at the moment the restoration was applied and 6) after completion of the treatment.

The heart rate of the patients was measured using a Polar® Tempo- bandage around the chest. For children, aged 6-7 years, normative values for the average of the heart rate in rest vary between 100-95 bpm [18]. The children participating in this study were in good health and therefore the heart rates could be assumed to be comparable to normative standards. The behavior of the children was classified according to a six-point modified Venham- scale [19, 20]. (Table 1) The general behavior of the child during the whole treatment was also registered on the modified Venham- scale as the Venham Overall score, and the highest observed score was noted as the Venham Peak score.

Table 1 Venham index; Modified 6-point scale

<table>
<thead>
<tr>
<th>Venham - Index</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 = relaxed, smiling, willing, able to converse, displays behaviour desired by the dentist</td>
<td></td>
</tr>
<tr>
<td>1 = uneasy; concerned, may protest briefly to indicate discomfort, hands remain down or partially raised. Tense facial expression, “high chest”. Capable of cooperating</td>
<td></td>
</tr>
<tr>
<td>2 = tense; tone of voice, questions and answers reflect anxiety. During stressful procedure verbal protest, crying, hands tense and raised, but not interfering very much. Protest more distracting and troublesome. Child still complies with request to cooperate</td>
<td></td>
</tr>
<tr>
<td>3 = reluctant; pronounced verbal protest, crying. Using hands to try to stop procedure. Treatment proceeds with difficulty</td>
<td></td>
</tr>
<tr>
<td>4 = interference; general crying, body movements sometimes needing physical restraint. Protest disrupts procedure</td>
<td></td>
</tr>
<tr>
<td>5 = out of contact; hard loud crying, swearing, screaming. Unable to listen, trying to escape. Physical restraint required</td>
<td></td>
</tr>
</tbody>
</table>

Both the recording of the heart rate and the observations were carried out by one of the authors, not taking part in the actual patient treatment. Prior to the current study, the observer was trained in using the Venham behavior scale by scoring 42 videotapes of children in a dental situation. These observations were compared to the consensus score of two calibrated observers, who scored the same tapes for another study [20]. This resulted in a Cohen’s Kappa of 0.87, implying a good agreement.

To analyze a difference in the Venham scores between both treatment groups, a Chi-square test for trend was used. Student’s T-test was used to analyze the heart rate of the patients recorded in both treatment groups. The relationship between the heart rate and the Venham score was estimated by Pearson’s correlation coefficient.
To investigate the effect of potential confounding variables on the relation between treatment method and outcome measurement, two-way analyses of variance were done at each time point. Each analysis tested three effects: the influence of the treatment method (main effect for treatment), the influence of the confounding variable (main effect for confounding) and the effect modification, i.e. the influence the confounding factor may have on the relation between treatment and outcome (interaction). Potential confounders/modifiers employed were age (using a cut point at 6 years, 4 months), gender, operating dentist, and the behavior of the children at entrance of the operating room, classified into 3 groups, according to the Venham score at that moment: no (VS=0, n=141), low (VS=1, n=206) and high (VS>1, n=56) anxiety.

For all tests a two-sided significance level of 0.05 was used. Confidence intervals were estimated with a 95%-level. SPSS 8.0 was used for all statistical testing.

Results

For this study, 403 children, 208 boys and 195 girls, mean age 6.3 yrs (range 4.9-7.9) were selected from 49 elementary schools in Bandung. The children were in good health and used no special diet, according to medical reports from the hospital. Each dentist treated about the same number of patients in each group. 201 Children (99 boys, 102 girls) were treated with rotary instruments (MCP) and 202 children (109 boys, 93 girls) with hand instruments (ART). No relations could be found between the treatment and either gender or operator in numbers of patients.

Table 2 Two-sided tail probabilities for testing equality of treatment groups at the different time points during treatment (Chi-square test for trend for Venham behaviour score, Student’s T-test for heart rate). Pearson correlation between Venham score and heart rate (all p-values < 0.05); both groups combined

<table>
<thead>
<tr>
<th></th>
<th>Venham score p-value</th>
<th>Heart rate p-value</th>
<th>Correlation r</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entrance</td>
<td>0.153</td>
<td>0.256</td>
<td>0.614</td>
</tr>
<tr>
<td>Start</td>
<td>0.000*</td>
<td>0.153</td>
<td>0.464</td>
</tr>
<tr>
<td>Deep excavation</td>
<td>0.000*</td>
<td>0.030*</td>
<td>0.369</td>
</tr>
<tr>
<td>Matrix</td>
<td>0.054</td>
<td>0.296</td>
<td>0.324</td>
</tr>
<tr>
<td>Restoration</td>
<td>0.028*</td>
<td>0.483</td>
<td>0.403</td>
</tr>
<tr>
<td>End</td>
<td>0.051</td>
<td>0.521</td>
<td>0.387</td>
</tr>
<tr>
<td>Peak</td>
<td>0.002*</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>Overall</td>
<td>0.000*</td>
<td>-----</td>
<td>-----</td>
</tr>
</tbody>
</table>

* significant at p=0.05
The results of the Venham observations and the heart rate measurements during the specific phases of the treatment session are summarized in table 2.
At the entrance of the children into the operating room no significant difference between the treatment groups for Venham score and heart rate could be found (resp. p=0.153 and p=0.256).

During all five treatment time points, the Venham scores of the children in the ART group were lower than those of the children in the MCP group (most p<0.05). During the application of the matrix and at the end of the treatment the differences were marginally non-significant though (p=0.054 resp. p=0.051). A strong significant interaction was found for the observations at the start and during deep excavation (both p=0.000).
The Venham Overall score showed that children treated with ART were significantly more comfortable and relaxed than children in the MCP group. The Venham Peak scores are significantly higher in the MCP group, indicating the children felt less comfortable compared to those in the ART group.

Student’s T-test on the heart rate measurements of the children during the treatment shows no significant differences between both treatment groups, except for the moment of deep excavation (p=0.03, Table 2). These results are visualized in figure 1. Although not significant, there is a systematic difference between the heart rate of the children in both groups.

To investigate the role of confounding on the relation between treatment method and outcome measurement, two-way analyses of variance were done at each time point.
The influences of the confounding variables can be summarized as follows (Table 3):

![Figure 1](image-url)  
**Figure 1** Heart rate of the children during the treatment according to the ART method (●) and with MCP (■), 95% confidence interval indicated.
The influence of the operator appears to be strong on both Venham score and heart rate of the child. No significant interaction could be found between the dentist and the treatment method during the treatment. This implies that the influence a dentist has on the behavior and the heart rate of the child, is irrespective of the treatment method he or she uses.

Gender seems an important factor as well. Significant differences were found at almost all time points. Girls showed higher scores on the Venham scale and their heart rates were higher compared to those of the boys. The age of the children had a significant influence on the Venham score only during the restoration of the cavity. The older children showed a lower score.

The initial anxiety level (as defined by the Venham Score at entrance) also showed a strong influence on the outcome measurements: the less anxious the children were, the lower their heart rate and Venham score during treatment.

### Discussion

According to the results of this study Atraumatic Restorative Treatment appears to be less stressful for children in comparison to the more usual method as observed with behavioral measurements. Physiological measurements (heart-rate) did show a less clear influence from the treatment method: only during deep excavation, the heart rate of the children in the ART group was significantly lower.

### Table 3

<table>
<thead>
<tr>
<th></th>
<th>Gender</th>
<th>Age</th>
<th>Dentist</th>
<th>Initial anxiety level</th>
</tr>
</thead>
<tbody>
<tr>
<td>H-entrance</td>
<td>0.000*</td>
<td>0.538</td>
<td>0.135</td>
<td>0.000*</td>
</tr>
<tr>
<td>H-start</td>
<td>0.000*</td>
<td>0.630</td>
<td>0.010*</td>
<td>0.000*</td>
</tr>
<tr>
<td>H-deep exc.</td>
<td>0.007*</td>
<td>0.290</td>
<td>0.044</td>
<td>0.000*</td>
</tr>
<tr>
<td>H-matrix</td>
<td>0.000*</td>
<td>0.090</td>
<td>0.002*</td>
<td>0.000*</td>
</tr>
<tr>
<td>H-restoration</td>
<td>0.000*</td>
<td>0.018</td>
<td>0.009*</td>
<td>0.000*</td>
</tr>
<tr>
<td>H-end</td>
<td>0.000*</td>
<td>0.371</td>
<td>0.336</td>
<td>0.000*</td>
</tr>
<tr>
<td>V-entrance</td>
<td>0.000*</td>
<td>0.844</td>
<td>0.098</td>
<td>-----</td>
</tr>
<tr>
<td>V-start</td>
<td>0.010*</td>
<td>0.878</td>
<td>0.010*</td>
<td>0.000*</td>
</tr>
<tr>
<td>V-deep exc.</td>
<td>0.013*</td>
<td>0.494</td>
<td>0.223</td>
<td>0.000*</td>
</tr>
<tr>
<td>V-matrix</td>
<td>0.168</td>
<td>0.166</td>
<td>0.000*</td>
<td>0.000*</td>
</tr>
<tr>
<td>V-restoration</td>
<td>0.091</td>
<td>0.013*</td>
<td>0.001*</td>
<td>0.000*</td>
</tr>
<tr>
<td>V-end</td>
<td>0.001*</td>
<td>0.127</td>
<td>0.000*</td>
<td>0.000*</td>
</tr>
</tbody>
</table>

* significant at p=0.05
The Venham score and heart rate were moderately correlated during all phases of the treatment. The operator did have an effect on the behavior of the child. Also gender and age were confounding factors, as was the initial anxiety. Boys scored lower on both psychological and physiological measurements, irrespective of the treatment method used. Younger children scored higher on the Venham scale during restoration in both treatment groups. None of these factors showed a significant influence on the differences between treatment groups for Venham score or heart rate.

As mentioned in the introduction, research suggests that dental anxiety is mainly associated with the injection-needle and the bur [12, 13]. Both instruments were absent during the ART approach and this could be a suitable explanation for the higher acceptance of this method. Studies on this subject [8, 14], including the present study in particular, focused on the bur as variable. None of the studies drew attention to the fact that no local anesthetics are used. This could be an interesting subject for further research.

To assess dental anxiety in children, many measurement techniques have been proposed and tested for validity and reliability [16]. No consensus was established for any method to be preferred. Also for the measurement of pain several methods have been investigated and applied, without reaching consensus about a preferred technique [21, 22]. Venham (1977) made a distinction between behavior and fear scores and found a high correlation. This finding was replicated in subsequent research [20, 23]. Benjamins [24] found that heart rate is positively correlated to both dental anxiety and pain. Correlation to other physiological reactions such as blood pressure, skin conductance and increase of salivary cortisol were found to be inconsistent. Based on these latter findings the authors consider the Venham score and the heart rate as suitable indicators to represent the extent of discomfort felt during dental treatment.

In this study, the Venham score shows a significant difference between the treatment methods, while the heart rate did not show the same result. An explanation for this finding might be that both criteria measure different manifestations of discomfort. This confirms the multidimensional aspect of this entity.

Gender is a confounding factor with respect to the behavior of children during dental treatment. In this study both heart rate and Venham score of the boys appeared to be lower than those of the girls, irrespective of the treatment method used. This finding could be the result of cognitive dissonance; a contradiction between a person’s feelings, knowledge and actual behavior [25]. This behavior pattern is probably due to a difference in both psychological development and the socialization process. Gender differences according to fear and anxiety have been reported in several studies [26-29].
The effect of the factor age could be explained by the fact that younger children do not have the same coping capacities compared to the older children, because of their psychosocial development [25, 28]. It cannot be explained, however, why this influence was only observed during restoration. Assumptions can be made, though, that the younger children might get tired or lose control at this time.

From the results of this study it appears that the operating dentist influenced the behavior of the child. This might be caused by cultural differences, language problems or even technical skills.

Cultural influences are expected to effect the results of this study. Different cultures might have different coping strategies in certain situations [30, 31]. Although the values for discomfort can be different in other cultures or populations, the tendency is expected to be the same as in this study.

In this study, the Venham score was observed by one of the authors, not participating in the treatments, though aware of the treatment method that was randomly chosen for the child. This could bias the results, favoring one of the treatment methods. Yet, this is very unlikely because four operators were treating patients at the same time, so four children had to be observed accurately. There was no time to make considerations favoring one of the treatment methods.

It can be concluded that children experience less discomfort receiving dental treatment using only hand instruments than children who are treated using burs, when no local anesthetics are used. Gender and initial anxiety level appear to have an important effect on the behavior of the child, while also operating dentist might a role. None of these confounding variables seems to have a measurable effect on the difference in treatment effect, though.

The lower degree in discomfort experienced during dental treatment could make a good case for the widespread increase in the use of hand instruments as with the ART approach.

Further research should focus on cultural aspects and child coping behavior to optimize the use of the ART method.

**Acknowledgements**

The authors are grateful to Drg. Roosje Owen and the staff of the Pedodontic Department of the Fakultas Kedokteran Gigi in Bandung, Indonesia, for their help and enthusiastic cooperation during the project; the Puskes mas of Bandung for their support and time; Drg. Adi Wiradidjaja for her help, support and hospitality; the University of Groningen, in particular Ms. A. Nijhuis and Ms. M.Vos for their contribution during the operative phase; Dr. J.E. Frencken, Nijmegen (the Netherlands) for his support and critical reading of the manuscript.

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References


Three-year survival of single- and two-surface ART restorations in a high-caries child population

M.C.M. van Gemert-Schriks
W.E. van Amerongen
J.M. ten Cate
I.H.A. Aartman

Abstract

The aim of this study was to evaluate the survival of single- and two-surface ART restorations in the primary and permanent dentitions of children from a high-caries population, in a field setting.

Materials and methods:
The study was conducted in the rainforest of Suriname, South America. ART-restorations, made by four Dutch dentists, were evaluated after six months, one, two and three years.

Results:
475 ART restorations were placed in the primary dentition and 54 in first permanent molars of 194 children (mean age 6.09 ± 0.48 years). Three-year cumulative survivals of single- and two-surface ART restorations in the primary dentition were 43.4% and 12.2%, respectively. Main failure characteristics were gross marginal defects and total or partial loss. Three-year cumulative survival for single-surface ART restorations in the permanent dentition was 29.6%. Main failure characteristics were secondary caries and gross marginal defects. An operator effect was found only for two-surface restorations.

Conclusion:
The results show extremely low survival rates for single- and two-surface ART restorations in the primary and permanent dentitions. The variable success for ART may initiate further discussion about alternative treatment strategies, especially in those situations where choices have to be made with respect to a well-balanced, cost-effective package of basic oral health care.
Introduction

The concept of minimal invasive dentistry has evolved as a consequence of an increased understanding of caries and the development of adhesive restorative materials [27]. Within this concept, prevention and hard tissue preservation are the primary goals, and dentists are encouraged to prefer a more conservative and biological approach rather than a surgical approach, although the latter is sometimes unavoidable. The Atraumatic Restorative Treatment technique (ART) is part of a minimal invasive approach and, as such, a technique that meets the specific goals mentioned above. In brief, with ART, soft demineralised carious tooth tissue is removed using hand instruments only, followed by restoration of the tooth with an adhesive restorative material, often glass-ionomer cement [4, 7]. Because neither electricity nor running water is required for this treatment approach, ART can be applied in almost any setting. Although initially developed to provide restorative dental treatment in outreach or rural areas, ART or modified ART techniques are increasingly introduced into dental clinics in industrialized countries [1, 11, 14].

Since its introduction in the mid-1980s, ART has been evaluated in several community field trials. These studies served mainly to obtain information on technical aspects of the process, handling characteristics of the restorative material, and on the survival of the restorations. They led to improvement of the technique [20] and to the development of new, more appropriate glass-ionomer restoration materials, especially for ART purposes. Studies focussing on the survival of ART restorations have shown that the ART approach is very successful in restoring single-surface dentine lesions in the permanent dentition: 3-year survival rates of 71-92% have been reported [5, 6, 9, 10, 12, 20]. Regarding the survival rates of ART restorations in the primary dentition, only a few field studies were performed. They showed acceptable survival rates (65-96.7%) for single-surface ART restorations, but generally low success rates (31–76.1%) for multi-surface ART restorations, even with the newer glass-ionomer materials [2, 3, 11-13, 19, 23, 24, 28]. Although its performance under multi-surface conditions is disappointing, ART is considered a valuable approach towards the treatment of dental caries. The use of ART has resulted in the retention of many teeth that would otherwise have been extracted in a later stage. Nevertheless, there still remain some controversies towards the technique, presumably based on the inconsistency in survival results. Moreover, a recent study, investigating the influence of dental treatment on the oral health of a Surinamese child population, concluded that performing ART restorations only, did not contribute significantly to an improvement of the oral health, suggesting that ART alone is not a sufficient solution in the battle against dental decay [30].

Frencken et al. (2002) described comprehensively that ART should be part of a basic package of oral care in which prevention and urgent care are also represented. However, within this...
package, these three components should be geared to one another as much as possible and the individual effects of all three components must be sufficient and beneficial under different circumstances. When the success of either component, particularly ART, cannot be guaranteed, its contribution in the package should be reduced. Thus, the evaluation of ART in different countries or communities, amongst different kinds of caries-risk populations and under diverging conditions remains useful. Therefore, the aim of this study is to evaluate the survival of both single- and two- surface ART restorations in the primary and permanent dentitions of children from a high-caries population in a field setting on a longitudinal base.

Materials and methods

This cohort study was conducted in the rainforest of Suriname, South America. It was part of a large-scale project investigating the influence of dental treatment on the oral health of children [30]. Within the scope of that particular project, 380 6-year old children were divided randomly among four different treatment groups. Material presented in the current article, concerns only those children who received restorative treatment, according to the ART method, either in their primary or permanent dentitions.

The restorative treatments were performed in accordance with the ART guidelines [4, 7] and took place in empty classrooms where four children were treated at the same time. Ketac-Molar (3M ESPE®) was used as the restorative material of choice. The treatments were carried out by four Dutch dentists who were trained in ART during a one-week ART course and by using ART in children from their own practices, for a period of 3 months, before the start of the treatment phase of the study. They were assisted by six Surinamese health care assistants from the Medical Mission who completed an ART course supplemented with some basic dental knowledge. The dentists were asked to note any contamination with blood and/or saliva during the restoration of the cavity. Furthermore, the presence or absence of adjacent teeth was noted. During the treatment, one of the authors (MGS), who was not involved in the treatment phase, observed and classified the overall behaviour of the child, based on a modified Venham scale [23, 29]. Prior to the study, this observer was trained in using the Venham behaviour scale by scoring 42 videotapes of children in a dental situation. These observations were compared to the consensus score of two calibrated observers. This comparison resulted in a Cohen’s Kappa of 0.87, implying an excellent agreement.

Restorations were not assessed at the time of placement (T0). The children were revisited for evaluation of the ART restorations six months (T1), one year (T2), two years (T3) and three years (T4) after the initial treatment. The same author and dentist mentioned above (MGS),
evaluated the restorations according to the ART criteria (Table 1) using a CPITN probe, a mouth mirror and a head lamp. Prior to the study, this person was calibrated against a ‘gold standard’ (Kappa 0.94). This gold standard was achieved by the consensus of two experienced dentists during the assessment of 24 extracted molars with ART restorations. Restorations scored code 00 or 10 were considered successful, codes 11–40 were classified as failures, and codes 50-90 were assigned in case the tooth was unavailable for evaluation. If a tooth or restoration showed multiple defects, a marginal defect dominated an over- or under-filled restoration (10, 11 > 12, 13), secondary caries dominated a marginal defect (20, 21 > 10, 11), absence of a restoration dominated secondary caries (30 > 20, 21) and an over-filled cavity dominated an under-filled cavity (13 > 12).

<table>
<thead>
<tr>
<th>Table 1 Evaluation criteria for the ART restorations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Code</strong></td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td>0</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>11</td>
</tr>
<tr>
<td>12</td>
</tr>
<tr>
<td>13</td>
</tr>
<tr>
<td>20</td>
</tr>
<tr>
<td>21</td>
</tr>
<tr>
<td>30</td>
</tr>
<tr>
<td>40</td>
</tr>
<tr>
<td>50</td>
</tr>
<tr>
<td>60</td>
</tr>
<tr>
<td>70</td>
</tr>
<tr>
<td>90</td>
</tr>
</tbody>
</table>

**Statistical analysis**

Statistical analyses were performed using SPSS for Windows, version 12.0.1 (SPSS Inc., Chicago, USA). All significant differences were detected at a 95% confidence level. Kaplan-Meier survival analyses were performed on the censored data of both single- and two-surface restorations. The significance of differences between survival curves was determined with log-rank tests. Possible confounding variables were taken into account using a Cox regression analysis.
Results

As stated in the materials & methods section, the children in this study were derived from a larger study population of children participating in another project. The overall caries prevalence, expressed in terms of decayed, missing and filled surfaces (dmfs) among that group of children, was 11.51 (±10.5; range 0-53) in the primary dentition and 0.20 (±0.62; range 0-5) in the permanent dentition. According to the standards of the World Health Organisation [17], this denotes a high-caries child population based on the caries prevalence in the primary dentition. Within the larger group, 194 children (mean age 6.09 ± 0.48 years) received ART restorations in either their primary or permanent teeth, or both. Only these children were included in the current study. Their baseline caries prevalence was 12.75 (±9.88; range 0-53) in the primary dentition and 0.23 (±0.67; range 0-5) in the permanent dentition.

Table 2 Baseline data for the ART restorations

<table>
<thead>
<tr>
<th></th>
<th>Primary Dentition</th>
<th>Permanent Dentition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of filled surfaces</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Number of restorations</td>
<td>133</td>
<td>342</td>
</tr>
<tr>
<td>Number of Children (N)</td>
<td>61</td>
<td>147</td>
</tr>
<tr>
<td>Mean number of restorations per child</td>
<td>3.50 (1.61; 1-7)</td>
<td>3.64 (1.73; 1-8)</td>
</tr>
<tr>
<td>Dentist</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>43 (32.3%)</td>
<td>74 (21.6%)</td>
</tr>
<tr>
<td>2</td>
<td>41 (30.8%)</td>
<td>84 (24.6%)</td>
</tr>
<tr>
<td>3</td>
<td>34 (25.6%)</td>
<td>89 (26.0%)</td>
</tr>
<tr>
<td>4</td>
<td>15 (11.3%)*</td>
<td>95 (27.8%)</td>
</tr>
<tr>
<td>Adjacent tooth present</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>117 (88.0%)</td>
<td>303 (88.6%)</td>
</tr>
<tr>
<td>No</td>
<td>16 (12.0%)</td>
<td>39 (11.4%)</td>
</tr>
<tr>
<td>Contamination blood/saliva</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>13 (9.8%)</td>
<td>110 (32.2%)*</td>
</tr>
<tr>
<td>No</td>
<td>120 (90.2%)</td>
<td>232 (67.8%)</td>
</tr>
<tr>
<td>Venham behaviour score</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>50 (37.6%)</td>
<td>78 (22.8%)</td>
</tr>
<tr>
<td>1</td>
<td>44 (33.1%)</td>
<td>137 (40.1%)</td>
</tr>
<tr>
<td>2</td>
<td>26 (19.5%)</td>
<td>82 (24.0%)</td>
</tr>
<tr>
<td>3</td>
<td>13 (9.8%)</td>
<td>33 (9.6%)</td>
</tr>
<tr>
<td>4</td>
<td>--</td>
<td>12 (3.5%)*</td>
</tr>
<tr>
<td>5</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

* Statistically significant difference at p=0.05, SD=Standard Deviation
At baseline (T0), 475 ART restorations were placed in the primary dentition (mainly 1st and 2nd molars) and 54 in the first permanent molars (predominantly mandibular). Table 2 presents data for the ART restorations, performed at baseline. A Mann Whitney U-test showed that children who received two-surface restorations scored higher on the Venham behaviour scale (p=0.005) than children that received single-surface restorations, in the primary dentition. Furthermore, dentists reported more contamination (Chi-square =25.02, df=1, p<0.001) when placing two-surface restorations than single-surface restorations.

The lost-to-follow-up-percentage of the restorations originally placed was 4.63%. After three years, the cumulative survival of the single-surface ART restorations in the primary dentition was 43.4% (Standard Error (SE) 10.9%). For the two-surface restorations a cumulative survival of 12.2% (SE 2.99%) was observed. The survival curves, with censored data, are presented in figures 1a and b. The cumulative survival of the single-surface ART restorations in the permanent dentition was 29.6% (SE 8.2%) after three years (Figure 2).

Table 3 represents the failure characteristics for the restorations in both primary and permanent dentitions at three years. The main failure characteristics of both single- and two-surface ART restorations in the primary dentition were gross marginal defects (score 11) and total or partial losses (score 30). For restorations in the permanent dentition, the main failure characteristics were secondary caries (score 21) and gross marginal defects (score 11).

A log-rank test indicated that there were no statistically significant differences in survival times between the four dentists regarding single-surface restorations in both primary and permanent teeth. However, regarding the two-surface restorations in the primary dentition, statistically
significant differences between the four dentists appeared (log-rank statistic 11.7, df 3, p=0.009). The separate survival curves are presented in figure 3.

![Figure 2 Survival curve single-surface ART restorations, permanent dentition](image1.png)

![Figure 3 Survival curves per dentist, two-surface ART restorations primary dentition](image2.png)

**Table 3** Failure characteristics for the ART restorations at three years

<table>
<thead>
<tr>
<th></th>
<th>Primary Dentition</th>
<th>Permanent Dentition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1-surface</td>
<td>2-surface</td>
</tr>
<tr>
<td>N_ Restorations baseline</td>
<td>133</td>
<td>342</td>
</tr>
<tr>
<td>N_ Failures</td>
<td>42</td>
<td>251</td>
</tr>
<tr>
<td>Failure score</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11: gross marginal defect</td>
<td>21 (15.8%)</td>
<td>86 (25.1%)</td>
</tr>
<tr>
<td>12: restoration present, under filled</td>
<td>1 (0.8%)</td>
<td>9 (2.6%)</td>
</tr>
<tr>
<td>13: restoration present, over filled</td>
<td>2 (1.5%)</td>
<td>11 (3.2%)</td>
</tr>
<tr>
<td>20: sec. caries, surface intact</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>21: sec. caries, surface defect</td>
<td>5 (3.8%)</td>
<td>1 (0.3%)</td>
</tr>
<tr>
<td>30: total or partial loss</td>
<td>13 (9.8%)</td>
<td>120 (35.1%)</td>
</tr>
<tr>
<td>40: pulpal inflammation</td>
<td>--</td>
<td>24 (7.0%)</td>
</tr>
<tr>
<td>50: restoration missing, extracted</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

Scores 60-90 were not included (censored data)

To detect any confounding variables on the survival of the ART restorations, a Cox regression analysis was performed. No significant relation could be found, indicating that neither the presence or absence of an adjacent tooth, nor contamination with blood and/or saliva, nor the behaviour of the child during the restorative phase of the treatment had an influence on the
three-year survival of the restorations in the primary dentition. No effect also could be found regarding the number of restorations per child. Neither of these variables had an effect on the survival rates in the permanent dentition, except for the presence of adjacent teeth. Restorations in teeth where no adjacent tooth was present were found to be more likely to fail (Hazard Ratio = 6.53, 95% CI 2.66-16.02, p<0.001).

Discussion

In contrast with other studies, the results of this study show extremely low survival rates for both single- and two-surface ART restorations in the primary and permanent dentitions. An operator effect was observed for two-surface restorations only. Neither the behaviour of the child during restoration, and the number of restorations per child, nor the contamination of preparations with blood or saliva had a significant influence on the survival of the restorations in this study.

This field study was performed correctly and the statistical power was sufficiently high to detect at least medium effects. However, because it was part of a large-scale randomized controlled clinical trial, no comprehensive criteria were formulated beforehand regarding, for example, the number of restorations per patient, and the location and the size of the cavities. This aspect is inherent to many cohort studies and it does not imply an inferior study quality, but it limits a meaningful comparison with other survival studies.

Although all possible efforts were exercised to trace the participating children over the evaluation period, 22 restorations (4.63%, eight children), all in primary molars, could not be evaluated at any of the recall visits. Either the children did not show up, or the teeth concerned had exfoliated before the first evaluation. These restorations were regarded as missing data and, therefore, excluded from further analysis. Twenty-six restorations (5.47%, 21 children) were “lost” for evaluation because the teeth either exfoliated or the child moved to another district during the course of the study, but after the first evaluation. These restorations (scores 60–90) were treated as censored data and not as true failures because they survived up to a certain moment.

Many causative factors could be suggested that might explain the failure of the ART restorations, such as secondary caries, cervical margin gaps, material properties, and field conditions (outside temperature, atmospheric humidity). However, many other ART studies face these or comparable problems and, therefore, these factors cannot sufficiently explain the extremely low survival rates found in this particular study. The operator difference for the
survival rates of the two-surface restorations was not unique, and not a sufficient explanation for the disappointing survival results. Operator effects are often found in ART studies [4, 9, 15, 21, 26] and, as in every profession, there will always be individual differences in technical skills. The finding that the absence of an adjacent tooth was related to a lower 3-year survival of single-surface ART restorations in permanent molars could not be explained. One can only speculate about possible reasons for this relationship, such as that these free-standing molars experience larger occlusal forces.

A possible influence of the relatively high caries prevalence on the survival of the restorations could be hypothesized, but is very doubtful. A study in Indonesia, where the child population exhibited a much higher caries prevalence, also found disappointing survival rates for two-surface ART restorations [28], but these rates were not as extreme as those found in the current study. The survival rates for single-surface ART restorations, derived from other earlier cited studies, were all very promising regardless of the caries profile of the study populations. Furthermore, no effect on the survival rates of the restorations was found when the number of restorations per child was included in the analysis.

The ART protocol prescribes not to eat or drink within at least one hour after the completion of the restorative treatment [7]. The children in the current study were not supervised after they received restorative treatment and consequently, their food intake could not be controlled. Future studies should take this aspect into account.

Other patient-related factors that may influence the survival of the restorations are the behaviour and saliva flow of the child. The survival of the ART restorations in this study was analysed at the restoration level. This method requires independency of the restoration data and, with respect to the mentioned patient-related possible bias, this assumption could not be guaranteed. To control for this lack of independency, the survival analyses also were performed at the patient level, including only one randomly-selected restoration per child. These analyses did not render higher survival rates.

The predominant failure characteristics for both single- and two-surface ART restorations in the primary dentition were gross marginal defects and total or partial losses. This agrees with previous studies concerning the survival of ART restorations in the primary dentition [6, 13, 25, 26]. Gross marginal defects could be induced by occlusal forces or insufficient wear resistance of the restorative material. Ketac-Molar was specifically developed for ART purposes [13], and it has shown excellent results for posterior restorations in the primary dentition [16, 22]. Glass-ionomer restorations can be dislodged for a number of reasons, such as insufficient cleaning and conditioning of the cavity, and improper mixing of the material. None of these conditions was recorded at the time the tooth was restored. However, all dentists and chair-side assistants followed the ART guidelines and the manufacturer’s instructions as much as possible under the given circumstances.
The main reasons for failure of the single-surface restorations in the permanent dentition were gross marginal defects and secondary caries. This latter finding is somewhat surprising and contrasts with earlier ART studies [5, 6, 10, 26]. Glass-ionomer cement has been the restorative material of choice for the ART technique, based mainly on its fluoride-releasing and, thus, caries-preventive properties [7]. Many studies underline these characteristics of glass-ionomer [18, 26, 31, 32].

The extremely low survival of the ART restorations observed in this study remains unexplained. Circumstances that were not recognized as possible interfering factors at the start of the study might have played an important role, including cultural and seasonal dietary influences. People living in the rainforest of Suriname eat seasonal fruits such as mangos and fruits of the fibre palm (Awarra). In particular, the latter may influence the survival of the restorations, given the frequency and method in which they are consumed. The authors have seen unusual wear patterns, also in adult dentitions, which might have been caused by excessive consumption of Awarras. A possible causality between these dietary habits and the survival of the ART restorations can only be disclosed by future controlled studies.

Although previous studies have suggested that ART should not be considered as a routine procedure to restore multi-surface cavities [13, 24], based on the results of this study, even the ART restoration of single-surface cavities might be reconsidered. This study underlines the inconsistency and variation in the success of the treatment. Apparently, certain conditions must be fulfilled to make ART successful. These conditions can be approached, but not always achieved, under all circumstances.

Conclusion
The uncertain predictability for the success of ART may introduce further discussion about alternative treatment strategies, especially in those situations where choices have to be made with respect to a well-balanced, cost-effective package of basic oral health care. To gain insight into factors determining the cumulative success rate of ART restorations, future studies should focus in more detail on variables that could possibly contribute to the failure of restorations.

Acknowledgments
This study was supported by the Netherlands Institute of Dental Sciences (IOT), the Netherlands Foundation for the advancement of Tropical Research (WOTRO), the Foundation “De Drie Lichten” in The Netherlands and 3M ESPE. The authors would like to thank the Director of the Surinamese Ministry of Health and the Medical Mission of Suriname for their intensive and enthusiastic cooperation, their inspiring input, and the provision of all facilities.
References


The effect of different dental treatment strategies on the oral health of children: a longitudinal randomized controlled trial

Clinical Oral Investigations 2008; in press
Abstract

The aim of the present study is to verify which strategy is the most effective in the treatment of dental decay of the deciduous dentition in a moderate to high caries child population under remote field conditions.

Materials and methods:
This study was carried out in the rainforest of Suriname. Three hundred and eighty schoolchildren, mean age 6.1 years (±0.5, range 5.1–7.1 years), were randomly assigned to four different groups: full dental treatment, only extractions, only restorations (ART) and no treatment. Parameters for oral health were defined as caries prevalence, caries incidence, sequela to dental caries, and dental pain.

Results:
Restorative dental care of the primary dentition, by means of ART, resulted in an increase in dmft. Extensive dental treatment, performing only extractions or no treatment did not render significant changes in the caries prevalence of children.

Conclusion:
Full dental treatment should be the strategy of choice whenever oral health care programmes are developed. However, when priorities are required due to situational, practical or economical reasons, extraction of severely decayed teeth is an effective treatment strategy.
Introduction

Despite great improvements in the global oral health status, dental caries still remains one of the most prevalent diseases [3, 26, 32, 33, 35, 47]. Although dental caries is seldom life threatening, its detrimental effects adversely influence people’s quality of life and therefore active caries receives adequate treatment [12]. Several strategies for the management of dental caries in the primary dentition have been proposed.

Extraction is the most basic way of managing dental caries. However, among other possible side effects, extraction of teeth might induce space problems by drifting of other primary or permanent teeth [12, 30]. Another approach is conventional restoration of all cavities [9, 12, 24], although this treatment option is currently under debate and there seems to be an unmistakable tendency to minimize the invasive approach of carious lesions to a preventive non-operative treatment [10, 21, 22, 24, 29, 37, 40]. The use of fluorides is an effective measure in the prevention of dental decay [4, 5, 46]. However, studies have shown that, in the absence of fluorides, dental decay could also be adequately prevented by means of oral hygiene instruction and frequently repeated professional tooth cleanings [1, 2]. Unfortunately, preventive strategies on their own are rarely sufficient to re-establish oral health and function in children with active caries and must often be supplemented with curative oral care [12].

To summarize, there is no consensus on what strategy is preferred to treat the diseased deciduous dentition adequately. Treatment decisions are not only guided by clinical considerations but also by attendance patterns, parent’s wishes and socio-economic background [19, 20, 36-41]. Furthermore, and this accounts especially for disadvantaged countries and communities, treatment decisions often depend on available budgets, adequate material and trained personnel. Although oral diseases are qualified as a major public health problem in these countries, oral health care is often highly underrepresented within a total health care system [14, 44]. The scarcely available funds must be utilized efficiently and priorities for an acceptable level of oral care must be established.

Appropriate oral health care should comprise the prevention of new dental decay, arrestment of existing carious lesions, prevention of pain and discomfort for children, and prevention of early loss of deciduous teeth. The aim of the present study is to verify which of several dental treatment strategies is the most efficient and effective with regard to the above mentioned clinical objectives, in the treatment of dental decay of the deciduous dentition in a moderate or high carious child population under remote field conditions.
Materials and methods

Study population
This study basically followed the CONSORT guidelines of a randomized controlled trial. The study was carried out in the rainforest of Suriname, a former Dutch colony located at the Northern coast of South America. It is divided into urban, rural and the interior areas, in terms of population and economic activity. The interior rain forested area, comprising about 80% of the country, is sparsely populated by tribal communities (12% of the total Surinam population), mainly Creole Bushnegroes (80%) and Amerindians (20%). The rainforest lacks an adequate infrastructure, electricity and running water [31]. Epidemiological data regarding the caries prevalence in this area have been reported in a separate study [42]. The target population was 400 6-year old school children with untreated dental decay and a non-contributory medical history. A power analysis indicated that with 80% power, 5% significance level and at least a medium effect size ($W=0.30$ or $f=0.20$) 100 patients per group were sufficient [7]. Seventeen schools, located in two different regions of the rainforest and selected from the database of the Medical Mission, participated in the study. Ethical clearance was obtained from the Director of the Surinam Ministry of Health. All schools were informed about the study and the objectives. The teachers were obligated to inform the parents. The parents or the teacher, in case the parents were illiterate, gave their approval for participation of a child by signing an informed consent letter. Without this approval, children were excluded from the study.

Oral examination and oral health parameters
Oral examination, using a headlamp, mouth mirror and dental probe, took place in the classroom whilst the child was lying on a table. Parameters for oral health were defined as caries prevalence, caries incidence, sequela to dental caries and the presence of dental pain. The criteria of the World Health Organisation (WHO) were used for the assessment of caries in the deciduous dentition [45]. To ensure that criteria were followed, all children were examined by one of the authors (MGS) who was calibrated with a gold standard (kappa 0.89). This gold standard was developed by consensus between two experienced investigators, using the WHO criteria, for 25 pictures of (pre)molars with and without dentine carious lesions. Caries prevalence was measured using the decayed, missing and filled teeth–index (dmft) [45]. In case a carious lesion had progressed into the dental pulp, or when pulpal exposure could rationally be expected following total excavation, the tooth was marked on the dental chart as “pulp”. Abscesses and/or fistulas (AbFi) as a result of this dentogenic infection were indicated, as was the presence of root remnants (RR). Dental pain was assessed by self report.

Randomisation and treatment groups
The children were collected from their classroom by one of the participating health care workers (HCW’s) who was not familiar with the sequence of group allocation of the children. Upon entrance, the children received a number which corresponded with a specific group number on a computerized
random list that was in the possession of the dentist who performed the oral examination of the children (MGS). In this way, all children were randomly assigned to four different treatment groups. Children in group 1 received full dental treatment of their primary dentition: all cavities that did not show signs of dentogenic infection nor gave rise to any pain complaints were restored according to the Atraumatic Restorative Treatment (ART) approach [13]. Teeth with deep carious lesions, where pulpal exposure was likely to be expected in case of total excavation, were extracted. Children in group 2 did not receive any restorative care. Only carious primary teeth with pulpal involvement were extracted. Children in group 3 only received ART restorative care of cavities that did not show pulpal involvement while deep caries lesions were left untreated. Children in group 4 received neither restorative treatment nor extraction of any of their carious primary teeth. In all groups, cavities in permanent molars were restored according to the ART approach. When a child reported dental pain and the perpetrating tooth was not involved in the initial treatment plan, they were treated by extraction, irrespective the treatment group.

Dental treatment

Treatment plans were made by the dentist who performed the initial oral examination (MGS). Thereafter the children were allocated sequentially to one of the four other dentists who performed the prescribed dental treatments. These Dutch dentists were extensively trained in ART prior to the study. Six Surinam medical health care workers (HCW’s), selected by the Medical Mission of Surinam, assisted the dentists during the treatment. These HCW’s graduated an ART Master class prior to the initiation of the project. Dental treatments were carried out in an unoccupied classroom.

Evaluation

Six months (T1), one (T2), two (T3) and three years (T4) after their initial visit and dental treatment, the children were evaluated. During these evaluations, the same examiner (MGS) recorded the dental status of the children as described earlier. Dental treatments were performed by other dentists immediately after the evaluations according to the allocated group. Children that were absent at an evaluation could reappear on the next evaluation and were not regarded as lost to follow-up. When a child had missed three or more evaluation visits, he or she was excluded from the study. From the first evaluation, all children received classical oral health instructions and dietary advices. These instructions were given by the HCW’s and repeated on every evaluation visit. Teachers were stimulated to repeat the classical oral health instructions during their daily classes.

Statistical analysis

Statistical analyses were performed using SPSS for Windows, version 12.0.1. All significant differences were detected at a 95% confidence level.
Results

Study population
The study started in February 2001. The original sample consisted of 490 children (mean age 6.1 years, ±0.5, range 5.1–7.1). The flowchart in the Appendix (page 145) represents details about the enrolment and allocation of the children. At the enrolment, 76 children were excluded because they appeared to be free of dental decay. Thirty four children were excluded from the study after the group allocation; two because they showed a contributory medical history and 32 because they had received dental treatment before. The remaining 380 children showed an equal distribution of males (192) and females (188) over the four treatment groups ($X^2=4.21$, df=3, $p=0.24$) and no differences in mean age amongst the groups were seen ($F_{(3,376)}=0.43$, $p=0.73$). The demographic characteristics of the sample are presented in table 1.

During the course of the study an increasing drop out was seen, though equally distributed among the different groups at each evaluation as proven by non significant Chi-square tests.

A total of 25 children (6.6%) did not show up at three or more evaluations and they were considered lost-to-follow-up. The main reasons for absence were illness, moving to another district, or work of the parents in the fields.

<table>
<thead>
<tr>
<th>All combined (n)</th>
<th>1 Full treatment</th>
<th>2 Extraction</th>
<th>3 ART</th>
<th>4 No treatment</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>96</td>
<td>91</td>
<td>96</td>
<td>97</td>
<td></td>
<td>380</td>
</tr>
<tr>
<td>Sexe</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n Male (%)</td>
<td>53 (55.2)</td>
<td>50 (54.9)</td>
<td>48 (50)</td>
<td>41 (42.3)</td>
<td>192 (48.6)</td>
</tr>
<tr>
<td>n Female (%)</td>
<td>43 (44.8)</td>
<td>41 (45.1)</td>
<td>48 (50)</td>
<td>56 (57.7)</td>
<td>188 (51.4)</td>
</tr>
<tr>
<td>Mean Age</td>
<td>6.11</td>
<td>6.15</td>
<td>6.07</td>
<td>6.11</td>
<td>6.09</td>
</tr>
<tr>
<td>(SD, range)</td>
<td>(0.51, 5.12-7.06)</td>
<td>(0.48, 5.12-7.05)</td>
<td>(0.45, 5.15-7.09)</td>
<td>(0.48, 5.11-7.09)</td>
<td>(0.48, 5.11-7.09)</td>
</tr>
<tr>
<td>Mean dmft</td>
<td>6.42</td>
<td>6.30</td>
<td>5.48</td>
<td>6.86</td>
<td>6.26</td>
</tr>
<tr>
<td>(SD, range)</td>
<td>(3.76, 1-17)</td>
<td>(3.23, 1-17)</td>
<td>(3.20, 0-16)</td>
<td>(3.37, 1-18)</td>
<td>(3.42, 0-18)</td>
</tr>
</tbody>
</table>

Caries prevalence
The caries prevalence in the deciduous dentition of the children is presented in table 1. Because dmft showed a skewed distribution it was regarded as a non parametric variable. None of the participating children received any form of dental treatment prior to this study, the baseline-dmft consisted of the decayed factor only. A Kruskall Wallis (KW) test showed a statistically significant difference in caries prevalence in the primary dentition between the four treatment groups at baseline ($p_{dmft}=0.024$). Post hoc Mann Whitney U (MWU) tests showed that children in group 3 had a significantly lower dmft than children in group 4 ($p=0.002$).
Through the course of the study, the caries experience in the primary dentition in the four treatment groups showed various trends (Figure 1). Separate Friedman tests indicated that within each group, the dmft-scores differed significantly between all time points, except in group 1 ($p_{(\text{group2})}=0.001$, $p_{(\text{group3})}=0.013$, $p_{(\text{group4})}<0.001$). Post hoc Wilcoxon Signed Ranks (WSR) tests were performed to describe the dmft changes between all time points separately for all four groups. Table 2 shows the statistically significant p-values. Attention should be paid to the overall drop in dmft that was observed between T3 and T4. Given the fact that Negro children show an earlier eruption pattern than Caucasians [28], exfoliation is very likely to have accounted for this pattern. To correct for possible bias, the authors choose to take T3 as the last evaluation time point instead of T4. Between T0 and T3, an increase in dmft is observed in group 3 ($p<0.001$).

### Table 2 Statistically significant p-values caries incidence

<table>
<thead>
<tr>
<th>Group</th>
<th>T0-T1</th>
<th>T1-T2</th>
<th>T2-T3</th>
<th>T3-T4</th>
<th>T0-T3</th>
<th>T0-T4</th>
</tr>
</thead>
<tbody>
<tr>
<td>dmft</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>n.s.</td>
<td>0.023</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>2</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
<td>&lt;0.001</td>
<td>n.s.</td>
<td>0.012</td>
</tr>
<tr>
<td>3</td>
<td>0.001</td>
<td>n.s.</td>
<td>0.018</td>
<td>n.s.</td>
<td>&lt;0.001</td>
<td>n.s.</td>
</tr>
<tr>
<td>4</td>
<td>n.s.</td>
<td>n.s.</td>
<td>&lt;0.001</td>
<td>n.s.</td>
<td>&lt;0.001</td>
<td></td>
</tr>
</tbody>
</table>

n.s. = not statistically significant, ↑ = increase in dmft, ↓ = decrease in dmft

### Dentogenic infections

The presence of dentogenic infections at T0 and T3 is presented in table 3. KW test showed significant differences between the four treatment groups regarding the mean number of carious teeth with "pulp" at baseline ($p=0.044$). Post hoc MWU tests showed that children in group 3 presented less "pulp" compared to children in group 1 ($p=0.047$) and children in group 2 ($p=0.005$). WSR tests showed that
from T0 to T3, the mean number of carious teeth with suspected pulp involvement decreased significantly in group 1 and 2 (p<0.001). An increase was seen in group 4 (p=0.002).

The presence of root remnants (RR) and abscesses and/ or fistulas (AbFi) showed a skewed distribution and therefore, these variables were dichotomised into “not present” or “one or more present”. At T0, 67.1% of the children (255) had one or more carious lesions which had advanced into the dental pulp. From these 255 children, 77 (30.2%) had one or more AbFi and 30 (11.8%) had one or more RR. Pearson Chi-square tests showed no significant differences between the four treatment groups regarding the presence or absence of RR (X²= 6.61, df=3, p=0.086) or AbFi (X²=6.68, df=3, p=0.083) at baseline. McNemar tests showed that during the course of the study (T0-T3), the number of children that had one or more AbFi decreased in groups 1 and 2 (p(group1)=0.021, p(group2)<0.001) whereas an increase was observed in group 4 (p =0.031). The number of children that had one or more RR decreased in groups 1 and 2 (p(group1)=0.004, p(group2)=0.006) and increased in groups 3 and 4 (p(groups3,4)<0.001).

Table 3 Overview of pulpal lesions (pulp) occurring in the study population, subdivided into present abscesses and/or fistulas (AbFi) and root remnants (RR)

<table>
<thead>
<tr>
<th>Group</th>
<th>1 Full treatment</th>
<th>2 Extraction</th>
<th>3 ART</th>
<th>4 No treatment</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>T0 N (total population)</td>
<td>96</td>
<td>91</td>
<td>96</td>
<td>97</td>
<td>380</td>
</tr>
<tr>
<td>Mean number of pulp (SD, range)</td>
<td>2.40 (2.56, 0-11)</td>
<td>2.59* (2.49, 0-10)</td>
<td>1.74* (2.23, 0-11)</td>
<td>2.21 (2.51, 0-10)</td>
<td>2.23 (2.46, 0-11)</td>
</tr>
<tr>
<td>N (children with pulp&gt;0)</td>
<td>68</td>
<td>68</td>
<td>57</td>
<td>62</td>
<td>255</td>
</tr>
<tr>
<td>N 1/more Ab/Fi present (% from children with pulp&gt;0)</td>
<td>17 (25)</td>
<td>25 (36.8)</td>
<td>22 (38.6)</td>
<td>13 (21)</td>
<td>77 (30.2)</td>
</tr>
<tr>
<td>N 1/more RR present (% from children with pulp&gt;0)</td>
<td>9 (13.2)</td>
<td>13 (19.1)</td>
<td>4 (7)</td>
<td>4 (6.5)</td>
<td>30 (11.8)</td>
</tr>
<tr>
<td>T3 N (total population)</td>
<td>80</td>
<td>73</td>
<td>82</td>
<td>88</td>
<td>323</td>
</tr>
<tr>
<td>Mean number of pulp (SD, range)</td>
<td>0.18 (0.38, 0-1)</td>
<td>0.29 (0.70, 0-4)</td>
<td>1.84 (2.02, 0-10)</td>
<td>3.14 (2.41, 0-10)</td>
<td>1.43 (2.07, 0-10)</td>
</tr>
<tr>
<td>N (children with pulp&gt;0)</td>
<td>14</td>
<td>14</td>
<td>55</td>
<td>73</td>
<td>156</td>
</tr>
<tr>
<td>N 1/more Ab/Fi present (% from children with pulp&gt;0)</td>
<td>4 (28.6)</td>
<td>1 (7.1)</td>
<td>17 (31.5)</td>
<td>25 (34.2)</td>
<td>48 (30.2)</td>
</tr>
<tr>
<td>N 1/more RR present (% from children with pulp&gt;0)</td>
<td>0</td>
<td>1 (7.1)</td>
<td>23 (42.6)</td>
<td>19 (26)</td>
<td>43 (27)</td>
</tr>
</tbody>
</table>

* statistically significant difference between groups at baseline (p<0.05)

Discussion

This study indicated that when only ART is performed in the primary dentition, an increase in caries prevalence is seen. Full dental treatment, performing only extractions or no treatment, did not bring about significant changes in the caries prevalence of children.
In this study, caries prevalence (dmft) showed a skewed distribution and was regarded as a non-parametric variable. Consequently, only a comparison of variables between different groups at one time point or a comparison of the variables at different time points within one group was possible. For the purpose of this study, the latter was preferred.

During the course of the study, only 25 children (6.6%) were lost to follow-up. This percentage is very low regarding the field conditions and the effect on the power of the study is considered negligible.

Regarding the caries prevalence in the primary dentition at baseline, significant differences between the four treatment groups were observed that were regarded as a consequence of the randomisation. All children vary in their caries risk profile, not only based on different dietary habits or former caries experience, but also due to a genetic variance in susceptibility to develop dental decay [6, 34]. Although a baseline disproportion of caries prevalence between groups is undesirable in a randomized controlled trial [18], in the current study it is considered to have had no or negligible influence on the results whereas the trends in caries prevalence are described and evaluated per group separately and no statistical comparisons between the groups were made, as stated in paragraph 2 of this discussion.

The current study lacks a true double-blind evaluation whereas the same examiner performed the randomisation and the evaluations. Although the treatment group was not visible on the dental chart of the patient, any examiner could have identified the child’s allocated group due to the treatment of the dentition. The examiner was not aware of information upon which dentist had performed the treatment.

As stated in the introduction, appropriate oral health care should comprise the prevention of new dental decay, the prevention of progression of carious lesions, the prevention of pain and discomfort for children, and the prevention of early loss of deciduous teeth. When the treatment strategies from this study are evaluated in the light of these clinical measures one might conclude that both full treatment and performing only extractions fulfil three of the four objectives and can thus be regarded as the most effective treatment strategies with regard to oral health. In both treatment groups, no significant changes in caries prevalence were observed and the number of dentogenic infections decreased significantly which indicates that progression of lesions was controlled adequately. Moreover, pain and discomfort as a consequence of dental decay were prevented.

The fourth objective, the prevention of early loss of deciduous teeth, could not be met in either of these two strategies. In this study, extraction was indicated when a carious lesion had progressed onto the dental pulp. The diagnosis of existing or suspected dentogenic infection is difficult to assess based upon the clinical aspect of the lesion alone. The use of intra oral radiographs is advisable, but unfortunately these were not available in the current study given the field conditions. In advanced general practices, various restorative options for the treatment of deep dental decay are advised [11, 15-18, 27, 28], which could not be performed under remote field circumstances.
Many controversies exist regarding extraction of primary teeth. Premature loss of primary molars can cause space problems such as tipping of the first permanent molars, crowding in the dental arch and impaction of the permanent predecessor [8, 30]. In the current study, no effect of the various dental treatments could be found on the dental arch measures (data not shown), but further investigation upon this subject is required.

In this study, children in the ART group showed an increase in caries prevalence. Restorative treatment leaves the risk for new decay, either secondary caries along the margins of a restoration or new decay on originally sound tooth surfaces. Moreover, caries can develop on adjacent surfaces that were damaged during preparation [23]. In this study, only 4% of the ART restorations in the primary dentition failed due to secondary caries [25] which suggests that the greater part of the increase in caries prevalence is probably due to new dental decay.

The clinical relevance of the results of this study goes beyond the interests of this specific Surinam population. In fact, it should be considered in any other situation where due to situational, economical, psychological or practical circumstances, choices have to be made regarding the most suitable treatment option with the most optimal prognosis under the given conditions.

**Conclusion**

Full dental treatment might be the treatment strategy of choice whenever uniform oral health care programmes are developed. However, when priorities have to be established due to situational, practical or economical reasons, extraction of severely decayed teeth appears to be an effective treatment strategy.

**Acknowledgments**

This study was supported by the Netherlands Institute of Dental Sciences (IOT), the Netherlands Foundation for the advancement of Tropical Research (WOTRO), the Foundation “De Drie Lichten” in The Netherlands and 3M-ESPE. The authors would like to thank the director of the Surinam Ministry of Health and the Medical Mission of Surinam for the intensive and enthusiastic cooperation, the provision of all facilities and the inspiring input.
References


The influence of dental caries on body growth in prepubertal children

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W.E. van Amerongen
I.H.A. Aartman
J.M.B. Wennink
J.M. ten Cate
J.J. de Soet

Caries Research, submitted
Abstract

Dental decay and dental treatment are suggested to be related to body growth in children. The aim of this study was first to assess the relation between dental caries and body proportions cross sectionally in a Suriname caries child population, and secondly, to investigate whether dental treatment had a significant influence on body growth of these children in a randomized controlled trial using different treatment strategies.

Materials and methods:
380 6-year old children with untreated dental decay participated in the study. Caries prevalence and presence of dentogenic infections were recorded. All children were randomly assigned to four different treatment groups, ranging from full dental treatment to no invasive treatment at all. Body growth was evaluated by children’s height, weight and body mass index. Participants were evaluated after six months, one, two and three years.

Results:
Cross sectionally, negative correlations were observed between anthropometric measures and the number of untreated carious surfaces and caries experience of the children. Next, no significant differences in growth pattern between the treatment groups were observed.

Conclusion:
Based on these results it is suggested that caries activity is a negative predictor for body growth in children and dental intervention does not show significant improvement within 3 years.
Introduction

For many years it is suggested that oral infections negatively affect general health [Garcia et al., 2000]. Several possible explanations for an oral-systemic relationship have been described [Li et al., 2000]. Synergism is assumed because some general disease conditions can be associated with oral manifestations that increase the risk of oral disease and some oral diseases in turn, can act as risk factors for general health [Petersen et al., 2005]. Particularly from the field of periodontology, an association has been described between periodontal diseases and certain systemic conditions, such as cardiovascular diseases, respiratory diseases, diabetes mellitus, low birth weight and preterm birth [Drangsholt, 1998; Loesche et al., 1998; Beck et al., 2000; Garcia et al., 2000; Li et al., 2000; Glurich et al., 2002; Mojon, 2002].

Possible systemic effects of dental caries have not been investigated as thoroughly as the systemic effects of periodontal diseases. However, similar outcomes may be expected, since dental caries is, like periodontitis, a chronic multifactorial infectious disease. Immune factors have been found to play an essential role in the etiology of chronic multifactorial diseases [Tetley, 2005; Pietruska et al., 2006; Balfour, 2007; de Sa et al., 2007]. De Soet et al. [2003] reported an association between dental caries and systemic parameters of inflammation. Moreover, systemic responses to Streptococcus mutans and infected dental pulps have been described [Kim and Lim, 2002; Hahn et al., 2004; Hahn and Liewehr, 2007]. Based on these findings, it is suggested that dental caries may induce a systemic immune response that may especially occur when caries progresses into pulpal inflammation [Skogedal and Tronstad, 1977; Duggal et al., 2002].

Apart from these immunologic parameters, a reliable clinical diagnostic tool for the measurement of general health is desired, in order to identify adverse health outcomes caused by dental decay. Assessment of children’s height and weight is widely accepted as a valid clinical indicator of general health and well being [Burgemeijer et al., 1998; de Onis and Blössner, 2003]. Body growth is influenced by genetic, constitutional and environmental factors, including malnutrition and the occurrence of infectious diseases [Mata et al., 1972; de Beer, 2001; Bhutta, 2006]. Dental caries is one of the most prevalent infectious diseases worldwide [Petersen et al., 2005] and it can thus be hypothesized that the possible systemic effects of dental caries could be reflected in a deviant growth pattern. Several studies confirmed this hypothesis as they showed that dental decay and dental treatment affected general body growth in children [Elice and Fields, 1990; Acs et al., 1992; Ayhan et al., 1996; Acs et al., 1998; Acs et al., 1999; Nicolau et al., 2005]. For example, Acs et al. [1992] reported that children with nursing caries weighed significantly less compared to their matched controls. They also presented children with early childhood caries that exhibited growth retardation and showed a “catch-up-growth” after dental rehabilitation [Acs et al., 1998; Acs et al., 1999]. Furthermore, Aydan et al. [1996] reported that children with rampant or nursing caries showed significantly less height or lower weight compared to their matched controls. The affluent studies indicate that, with respect to aetiology, it could be that toothache...
and infection alter eating and sleeping habits, dietary intake and physiological processes that underlie normal growth [Acs et al., 1992; Ayhan et al., 1996; Thomas and Primosch, 2002]. If body growth in children is adversely affected by dental decay, problems can be expected especially in those countries and communities where populations are at high risk to develop dental decay due to nutritional deficiencies, high sugar consumption, inadequate exposure to fluorides and limited access to oral health services [Pilot, 1988; Alvarez et al., 1993; Marthaler et al., 1996; Speechley and Johnston, 1996; Miura et al., 1997; Pakhomov, 1999; Diehnelt and Kiyak, 2001; Gray and Davies-Slowik, 2001; Reich, 2001; Haugejorden and Birkeland, 2002; Jamieson et al., 2004]. One of these countries is Suriname. The Interior of Suriname, covering about 80% of the country, is sparsely populated by tribal communities. Children living throughout the Interior, especially in the Creole population, show an increasing percentage of growth retardation that has mainly been attributed to a shortage of protein in the diet [van der Crabben et al., 2004]. However, given the knowledge that these children also have limited access to oral care services and suffer from untreated dental decay [van Gemert-Schriks et al., 2008b], it might be questioned if dental caries and/or concomitant dentogenic infection underlies this growth retardation as well. Insight in this relationship could have important implications for oral health care planning in these countries.

The purpose of the current study was to investigate the relation between oral health and body growth of prepubertal children living throughout the rainforest of Suriname. The study was based on the following hypotheses: dental caries is inversely proportional to body stature in prepubertal children, and, children with untreated dental decay show less body growth compared to children that receive dental treatment of their carious teeth. To test these hypotheses, the study was divided into two parts.

The aim of the first part was to analyse the relation between dental caries and body proportions cross-sectionally in a child population with diagnosed dental decay.

The aim of the second part of the study was to investigate whether treatment of dental decay had a significant influence on the general health, in terms of body growth, of prepubertal children. Based on a randomized controlled trial (RCT) design, four different dental treatment strategies were applied, in order to distinguish the key components of dental treatment that account for the hypothesised improvement in body growth.

**Materials and methods**

The study population was 6-yr old school children living in the interior of Surinam, with a non-contributory medical history and with dental decay but without any former dental treatment experience. Seventeen schools, located in two different regions of the rainforest and selected...
from the database of the Medical Mission, participated in the study. Ethical clearance was obtained from the Director of the Surinam Ministry of Health. All schools were informed about the study and its objectives. The teachers were obligated to inform the parents. The parents or the teacher (in case the parents were illiterate) gave their approval for participation of the child by signing an informed consent letter. Without this approval, children were excluded from the study.

Dental examination
All children received dental examination, using a mouth mirror and a dental probe. Dental caries status was recorded individually in terms of dmfs, a numeric expression of the caries prevalence [WHO, 1997]. All children were examined by one of the authors, who was calibrated with a gold standard (Cohen’s kappa 0.89). This standard was developed by consensus between two experienced investigators on scoring 25 pictures of molars with and without dentine carious lesions. For the purpose of this study, caries experience in the primary and the permanent dentition were combined in one parameter: total-dmfs. The combined number of total decayed surfaces (total-ds) in primary and permanent dentition was noted separately in order to be able to identify possible effects of untreated carious lesions.

The presence of pulpal inflammation (pulp) was reported if a carious lesion had reached the pulp and/or when pulpal exposure was expected on excavation. The presence of fistulas and/or abscesses (AbFi) as a result of the dentogenic infection was noted. For the purpose of this study, these variables were dichotomized into ‘one or more present’ or ‘not present’.

Anthropometric measures
Height and weight of all children were measured and from these anthropometric data, the individual Body Mass Index (BMI, weight/height$^2$) was calculated. Height was assessed to the nearest 0.1 cm using a digitally standardized Height Measuring Unit (Soehnle®, Germany). Weight was assessed to the nearest 0.01 kg using a calibrated digital Gamma 7401 scale (Soehnle®, Germany). These body growth measurements were performed by one of the team-members, who was not familiar with the sequence of group allocation of the children.

In order to follow up individual growth, height scores and BMI calculates were transformed into standard deviation scores (SDS$_H$, SDS$_{BMI}$). In this manner, each child was its own control in the follow up years. The SDS-values in the current study were calculated according to Dutch references [Gerver and de Bruin, 1996; Burgemeijer, 1998; Fredriks et al., 2000; van Buuren and Fredriks, 2001; van Buuren, 2004; van Dommelen et al., 2004; van der Crabben et al., 2004], since there was no growth chart of rainforest children available.

Randomisation and treatment groups
With respect to the RCT part of the study, the Consolidated Standards of Reporting Trials (CONSORT) guidelines were followed. A power analysis indicated that for a oneway ANOVA with
four groups, with 80% power, 5% significance level and somewhat less than a medium effect size ($f=0.20$), 69 patients per treatment group were sufficient [Cohen, 1988]. Taking 30% loss-to-follow-up into account, 100 patients per group was recruited at baseline.

The children were collected from their classroom by one of the participating health care workers who were not familiar with the sequence of group allocation of the children. Upon entrance, the children received a number which corresponded with a specific group number on a computerized random list that was in the possession of the dentist who performed the oral examination of the children.

Children in group 1 received full dental treatment of their primary dentition: all cavities that did not show signs of pulpal inflammation, as described earlier, or dentogenic infection, nor gave rise to any pain complaints were restored according to the Atraumatic Restorative Treatment (ART) approach [Frencken et al., 1996]. Teeth with deep carious lesions, where pulpal exposure was likely to be expected in case of excavation, were extracted. Group 2 did not receive any restorative care. Only carious primary teeth with pulpal involvement were extracted. Group 3 only received ART restorative care of cavities that did not show pulpal involvement while deep carious lesions were left untreated. Group 4 received neither restorative treatment nor extraction of any of their carious primary teeth. In all groups, cavities in permanent molars were restored according to the ART approach or extracted when caries had progressed into the dental pulp. When a child reported dental pain, the perpetrating tooth was extracted, irrespective the treatment group. At the end of the study all children were treated with extractions or ART restorations.

All dental treatments at baseline were performed by four Dutch dentists. At the time of the evaluations, dental treatments, according to the initially allocated group, were performed by other Dutch dentists. The examination of the children at baseline and at the follow-up sessions was performed by the same person, not participating in the dental treatments.

Evaluation

The children were evaluated at the start of the study, after six months, one year, two years, and three years. At each evaluation, the child’s oral health status was evaluated according to the same standards mentioned above. Caries increment was recorded and height and weight were measured. All children received dental treatment according to their treatment group protocol.

Statistical analysis

Statistical analyses were performed using SPSS for Windows, version 12.0.1. Kolmogorov-Smirnov (KS) tests were used to analyse the normality of the distributions of the different continuous parameters. All significant differences were detected at a 95% confidence level. Variables that showed a normal distribution were analysed using parametric tests (Independent samples t-tests, General Linear Model (GLM) for repeated measures). Variables that showed a non normal distribution were analysed using non parametric statistics (Spearman correlation, Wilcoxon Signed Rank Tests). Cross sectional analyses to detect a relationship between dental
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Caries and body proportions were performed at baseline and at all evaluation time points. Body growth was only evaluated on the long run, between baseline and 3y, rather than between all separate time points.

Results

Part I: Cross sectional analysis

The sample consisted of 380 children (mean age 6.1 years, ±0.5, range 5.1–7.1). The demographic characteristics are presented in table 1. At baseline, the mean total-dmfs was 14.0 (±10.1) and consisted of the decayed factor only because none of the children had received any form of dental treatment before their first visit. This variable showed a skewed distribution (KS, 2-sided p<0.001). The anthropometric data at baseline are summarized in table 1. Height, weight and BMI were normally distributed (KS, 2-sided p>0.05).

Table 1 Demographic characteristics and anthropometric measures at baseline

<table>
<thead>
<tr>
<th>Group</th>
<th>1 Full treatment</th>
<th>2 Extraction</th>
<th>3 ART</th>
<th>4 No curative treatment</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>All combined (n)</td>
<td>96</td>
<td>91</td>
<td>96</td>
<td>97</td>
<td>380</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n Male (%)</td>
<td>53 (55.2)</td>
<td>50 (54.9)</td>
<td>48 (50)</td>
<td>41 (42.3)</td>
<td>192 (48.6)</td>
</tr>
<tr>
<td>n Female (%)</td>
<td>43 (44.8)</td>
<td>41 (45.1)</td>
<td>48 (50)</td>
<td>56 (57.7)</td>
<td>188 (51.4)</td>
</tr>
<tr>
<td>Mean Age</td>
<td>6.11</td>
<td>6.15</td>
<td>6.07</td>
<td>6.11</td>
<td>6.09</td>
</tr>
<tr>
<td>(SD, range)</td>
<td>(0.51, 5.12-7.06)</td>
<td>(0.48, 5.12-7.05)</td>
<td>(0.45, 5.15-7.09)</td>
<td>(0.48, 5.11-7.05)</td>
<td>(0.48, 5.11-7.09)</td>
</tr>
<tr>
<td>Height</td>
<td>111.3</td>
<td>112.0</td>
<td>112.2</td>
<td>111.6</td>
<td>111.8</td>
</tr>
<tr>
<td>(SD, range)</td>
<td>(6.0, 92.8-127.0)</td>
<td>(5.5, 99.6-121.0)</td>
<td>(4.6, 100.3-124.0)</td>
<td>(5.5, 91.8-121.33)</td>
<td>(5.4, 91.8-127.0)</td>
</tr>
<tr>
<td>Weight</td>
<td>18.7</td>
<td>18.7</td>
<td>18.5</td>
<td>18.6</td>
<td>18.6</td>
</tr>
<tr>
<td>(SD, range)</td>
<td>(2.7, 13.4-28.0)</td>
<td>(2.2, 14.7-25.1)</td>
<td>(2.2, 14.1-23.7)</td>
<td>(2.2, 11.8-2.4)</td>
<td>(2.3, 11.8-28.0)</td>
</tr>
<tr>
<td>BMI</td>
<td>15.0</td>
<td>15.0</td>
<td>14.7</td>
<td>14.9</td>
<td>14.9</td>
</tr>
<tr>
<td>(SD, range)</td>
<td>(1.3, 12.3-21.7)</td>
<td>(1.2, 12.8-18.3)</td>
<td>(1.0, 12.4-17.5)</td>
<td>(0.9, 12.5-17.8)</td>
<td>(1.1, 12.3-21.7)</td>
</tr>
<tr>
<td>SDS&lt;sub&gt;H&lt;/sub&gt;</td>
<td>-1.8</td>
<td>-1.7</td>
<td>-1.5</td>
<td>-1.7</td>
<td>-1.7</td>
</tr>
<tr>
<td>(SD, range)</td>
<td>(1.0, -5.6-0.7)</td>
<td>(0.9, -3.6-0.3)</td>
<td>(0.8, -3.8-0.2)</td>
<td>(0.9, -4.4-0.6)</td>
<td>(0.9, -5.6-0.7)</td>
</tr>
<tr>
<td>SDS&lt;sub&gt;BMI&lt;/sub&gt;</td>
<td>-0.4</td>
<td>-0.5</td>
<td>-0.6</td>
<td>-0.5</td>
<td>-0.5</td>
</tr>
<tr>
<td>(SD, range)</td>
<td>(0.9, -2.7-2.7)</td>
<td>(0.8, -2.1-1.4)</td>
<td>(0.8, -2.7-1.1)</td>
<td>(0.6, -2.4-1.2)</td>
<td>(0.8, -2.7-2.7)</td>
</tr>
</tbody>
</table>

SD = Standard Deviation
SDS<sub>H</sub>, SDS<sub>BMI</sub> = Standard Deviation Score Height or BMI
A negative correlation was found between caries prevalence (total-dmfs) and SDS\textsubscript{H} at baseline (R=-0.13, p=0.01). This means that children with more decay were more negatively diverging, from the standard mean at their individual growth chart. At the different evaluation time-points during the study, length and weight measures appeared to show various correlations with the number of untreated dental carious surfaces (total-ds) and caries status (total-dmfs) of the children (Table 2). For BMI or SDS\textsubscript{BMI} no significant correlations were found. Independent samples t-tests could not prove any significant relation between dentogenic infections and body proportions.

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Height</th>
<th>SDSH</th>
<th>Weight</th>
<th>BMI</th>
<th>SDSBMI</th>
</tr>
</thead>
<tbody>
<tr>
<td>T0</td>
<td>380</td>
<td>n.s.</td>
<td>R = -0.13*</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>p = 0.014</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1</td>
<td>352</td>
<td>n.s.</td>
<td>R = -0.12*</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>p = 0.023</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>352</td>
<td>R = -0.14**</td>
<td>R = -0.11*</td>
<td>R = -0.12*</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>p = 0.008</td>
<td>p = 0.048</td>
<td>p = 0.024</td>
<td></td>
</tr>
<tr>
<td>T2</td>
<td>342</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>342</td>
<td>R = -0.11*</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T3</td>
<td>321</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>321</td>
<td>R = -0.13*</td>
<td>n.s.</td>
<td>R = -0.15**</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>p = 0.024</td>
<td>p = 0.009</td>
</tr>
<tr>
<td>T4</td>
<td>301</td>
<td>R = -0.13*</td>
<td>n.s.</td>
<td>R = -0.14*</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>p = 0.02</td>
<td>p = 0.02</td>
</tr>
<tr>
<td></td>
<td>301</td>
<td>R = -0.17**</td>
<td>n.s.</td>
<td>R = -0.18**</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>p = 0.003</td>
<td>p = 0.002</td>
</tr>
</tbody>
</table>

n.s. = not significant, ** = significant at 0.01, * = significant at 0.05

Part II: RCT

Study population

Details about the enrolment and allocation of the children are presented in the flowchart in the Appendix (page 145). At the enrolment, the caries free children were excluded. Moreover, 34 children did not receive the allocated intervention because they appeared to show a contributory medical history or because they had received dental treatment before. The remaining 380 children showed an equal distribution of males (192) and females (188) over the four treatment groups (X\textsuperscript{2}=4.21, df = 3, p=0.24) and no differences in mean age amongst the groups were observed (F\textsubscript{(3,376)}=0.43, p=0.73). The demographic characteristics of the sample are presented in table 2.
The children were all from Creole origin. According to the records of the Medical Mission, there were no differences with respect to economical status, care services, medical health burdens, nutritional habits or educational level between the two regions. Although all possible efforts were performed to trace the participating children, an increasing drop out was seen during the course of the study, though equally distributed among the different groups at each evaluation as proven by non significant Chi square tests. The main reasons for absence were illness, moving to another district, or work of the parents in the fields. Children that were absent at one evaluation could reappear on the next and were therefore not regarded as lost to follow-up. When a child had missed three or more evaluation visits, he or she was excluded from the study (25 children, 6.6%). At T4, 79 children were absent (20.8%). Therefore, the longitudinal analysis of body growth was performed on 301 children.

**Oral health, longitudinal analysis**

During the course of the study, all children showed caries activity and developed new dental decay as is shown by the increase in total-dmfs presented in figure 1. In this figure, means and Standard Errors are indicated. The caries increment was significant for children in group 3 where the total-dmfs increased from 11.7 (±9.0) to 16.3 (±10.1) (Wilcoxon Signed Rank test (WSR), \(p_3<0.001\)) and in group 4 where the total-dmfs increased from 15.4 (±10.7) to 18.4 (±12.4) (WSR, \(p_4=0.035\)). Attention should be paid to the overall drop that was observed between 2 and 3 yrs and that was most probably caused by exfoliation. Regarding the dentogenic infections, WSR tests showed that during the course of the study, the mean number of carious teeth with suspected pulp involvement decreased significantly in group 1 and 2 (\(p<0.001\)). An increase was seen in group 4 (\(p_4=0.002\)). Mc Nemar tests showed that during the course of the study, the number of children that had one or more AbFi decreased in groups 1 and 2 (\(p_{(group1)}=0.021, p_{(group2)}<0.001\)) whereas an increase was observed in group 4 (\(p=0.031\)).

![Figure 1](image-url)  
**Figure 1** Caries experience (dmfs-total) during the course of the study. Means and Standard Errors.
**Body growth, longitudinal analysis**

Data of body growth during time are presented in figure 2. During the course of the study, all children showed a significant increase in height, weight and BMI (GLM, all p’s<0.001). Girls showed a significantly larger increase compared to boys regarding all three growth parameters (GLM, all p<0.001). All children showed a normal individual growth pattern and no significant changes regarding the SDS-values for heights were observed between baseline and 3yrs. No significant differences in growth patterns between the four treatment groups were observed.

**Figure 2.** Body growth between baseline and 3 yrs. Parameters have different dimensions: height=cm (from 100 cm), SDSH=m, weight=kg, BMI=kg²/cm

**Discussion**

In this study, a negative correlation was observed between body proportions and the presence of dental caries. In other words, in this particular Surinam Bush Creole population with untreated dental decay, shorter children and/or children that show lower weight, tended to have more decay or vice versa.

This finding is in line with earlier studies [Elice and Fields, 1990; Acs et al., 1992; Alvarez et al., 1993; Ayhan et al., 1996; Acs et al., 1998; Acs et al., 1999; Low et al., 1999; Nicolau et al., 2005]. However, the results can hardly be compared since these studies were conducted retrospectively, concerned case reports, concerned a younger age group or children from heterogeneous backgrounds, or consisted of children with diagnosed non-organic growth retardation. The current study includes children with homogeneous demographic characteristics such as age, race, nutritional status, habitat, economic background and both medical and dental history. As such, this study is considered unique and incomparable to studies that have been undertaken upon this subject so far.
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The correlation between weight and dental caries could not be established at all time points in the current study. Children that develop dental decay often exhibit cariogenic dietary habits that are highly caloric and inductive of overweight. When these carious lesions progress, the child might develop dental pain that can lead to a refusal of food, provoke lower weight gain or retarded growth. These two patterns may occur simultaneously in different children of one population with the consequence that an overall effect is levelled out. This same argument might explain the absence of a correlation between BMI and dental caries, whereas within BMI, an internationally accepted measure for growth, weight is represented [WHO, 1997; Fredriks et al., 2000; van Buuren, 2004; van Dommelen et al., 2004].

Considering the longitudinal analyses, it was observed that, with regard to the stable standard deviation scores of height and BMI during the course of the study, all children showed a normal growth pattern in accordance with their own individual growth curves. Although the curves of children with higher caries rates were in lower SDS ranges, they all showed comparable patterns and it could thus be concluded that none of the dental intervention strategies had an affect on the body growth of the children in the course of 3 years. This finding is contradictory to those of other studies where a catch-up growth was observed after dental rehabilitation in children with rampant caries and diagnosed, non organic growth retardation [Elice and Fields, 1990; Acs et al., 1998; Acs et al., 1999]. However, it is not known whether the children in the current study were retarded in their body growth at baseline, since no reference growth charts are available for Surinamese children or for this Bush Creole population in particular.

In the current study, girls showed more growth compared to boys. It has been documented that girls show earlier pubertal growth acceleration than boys [van den Brande et al., 1998]. Creole girls might experience their menarche at an earlier age than Caucasian girls and the early onset of their growth acceleration might thus be visible in the results. At baseline, an age of 6 years was set as an inclusion criterion with regard to the cognitive level of the child to cooperate with the dental treatment. Though it seems to be a rather short period of time to evaluate body growth, three years was chosen as a cut-off in order to minimize the risk for bias from individual variation, both in pubertal onset and in natural tooth exfoliation [Moslemi, 2004].

Dental caries is classified as an infectious disease and it has been well established that body growth is negatively influenced by infectious diseases [Mata et al., 1972; de Beer, 2001; Bhutta, 2006]. With the invasive treatment of dental caries, the symptoms of this infectious disease might be contended, but the disease itself is not eradicated. Apparently, all children remained caries active because they all developed new dental decay during the course of the study. It is therefore suggested that caries activity rather than caries experience may be a negative predictor for body growth in children. This would involve a more prominent role for primary preventive measures within any oral health care program.

However, body growth is influenced by numerous factors, e.g. regular occurring other infectious diseases, such as malaria and worms and malnutrition [van den Brande et al., 1998; Uauy, 2007; Walker et al., 2007; Uauy et al., 2008]. Based on the results of the current study it is therefore
not possible to draw definite conclusions upon an exclusive cause and effect relationship between neither dental decay or caries activity and body growth. Probably, immunity could serve as a possible link [Uauy, 2007; Uauy et al., 2008]. Future studies should include systemic infectious parameters that can possibly identify more specifically the systemic effects of dental decay and trace responsible underlying factors or mechanisms. These studies should also include children with higher caries levels. The children from the current study showed a moderate caries prevalence according to the severity criteria of the WHO [Marthaler et al., 1990; van Gemert-Schriks et al, 2008b]. It could be hypothesized that in children with more dental decay, relations between caries or dental treatment and body growth appear even more evident.

In this study, a negative correlation was found between individual body proportions and dental caries prevalence in a caries active, prepubertal Surinam child population. No significant influence of dental treatment on the body growth of these children could be established. Based on these results it might be suggested that caries activity is a negative predictor for body growth in children. Future studies should focus on child populations with more caries and include systemic parameters for infection before definite conclusions upon a true relation between dental caries and systemic health can be drawn.

Acknowledgments
This study was supported by the Netherlands Institute of Dental Sciences (IOT), the Netherlands Foundation for the advancement of Tropical Research (WOTRO), the Foundation “De Drie Lichten” in The Netherlands and 3M-ESPE. The authors would like to thank the director of the Surinam Ministry of Health and the Medical Mission of Suriname for their intensive and enthusiastic cooperation, the provision of all facilities and their inspiring input.
References


Dental caries related to plasma IgG and $\alpha_1$-acid glycoprotein

J.J. de Soet
M.C.M. Schriks
E. Kratz
D. C. W. Poland
W. van Dijk
W.E. van Amerongen

Caries Res 2003; 37: 79-84
Abstract

This study was aimed at determining whether dental caries is associated with induction of the systemic immune system or cytokine response.

Materials and methods:
For this purpose, 85 children from Den Pasar, Bali, Indonesia, aged 6–7 years, were examined clinically and blood plasma was obtained via finger puncture. The concentrations of the acute-phase protein alpha(1)-acid glycoprotein (AGP), total IgG and the specific IgG and IgM immunoglobulins against Streptococcus mutans were determined. Immunoelectrophoresis was used for the determination of the AGP concentration and ELISA for IgG and IgM detection.

Results:
The mean dmft of the whole group was 8.8 (±2.9), the mean number of infected pulps was 3.9 (±2.2) and the mean number of abscesses was 0.5 (±0.8). The plasma concentration of AGP ranged between 0.13 and 1.6 mg/ml serum (mean 0.86 ±0.26 mg/ml). Stepwise regression analysis revealed that the concentration of IgG against S. mutans (log-transformed) was significantly correlated with dmft (adjusted $r^2 = 0.083$, standardized β coefficient=0.31, p=0.008). When the concentration AGP was included in the model the correlation improved significantly (for IgG: adjusted $r^2=0.157$, standardised β coefficient=0.36, p=0.002; for AGP: β coefficient=–0.30, p=0.009).

Conclusions:
The results suggest a relationship between caries and systemic parameters of inflammation. On the basis of this, severe caries might have consequences on the general health of the subject.
Introduction

Dental caries in young children can be a severe problem, especially in less-developed countries where dental health care is scarce. Also, dental education with respect to oral hygiene and use of dietary sugars is often completely absent. Indeed, in countries such as Thailand, Indonesia, and Surinam, the dmft of young children is high [Holm, 1990; Kreulen et al., 1997b; Sekiguchi and Machida, 1999]. Treatment is most often restricted to extraction of teeth in cases of severe tooth-pain. Beside the fact that this treatment is not pleasant for the patient, extraction of teeth might cause other problems at a later age, such as orthodontic problems. The current standard in the western societies is that infected teeth should be either restored or extracted, with the aim of preventing progression of the caries lesion either within the infected tooth, or within the adjacent teeth. Besides the effect of carious tissue on other teeth, the infection may affect the general health of the child. Such an effect has been described earlier. Children with rampant caries have a retarded growth and retarded weight gain when not treated. When the caries is treated, this retardation is lost, possibly due to the fact that the children are able to eat properly again [Aychan et al., 1996; Acs et al., 1998, 1999]. A higher level of local acute-phase proteins was found in inflamed pulps than in healthy pulps [Proctor et al., 1991]. It is possible that severe caries also interferes with systemic factors, thereby negatively influencing the general health. Endocarditis is only one example related to oral health.

The present study was aimed at investigating whether systemic factors can be found which correlate with dental caries in caries-active children. We determined the concentrations of immunoglobulin IgG, total and specific for Streptococcus mutans. Antibody levels against S. mutans will normally not correlate to general health. However, in severe caries patients, antibody concentrations against S. mutans are increased and therefore indicative for a systemic immune response to the infection. We wondered whether this infection might affect the general health. For this, we tested another systemic factor, the acute-phase protein alpha(1)-acid glycoprotein (AGP). AGP is elevated in patients with severe acute and chronic inflammations [de Graaf et al., 1994; Eap and Baumann, 1993; Havenaar et al., 1997]. Increased levels of AGP are a negative predictor in the clearance of parasites in visceral leishmaniasis, a disease often found in tropical countries [Wasunna et al., 1995]. Elevated AGP levels in situations with a local infection such as dental caries may indicate that this infection can influence the general health when the inflammation is not treated. Chronic inflammatory conditions will continuously stimulate the liver to synthesize increased amounts of plasma acute-phase proteins, one of which is AGP [de Graaf et al., 1994; Eap and Baumann, 1993; Havenaar et al., 1997; Koj et al., 1993]. Under acute inflammatory conditions such type of stimulation is considered to assist in damping down local inflammatory reactions. However, under chronic inflammatory conditions the hepatic reaction instead appears to sustain inflammation. In
this study, AGP was chosen as a marker for a systemic inflammatory reaction, not only because it is one of the major acute-phase proteins, but also because it is an important drug-binding protein [Israili and Dayton, 2001]. The latter property has been shown to decrease the free plasma concentration of a great number of drugs and consequently their activity [Israili and Dayton, 2001].

Materials and methods

Subjects
The subjects in this study were 6-year-old children from the first 2 groups of 3 different primary schools in Den Pasar, Bali, Indonesia. The schools were all located around the University of Den Pasar. In order to be included in the study, the children had to be present at school at the time of measurement and they had to provide a letter of informed consent, signed by their parents. Ethical approval of the study was obtained from the University of Den Pasar, Indonesia.

Clinical procedures
Two dentists examined the children. The examination was performed in the classroom, using a headlamp, a mirror and a probe. The child was lying on a table. dmft was determined by using the WHO standards [WHO, 1997]. Caries in both primary and secondary teeth was determined, but in the present study, only dmft was taken into account. Caries lesions that had progressed to the extent that pulpal exposure was to be expected were recorded as ‘pulpal involvement present’. Furthermore, the presence of root remnants, abscesses and fistulae was recorded. From all subjects approximately 75µl venous blood was isolated by finger puncture and was obtained in heparincoated capillary tubes. After standing for 4h at room temperature, the blood samples were centrifuged and the resulting plasma was collected and stored at –15°C and finally transported frozen to Amsterdam. After the clinical procedures, the detailed dental status and treatment plans were handed over to the dental school in Den Pasar, thereby initiating treatment of the children by the local dentists.

Determination IgG and IgM specific for S. mutans
The ELISA was essentially performed as described previously [de Soet et al., 1987]. Briefly, a bacterial cell suspension was made of overnight-grown S. mutans cells (HG 982), diluted in coating mixture (6.75ml 0.2 M NaCO₃ and 12ml 0.2 M NaHCO₃ in 100ml water) to an A650 of 0.1. This suspension was incubated in 96-well microtiter plates at 4°C for 16h. Free binding sites were blocked by incubation with 1% bovine serum albumin in PBST (phosphate-buffered saline supplemented with 0.05% Tween 80) at room temperature for 30min. In between the incubations, the plates were washed three times with PBST. Plasma (2µl) diluted in PBST was added. The
plates were incubated for 2h at room temperature. After washing, 100 μl peroxidase-conjugated goat anti-human immunoglobulin IgG, HRP labelled (American Qualex, La Mirada, Calif., USA: 1:1,000 diluted in PBST supplemented with 1:200 normal goat serum) was added and incubated for 2h at room temperature. Peroxidase activity was measured by adding 100μl staining buffer [15ml Na2HPO4 (4.5g/100ml water), 300 μl TMB stock (25 mM tetramethylbenzidine (Sigma Chemical Co, St. Louis, Mo., USA), 87.3mg TMB.2 HCl in 10ml DMSO) with 60μl H2O2 (30%) in 15 ml of citric acid buffer (1.55g/100 ml water)]. The reaction was stopped after 20 min by the addition of 50μl H2SO4 (10%) followed by measuring the A450 absorbance of each well using a MR 7000 Micro plate reader (Dynatech Torrance, Calif., USA).

The determination of IgM specific for S. mutans was performed similarly, but by using peroxidase-conjugated goat anti-human immunoglobulin IgM, HRP labelled (American Qualex, La Mirada, Calif., USA: 1:1000 diluted in PBST). A batch of pooled human serum was used as a reference standard, which in the case of the negative control was absorbed with S. mutans prior to analysis.

The titer was defined as the dilution of the standard or samples where an A450 value was reached that was twice as high as the value of the negative control. The specificity of the determination of the concentration of antibodies to S. mutans was checked by absorption of the reference serum with S. mutans cells. This resulted in a complete loss of ELISA signal after 3 absorption steps, which indicates a specific test. The ELISA for the determination of the total IgG content was performed essentially as described above, with an affinity-purified non-conjugated goat anti-human IgG-Fc (KPL, Guildford, UK: 1:1,000 diluted in PBS) instead of the incubation with bacterial cells. All other incubations were identical.

AGP determination

The concentration of AGP was determined by rocket immunoelectrophoresis using polyclonal goat anti-human AGP antibodies (kindly provided by Dr. T. Stefaniak; Department of Veterinary Prevention and Immunology, Wrocław Agriculture Academy) for precipitation, as described by Laurell [1966]. Electrophoresis was carried out in 1% agarose M (Bio-Rad, Richmond, Calif., USA) in veronal-buffered saline (pH 8.6). Human Serum Protein Calibrator (Dakopats, Glostrup, Denmark), consisting of pooled human sera from healthy blood donors, was used as a standard for the determination of the AGP concentration.

Statistical analyses

Statistical analysis was performed using SPSS 10.0.7. The IgG data were log-transformed, and for some graphical representations categorized into 16 groups. Spearman correlations on the raw data as well as on categorized data were calculated. To test the relationship between 3 parameters, a stepwise regression analysis was performed to correlate the dmft value with IgG and AGP.
Results

Eighty-five children of 6–7 years were examined; 39 were boys and 46 were girls. No child was caries free and the mean dmft was high (8.8; Table 1). It is remarkable that most children had infected pulps, i.e. cavities to such an extent that pulpal exposure was visible or at least inevitably to be expected during excavation. Children with a high dmft had significantly more teeth with pulpal involvement (r=0.604, p<0.001). These children also had abscesses more often (r=0.356, p=0.001).

Table 1 Clinical data of 85 6-year-old children in Bali

<table>
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<tr>
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<th>Mean</th>
<th>SD</th>
<th>Range</th>
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<td>5.7–7.0</td>
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<td>2.9</td>
<td>1–17</td>
</tr>
<tr>
<td>Number of teeth with infected pulpas</td>
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<td>2.2</td>
<td>0–12</td>
</tr>
<tr>
<td>Number of residual roots</td>
<td>0.9</td>
<td>1.1</td>
<td>0–5</td>
</tr>
<tr>
<td>Number of abscesses</td>
<td>0.5</td>
<td>0.8</td>
<td>0–3</td>
</tr>
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</table>

The distributions of the concentrations of AGP and IgG specific for S. mutans are shown in figure 1. These data show a normal distribution, but with a relatively wide range for AGP (mean 0.86 ±0.26 mg/ml), suggesting that both healthy and less-healthy children were present in the group. It was concluded that all data were normally distributed. The concentration of AGP was significantly negatively correlated with dmft (r=−0.25 p=0.036, Spearman; Fig. 2). The IgG specific for S. mutans was correlated with both dmft (r=0.31, p=0.008, Spearman) and AGP (r=0.26, p=0.04, Spearman). Because of the normal distribution of the data, a stepwise regression analysis could be performed on the dmft, IgG and AGP. This analysis revealed that dmft was significantly correlated with the log-transformed concentration of IgG against S. mutans (adjusted $r^2=0.083$, standardized β coefficient=0.31, p=0.008). When the concentration of AGP was included in the model, the prediction improved significantly (for IgG: adjusted $r^2=0.157$, standardized β coefficient=0.36, p=0.002; for AGP: β coefficient=−0.30, p=0.009). Other factors, such as total IgG and IgM against S. mutans were not significantly correlated with dmft, AGP or IgG against S. mutans.

Discussion

It has been found that cytokine production may be influenced by the caries process, especially due to S. mutans and Lactobacillus casei infection [Hahn and Falkler,1992; Hahn et al., 2000; Plitnick et al., 1998]. In the present study, no bacterial counts were performed, since we expected that
Dental caries related to plasma IgG and α1-acid glycoprotein

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Figure 1 The frequency distributions of dmft and plasma concentrations of AGP and IgG against S. mutans. Analyses of the data indicated normal distributions.

Figure 2 Mutual correlations between dmft, the concentration of AGP and the concentration of IgG against S. mutans in the plasma of the patients. The bars indicate the means with standard deviation.

a Correlation of dmft with log-transformed concentrations IgG to S. mutans (r=0.31, p=0.003).

b Correlation of dmft with AGP concentrations (r=−0.25, p=0.04).

c Correlation of log-transformed concentrations of IgG to S. mutans with AGP concentration (r= 0.26, p=0.04).

For graphical presentation, the IgG concentration on the x-axis is categorized.
in all children, a high number of salivary lactobacilli and \textit{S. mutans} could be detected [Kreulen et al., 1997a]. Although data are not available for Indonesia, a high caries incidence is usually associated with high salivary mutans streptococci counts. Moreover, the infrastructural problems in Bali did not allow us to perform bacterial cultures on a laboratory level.

The numbers of caries lesions found in the present study are similar to what has been reported before. For Indonesia, Koloway and Kailis [1992] reported a caries prevalence of more than 90% in pre-school children and a mean dmft of 8.0. The high percentage of untreated caries may be due to the shortage of dentists in Indonesia: 1 dentist/20,300 people [Sekiguchi and Machida, 1999].

A wide distribution in concentration of IgG to \textit{S. mutans} was found. The log-transformed concentrations correlated significantly with dmft, indicating that the infection by \textit{S. mutans} affects the immune system. Similar results were reported earlier [Challacombe and Lehner, 1976; Huis in ’t Veld et al., 1979; Parkash et al., 1994]. The concentration of the acute-phase protein AGP was more widely distributed than expected for a healthy population [Koj et al., 1993]. The results indicate a relationship between dmft, AGP and antibodies specific for \textit{S. mutans}. Moreover, dmft and IgG specific for \textit{S. mutans} were positively correlated, while dmft and AGP were negatively correlated. Similar results were found in a study on infection, length growth and acute phase proteins, such as AGP. It was reported that AGP is negatively correlated with retardation in growth [Hautvast et al., 2000]. Our findings of a negative correlation coefficient in only one parameter can be explained by assuming two counteracting mechanisms. Some data are available showing that different phases of a caries process are associated with a different cytokine response, which has possibly to do with the difference between infections caused by \textit{S. mutans} and lactobacilli. In both cases, a different cytokine response has been found [Plitnick et al., 1998; Hahn et al., 2000].

In the present study, we could not find any definite proof for such a mechanism, possibly because we were not able to investigate the children before and after restorative treatment. Moreover, the group was possibly too small to prove this two-phase system.

In this study, we showed that dental caries has systemic effects on the production of IgG, but also on induction of acute-phase proteins in the liver, such as AGP. These results are supported by the findings of others. Hahn and co-workers suggested that the presence of antibodies against cariogenic bacteria might be protective against invasion of these bacteria during the caries process [Hahn and Falkler, 1992]. Furthermore, it was reported that when AGP levels increase, infections might take a longer time to heal [Wasunna et al., 1995]. Therefore, it is suggested that severe dental caries might influence the general health of the affected child.

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References


Host and microbiological factors related to dental caries development

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Abstract

Studies on dental caries suggest that severe caries may induce a systemic immune response that especially occurs when caries progresses into pulpal inflammation and results in abscess or fistulae formation (AFF). We hypothesised that severe dental caries will affect the general health of children.

Materials and methods:
As parameters to monitor general health the acute phase proteins AGP, CRP and the cytokine neopterin were chosen. Also a polymorphism in the bacterial ligand CD14 (-260) was studied to investigate a relationship between genotypical sensitivity for bacterial infections and AFF. Surinam children aged 6 years were recruited and enrolled into a dental care scheme, randomly assigned to 4 groups with different treatment strategies, and monitored longitudinally.

Results:
348 children were included in the present study. Blood and saliva samples were taken at baseline and 1 year, and concentrations of serum AGP, CRP, neopterin, salivary Streptococcus mutans and CD14-260 C>T polymorphism were determined. There was no significant association between different treatment strategies and the serum parameters. Binary logistic regression analyses revealed a significant association between AFF as outcome variable and the CD14 genotype, the concentrations of CRP and of neopterin as factors (p<0.05). A significant negative association was found between the CD14-260 TT and AFF (p=0.035, OR=3.3) for the whole population. For children who had 4 or more carious lesions at baseline, the significance increased (p=0.005, OR=4.8) suggesting that the CD14-260 TT genotype was protective for AFF as a consequence of dental caries.

Conclusions:
General health is not significantly affected by dental caries treatment in Creole children. Children who have genotype CD14-260 TT are genetically protected in relation to formation of abscesses or fistulae as a consequence of severe dental caries.
Introduction

Dental caries is a multifactorial disease in which bacteria play an essential role [Beighton, 2005]. Among the large number of bacterial species present in dental plaque, Actinomyces spp., Streptococcus mutans and lactobacilli have been positively associated with dental caries [Corby et al., 2005].

Recently, the question whether severe dental decay bears consequences for the general health has been raised. It has been suggested that tooth decay in the primary dentition may lead to growth retardation which may be explained by reduced food intake due to rampant caries [Acs and Ng, 2002; Ayhan et al., 1996; Thomas and Primosch, 2002]. An association between the acute phase protein alpha(1)-acid glycoprotein (AGP) and the number of decayed, missing and filled teeth (dmft) in young Indonesian children has been reported [de Soet et al., 2003]. This observation suggests that severe dental caries may induce a systemic immune response that may especially occur when caries progresses into pulpal inflammation and results in abscess or fistulae formation [Duggal et al., 2002; Skogedal and Tronstad, 1977]. This finding raises the question whether other acute phase proteins or infection related serum factors, such as C-reactive protein and neopterin, can be found in increased concentrations in subjects with severe dental caries. The rationale to include neopterin is that this cytokine is an indicator for cell-mediated immune activation. It is released by macrophages and monocytes and found in increased concentration in viral infections and systemic inflammatory diseases [Cesur, 2005; Buchwald et al., 1997; Andert and Muller, 1995; Shaw, 1991]. In this context neopterin can be used as a marker to monitor the general health. But also the contribution of the host itself in caries development should be taken into account.

Dental caries progression and severity in twin studies have been linked to genetic traits [Bretz et al., 2005]. In twin studies, a genetic component in sugar preference has been proposed to play a role in caries susceptibility [Bretz et al., 2006]. In experiments with mice it has been shown that chromosomal loci, possibly correlated with salivary composition and immunity, are associated with caries susceptibility [Culp et al., 2005; Nariyama et al., 2004].

It has been reported that the response to Streptococcus mutans is a Th1 response, resulting in elevated concentrations of IFN-gamma, IL10 and activation of CD8(+) T-cells [Hahn et al., 2004]. In pulpal lesions, a mixed Th1/Th2 response has been found [Kim and Lim, 2002]. Gene-expression studies have shown that a range of inflammatory factors are up-regulated during infection of the pulp due to caries [Hahn and Liewehr, 2007c]. These cytokines may be responsible for pulpal reaction to the infection which may lead to abscess or fistulae formation. Since in severe caries, a Th2 response is eminent, it is to be expected that mediators of the Th2 response determine the immune-reaction [Adachi et al., 2007; Hahn and Liewehr, 2007a; Hahn and Liewehr, 2007b; Zehnder et al., 2003]. The molecule CD14 is an immune factor that is responsible for modulating Th1/Th2 responses [Baldini et al., 2002; Kedda et al., 2005]. These
immune factors play an essential role in the etiology of chronic multifactorial diseases such as Crohn's disease and periodontitis [Balfour, 2007; de Sa et al., 2007; Pietruska et al., 2006; Tetley, 2005]. CD14 is a co-receptor for Toll like receptors and binds bacterial cell wall components like lipopolysaccharide (LPS) from Gram negative bacteria lipoteichoic acid (LTA) and peptidoglycan (PGN) from Gram positive bacteria [Cuzzola et al., 2000; Flo et al., 2000]. The CD14:LTA and CD14:PGN complexes can bind to Toll-like receptor 2 on host cells, which leads to NF-kappa beta pathway activation resulting in Tumor Necrosis Factor-alpha and Interleukin-1 production. Different gene polymorphisms have been reported for CD14 including a polymorphism at -260 in the promoter region of the gene. This polymorphism involves replacement of a cytosine by a thymidine, resulting in transcription up-regulation of the gene. It has been found that CD14-260:T heterozygotes (CT) and homozygotes (TT) produce more cell-bound and soluble CD14 [Amar et al., 2004; LeVan et al., 2006; Shimada et al., 2004]. The TT genotype has been found more frequently in severe periodontitis [Laine et al., 2005] and in Helicobacter pylori-related gastritis [Zhao et al., 2007].

Given the above mentioned systemic and genetic involvements in chronic diseases, such as dental caries, the hypothesis of this study was that caries treatment improves general health which will result in reduced levels of acute phase proteins CRP and AGP which in turn influences levels of serum neopterin. Furthermore, it was hypothesised that individuals with the T-allele of the CD14-260 gene are more sensitive to abscesses or fistulae formation (AFF) as a result of severe caries.

Materials and methods

Experimental design
The present study was carried out in the interior of Surinam between 2002 and 2005. The study population consisted initially of 490 primary school children aged 6 years, who were randomly assigned into 4 treatment groups. A power analyses showed that 69 children per group were needed to determine a significant clinical effect [van Gemert-Schriks et al., 2008]. Based on an earlier study on AGP in Indonesian children this group size is large enough to detect differences in acute phase proteins when applicable [de Soet et al., 2003]. The participating schools were selected from the database of the Medical Mission. Children participated in the study when they 1) were 6 years of age at the start of the study and 2) did not show a medical history (heart diseases, diabetes, hepatitis or other serious systemic chronic diseases) according to the database of the Medical Mission. Ethical clearance was obtained from the director of the Surinam Ministry of Health. The parents had to approve participation of their child by a signed letter of consent. Oral examination was carried out by one investigator, calibrated with a gold standard (kappa value 0.89, [van Gemert-Schriks et al., 2007]). Caries was recorded according to the criteria of
the WHO [World Health Organization, 1987]. The prescribed decayed, missing and filled (DMF)-
tooth (T) index for caries prevalence was used for the primary and secondary dentition. A tooth
was considered ‘sound’ if it showed no clinical evidence of treated or untreated dentine caries
and ‘decayed’ if any lesion in a pit or fissure or on a smooth tooth surface, had a detectable
softened floor, undermined enamel or softened wall. A tooth was considered present in the
mouth when any part of it was visible or could be touched with the tip of the dental probe
without unduly displacing soft tissue. If a secondary and a primary tooth occupied the same
tooth space, the status of the permanent tooth was recorded. Abscess and/or fistula formation
(AFF) was recorded as the number of abscesses or fistulae in the whole mouth due to caries
activity.

During the first visit, children received different treatment as described by van Gemert-Schriks
et al. [2008]. The children were evaluated after 6 months, 1, 2 and 3 years. At each visit, oral
parameters (caries experience and signs of dentogenic infection) were recorded and dental
treatment was performed upon indication. Furthermore, at baseline and at the evaluation visits,
children’s body length and weight was determined and the body mass index was calculated (BMI
Quetelet index is weight/length²).

**Treatment**

The children were allocated into 5 treatment groups [van Gemert-Schriks et al., 2008]. Briefly, a
control group (Group 1) consisted of all children that where clinically caries free at the start of
the study (2002). Children in group 2 received full dental treatment of their primary dentition
including restoration of small carious lesions according to the Atraumatic Restorative Treatment
(ART) method [Frencken et al., 1996]. Extraction was performed for teeth with deep carious
lesions in which pulp exposure was likely or where visible signs of dentogenic infection (pain
complaints or abscess or fistulae formation) were present. In group 3 the carious teeth with
pulpal exposure were extracted. Children in this group did not receive any restorative care.
Children in Group 4 received ART restorative care of cavities that did not show pulpal involvement
while deep carious lesions were left untreated. Children in Group 5 received neither restorative
treatment nor extraction of carious primary teeth. In all groups, cavities in permanent molars
were restored according to the ART approach or extracted when caries had progressed into the
dental pulp. When a child reported dental pain, the tooth concerned was treated by extraction,
irrespective of the treatment group. At the end of the study, all decayed teeth were treated.

**Isolation of serum**

Blood was obtained at baseline and 1 year after treatment by a finger puncture. Blood was
collected in a capillary tube, coated with heparin and cells were separated from serum by
gravitation for 2 h. The tubes were kept frozen (-20°C) and transported on dry ice to Amsterdam,
The Netherlands. The concentration of AGP was determined as described previously [de Soet
et al., 2003]. The concentration of CRP was determined by an immunometric assay using the
Immulyte system of Diagnostic Products Corporation (Holliston, MA, USA). The concentration of neopterin was determined using a commercial kit (IBL, Mediphos, Renkum, The Netherlands), according to the manufacturers’ instructions.

**CD14 -260 C>T Genotyping**

To determine the -260C>T genotype of the CD14 gene (rs 2569190), a few drops of blood were collected onto a Whatman FTA card (Fisher Emergo, Landsmeer, The Netherlands). In Amsterdam, the DNA was eluted from the cards and the CD14-260 genotype was determined using a specific RFLP-PCR [Laine et al., 2005; Ouburg et al., 2005]. Briefly, specific primers (5’CCTGCAGAATCCTTCCTGTT 3’ and 5’TCACCTCCCCACCTCTTT 3’) for the -260 promoter region of the CD14 gene were added to a PCR-mix. The PCR was performed using a PE9700 PCR-cycler (Applied Biosystems, Foster City, CA, USA) with the following conditions: 5 min 95°C, directly followed by 35 cycles of [30 sc 95°C, 30 sc 59°C, 1 min 72°C] and 7 min 72°C. The amplimers were enzymically digested by HaeIII, resulting in a 83 bp amplimer for CD14-260:C and a 106 bp amplimer for CD14-260:T. The C.C, C.T and T.T genotypes were made visible by standard 2% agarose gel-electrophoresis.

**Detection of salivary Streptococcus mutans**

Saliva samples were collected at baseline by Sarstedt-Salivette (Sarstedt, NL) through active chewing on polyester rolls for 1 min. Rolls were transported at -20°C to Paramaribo and on dry ice to Amsterdam where saliva was isolated by centrifugation. DNA was extracted with a MagnaPure (Roche Molecular Diagnostics, Almere, The Netherlands) using a standard protocol with DNA Isolation Kit III [Boutaga et al., 2006]. The concentration of salivary S. mutans cells was determined by species specific real-time PCR for glucosyl transferase and for lactate dehydrogenase, using PCR primers and probes listed in Table 1. The probes were labelled with FAM as reporter and TAMRA as quencher.

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<th>Gene</th>
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<td>Forward</td>
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<td></td>
<td>Reverse</td>
<td>5’ gcctacacacactgaattga 3’</td>
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<td></td>
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<td></td>
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<tr>
<td></td>
<td>Probe</td>
<td>5’ TGATAACAAACAGGTACGCATCCACAG 3’</td>
</tr>
</tbody>
</table>

The PCR was performed as described earlier [Boutaga et al., 2005]. Briefly, RT-PCR amplification was performed in a total reaction mixture volume of 25 μl. The reaction mixtures contained 12.5 μl of 2 × TaqMan universal PCR master mix (PCR buffer, dNTP’s, AmpliTaq Gold, reference signal
Host and microbiological factors related to dental caries development

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[6-carboxy-X-rhodamine], uracil N-glycosylase, MgCl$_2$; Applied Biosystems, Foster City, CA, USA), 300–900 nM of the specific primer, 50–100 nM specific probe and 5 μl of purified DNA from plaque samples. The samples were subjected to an initial amplification cycle of 50°C for 2 min. and 95°C for 10 min, followed by 45 cycles at 95°C for 15 s and 60°C for 1 min using an ABI 7000 TaqMan PCR system and its Sequence Detection System software (Applied Biosystems, Foster City, CA, USA).

For quantification, the results from salivary samples were related to standard curve constructed with pure culture dilutions of *S. mutans*.

**Statistical analyses**

Bacterial counts (CFU/ml saliva) were converted to log$_{10}$. The presence of AFF was dichotomised for the presence or absence of AFF during the 3 years of the study. Differences between groups and between different treatment periods were analysed using an ANOVA with Bonferroni correction. For data that were not normally distributed, as shown by a Kolmogorov-Smirnov test, a Kruskal-Wallis test or Wilcoxon signed-rank test for pairs was used.

For logistic regression analysis, the continuous data sets for serum proteins were dichotomised, based on the median: higher then the median was noted as 1 and lower was 0. Caries experience was calculated as dmft + DMFT at baseline and at the end of the study (3 years) and dichotomised with a cut-off of 4.

The *S. mutans* counts were dichotomised with a cut-off of log$_{10}$(CFU/ml saliva) of 5.5. These data were used for further analysis.

For associations between the different serum proteins, *S. mutans* counts, *CD14* genotype and clinical data, logistic regression analyses were used by SPSSv15. To explore associations between AFF and the *CD14* genotype, serum proteins, a Fisher exact test was used. Results for Fisher exact tests are presented as p value, Odds Ratio (OR) and 95% confidence interval (CI). The correlation between caries experience and AFF was tested using the Pearson correlation coefficient.

In all tests, the level of significance was set at P < 0.05

**Results**

The patient population in which all parameters were tested was 348. 142 Children were excluded because they could not attend one or more visits of the dental team after the baseline measurement, due to illness, moving from the village or any other absence from school.

The salivary concentration of *S. mutans* varied between $10^4$ and $10^6$ cells/ml saliva, with no significant differences between the groups (Table 2). Caries experience was significantly lower in the control group than in the other groups (p<0.001), both at baseline and after 3 years (Table 2).

In the ART group, the total caries experience increased significantly during the 3 years (p<0.001;
Wilcoxon). The association between type of treatment and clinical parameters is published elsewhere [van Gemert-Schriks et al., 2008]. In 120 patients, AFF was observed as a result of severe caries including pulpal involvement. Caries experience at the different evaluations was significantly correlated with AFF, i.e. children with high total caries experience scores showed AFF more often (Pearson r = 0.39; p < 0.006). Only the caries-free controls and the full treatment group showed significantly lower AFF scores than the non-treatment group (p<0.002; OR 27.5, CI 6.3 to 121 and OR 3.2, CI 1.6 to 6.3 respectively; Table 2).

### Table 2
The numbers, gender, number of salivary S. mutans [log10(cfu/ml)], caries experience (dmft + DMFT) at baseline and 3 years, and the cumulative number of children with abscess and/or fistula formation (AFF) in the five different treatment groups. Means with SD in parenthesis.

<table>
<thead>
<tr>
<th>Time (years)</th>
<th>control</th>
<th>Full treatment only</th>
<th>Extraction only</th>
<th>ART filling only</th>
<th>no treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>53</td>
<td>75</td>
<td>66</td>
<td>77</td>
<td>77</td>
</tr>
<tr>
<td>% female</td>
<td>53</td>
<td>45</td>
<td>42</td>
<td>49</td>
<td>56</td>
</tr>
<tr>
<td>S. mutans (log cfu/ml)</td>
<td>4.94 (0.81)&lt;sup&gt;A&lt;/sup&gt;</td>
<td>5.14 (0.83)&lt;sup&gt;A&lt;/sup&gt;</td>
<td>5.12 (0.82)&lt;sup&gt;A&lt;/sup&gt;</td>
<td>5.18 (0.75)&lt;sup&gt;A&lt;/sup&gt;</td>
<td>5.20 (0.73)&lt;sup&gt;A&lt;/sup&gt;</td>
</tr>
<tr>
<td>dmft + DMFT</td>
<td>0</td>
<td>56.0 (3.90)&lt;sup&gt;B&lt;/sup&gt;</td>
<td>5.8 (3.15)&lt;sup&gt;B&lt;/sup&gt;</td>
<td>5.78 (3.19)&lt;sup&gt;B&lt;/sup&gt;</td>
<td>7.12 (3.49)&lt;sup&gt;B&lt;/sup&gt;</td>
</tr>
<tr>
<td>AFF</td>
<td>0.3</td>
<td>1&lt;sup&gt;A&lt;/sup&gt;</td>
<td>19&lt;sup&gt;B&lt;/sup&gt;</td>
<td>23&lt;sup&gt;C&lt;/sup&gt;</td>
<td>37&lt;sup&gt;C&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Within rows, means with the same superscript letter are not significantly different (Kruskal-Wallis); *significant difference between baseline and 3 years (Wilcoxon).

No statistical differences in blood concentrations of AGP, CRP and neopterin between the treatment groups were observed, either at baseline or 1 year after baseline (Table 3). None of these variables was correlated with caries experience at baseline, 1 and 3 years, or with BMI, gender, age or AFF.

Analyses of the frequency in CD14-260 C>T genotypes over the whole population of 348 children revealed that the CC genotype was most frequently found (54.3%) while the TT genotype was the lowest in prevalence (7.8%). The CT genotype was found in 37.9%. The allele frequency for

### Table 3
Mean blood parameters at baseline and 1 year in the five different treatment groups. Means with SD in parenthesis.

<table>
<thead>
<tr>
<th>Year</th>
<th>control</th>
<th>Full treatment</th>
<th>Extraction only</th>
<th>ART filling only</th>
<th>no treatment</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGP</td>
<td>0.76 (0.26)</td>
<td>0.79 (0.24)</td>
<td>0.74 (0.25)</td>
<td>0.80 (0.26)</td>
<td>0.74 (0.20)</td>
<td>0.77 (0.24)</td>
</tr>
<tr>
<td>(mg/L)</td>
<td>0.70 (0.19)</td>
<td>0.76 (0.23)</td>
<td>0.68 (0.21)</td>
<td>0.68 (0.21)</td>
<td>0.72 (0.20)</td>
<td>0.71 (0.21)</td>
</tr>
<tr>
<td>CRP</td>
<td>0.19 (0.36)</td>
<td>0.22 (0.34)</td>
<td>0.13 (0.23)</td>
<td>0.36 (0.53)</td>
<td>0.14 (0.34)</td>
<td>0.21 (0.39)</td>
</tr>
<tr>
<td>(nmol/L)</td>
<td>0.24 (0.35)</td>
<td>0.18 (0.30)</td>
<td>0.32 (0.80)</td>
<td>0.12 (0.21)</td>
<td>0.17 (0.21)</td>
<td>0.19 (0.39)</td>
</tr>
<tr>
<td>Neopt</td>
<td>3.03 (2.07)</td>
<td>2.72 (1.75)</td>
<td>3.88 (2.11)</td>
<td>3.37 (1.81)</td>
<td>2.01 (1.29)</td>
<td>2.68 (1.85)</td>
</tr>
<tr>
<td>(nmol/L)</td>
<td>2.19 (1.44)</td>
<td>1.59 (1.18)</td>
<td>3.12 (1.87)</td>
<td>2.01 (1.33)</td>
<td>1.38 (0.83)</td>
<td>1.95 (1.42)</td>
</tr>
</tbody>
</table>
this population was 73.3% for the C allele and 26.7% for the T allele. The CD14-260 genotype distribution of the study population was in Hardy-Weinberg equilibrium.

The serum values of AGP, CRP and neopterin were dichotomised as follows: a high value was AGP > 0.71 mg/L, CRP > 0.0 nmol/L and neopterin > 1.61 nmol/L.

A binary logistic regression analysis of AFF during the study period as dependent variable revealed no significant association with gender, BMI, S. mutans counts at baseline or caries experience. CRP (p=0.002; OR 2.2, CI 1.3 to 3.7), neopterin (p=0.003; OR 2.7, CI 1.4 to 5.2) and CD14 (p=0.039, OR 3.2, CI 1.1 to 9.6) were significantly associated with AFF.

In Figure 1, the prevalence of AFF in relation to the CD14-260 genotype is shown. The prevalence of AFF was significantly lower in the TT-genotype of CD14-260 (p=0.033; OR 3.25). This association was stronger in a subgroup of children who had caries experience > 3 at baseline (p=0.005; OR 4.8, CI 1.4 to 15.8).

![Figure 1: The proportion of children who developed abscesses and/or fistulae (AFF) during the 3 year study period as a percentage of the CD14-260 C>T genotype in the group of children who had a dmft + DMFT >3 at baseline.]

Discussion

High salivary counts of S. mutans have been reported as indicative of an increased caries risk [Beighton et al., 2005; Colby et al., 2005]. This could not be confirmed in the present study. Even the initially caries-free controls had large numbers of salivary S. mutans. This is possibly due to the high sugar content and low pH diet used in these areas, because of the abundant availability of sugar cane and fresh fruits. These data are not in contrast to what has been found in similar studies in Surinam, where almost all children tested were positive for cultured S. mutans and colonization level was not associated with caries experience. Differences between this study and our previous study in 2002 are due to the tested population (inland rural versus urban), age and caries incidence [de Soet et al. 2002].
The blood concentrations of AGP, CRP and neopterin were not significantly different between the 5 treatment groups or between baseline and 1 year.

The reason for measuring AGP and CRP was the previous observation where we found a relationship between the acute phase protein AGP and caries in caries-active children in Indonesia [de Soet et al., 2003]. This was found in a population with a high proportion of dental caries (mean dmft at 6 years 8.8 ±1.9). In the present population the mean total caries experience at 6 years (5.5 ±4.0) was significantly lower (p < 0.001, ANOVA), which may explain the lack of association in the present study. We used neopterin as a marker to monitor the health of the children after dental treatment. All values are relatively low compared to other infectious diseases [Ip et al., 2007]. We could not find significant differences in the measured serum factors between the treatment groups, nor between baseline and one year after initial treatment. We thus conclude that, using the serum factors CRP, AGP and neopterin, differences in general health due to dental treatment could not be established in this Surinam population. It is unlikely that these low levels have been caused by transport since the samples were transported frozen (at or below -20°C) and the factors measured were selected on the basis of their stability in epidemiological studies [Hartweg et al., 2007]. Based on the large variation in total caries experience at baseline (range from 0 to 18) we suggest that different subpopulations may exist.

In the present study, however, we could not define these subpopulations on the bases of any of the tested parameters. We should also keep in mind that the study population is genetically not well studied which may account for differences with previous studies.

In the present study we reported on a CD14 C-allele frequency of 73.3%. This is higher than found for a Caucasian population (54.0% and 57.3%: Eilertsen et al. [2003]; Laine et al. [2005] or 45.3% for a mixed population [de Sa et al., 2007]) . However, we must realize that the current study involves a Creole population that moved 2-3 centuries ago from Africa to Surinam. The C-allele frequency in African populations is between 72% and 85%, which is similar to what we found [Barber et al., 2007; Zambelli-Weiner et al., 2005].

Taking AFF as a sign of severe exacerbation outcome of caries, we found CRP, neopterin, total caries experience and CD14 -260 C>T to be involved with AFF conditions. These observations show systemic involvement as a result of severe caries in a group of individuals. It was found that the caries experience was associated with AFF, which is to be expected since AFF is not likely to develop without caries lesion development [Duggal et al., 2002].

An interesting finding was the correlation between the presence of the CD14 -260TT genotype and AFF. This correlation was stronger in a subgroup of children who had a relatively high number of carious lesions at baseline (> 3), which is to be expected since children with a low caries activity will develop less abscesses or fistulae.

It has been observed for multifactorial chronic inflammatory diseases such as Crohns disease and periodontitis, that abscesses were significantly associated with a genetically based up-regulation of the CD14 receptor [Balfour, 2007; Laine et al., 2005; Pietruska et al., 2006].
The results of the present study suggest that the presence of CD14-260: TT is protective for AFF. CD14 is a molecule that is associated with complex immune modulating systems. Immune modulation may be the result of either an up-regulation or a down regulation of CD14. Infectious diseases correlated with an up-regulation of CD14 is often due to an overproduction of cytokines that are associated with this typical genotype [Pietruska et al., 2006]. In the present study we observed protection in relation to AFF with this genotype.

Gram-positive cell wall products such as LTA and PG are less strong in binding to CD14 and the role of this complex is less studied than for Gram negative bacteria [Sutherland et al., 2005; Temple et al., 2003].

Because dental caries is associated with Gram-positive S. mutans, we suggest therefore that inflammation of the dental pulp with the Gram-positive is inhibited by an up-regulation of immune factors such as CD14, resulting in a faster clearance of the bacterial products.

In conclusion, based on the serum factors studied in this paper, we conclude that the general health is not significantly affected by dental caries treatment in Creole children. Children who have the genotype CD14 -260: TT are genetically protected in relation to formation of abscesses or fistulae as a consequence of severe dental caries.

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References


General Discussion and Conclusions
General Discussion and Conclusions

The aim of this thesis was to establish the effects of dental caries and dental treatment on the general health of children. More insight in this relationship would rationalize the optimal treatment strategy for caries in the primary dentition. Especially for less privileged countries where priorities in health care have to be made, a negative systemic effect of dental caries might place dental health care in a more prominent position.

The results of this study are compiled in the seven preceding chapters, each comprising one sub study. Before overall conclusions can be drawn, based on the results of these different sub studies, below some general considerations are discussed that are considered important for a proper interpretation of the overall study.

Population and study design

In general, environmental conditions are highly decisive for the course of the project. Although all efforts were undertaken to adhere to the protocol, unexpected and unpredicted circumstances inevitably required some flexibility. On the other hand, field studies in general suffer from the same possible biasing elements.

Another aspect that should be included in this general discussion is the population type involved. The Surinamese child population differs substantially from other, for example Asian or Caucasian populations. These differences include caries prevalence, behavioural aspects during dental treatments, dietary habits but also ethical demands. The results of the presented studies are therefore not necessarily the same for other population groups, who live in different countries or communities.

This study was performed in the rain forested Interior of Suriname. The advantage of such a rural environment is that it harbours a child population that has no or very little dental experience. On the other hand, it does bring certain limitations. Regarding the examination of the blood samples, for example, some valuable determinations were not carried out because necessary equipment or storage possibilities were not available.

Furthermore, due to the absence of electricity, no intraoral radiographs could be taken, which means that one possible diagnostic tool for the examination of dental caries is excluded [40]. Although it is well established and universally taught that diagnosis of dental caries, whether in the dental office, or during a field survey, should be carried out by visual examination of tooth surfaces, using a mouth mirror and perhaps a dental probe. This method has also been recognized by the World Health Organization [55]. Clinicians do not generally recognize this method as being perfect [26, 27, 44]. However, in a representative systematic review it was shown that, for proximal surfaces, radiographs had an overall sensitivity of 50% and a specificity of 87% [3]. The surplus value of radiographs can thus be disputed and the lack of it in the current study...
was therefore not regarded as a substantial shortcoming. Moreover, a possible underestimation of dental decay would be the same for all participating subjects, at all evaluation time points because one calibrated dentists performed all the examinations.

**Dental treatment strategies**

Within the Basic Package of Oral Care (BPOC), extractions are prescribed in case of dental pain. However, the BPOC does not suggest a valid tool to assess dental pain. Pain is a very subjective indicator for dental treatment. Moreover, pain is a complex, multidimensional emotion and therefore its objective assessment is challenging [4, 16, 49, 50, 52]. Pain experience, pain perception and pain behaviour differ between individuals. Studies indicated an ethnic variation in pain response as well [7, 10, 33, 43]. In the current study, dental pain was only assessed by self report of the children. Although this method has a proven validity [51], other measures for a reliable pain assessment could have been included in the study. However, the currently available methods that have proven sufficiently high sensitivity and specificity, such as the Dental Discomfort Questionnaire [49, 50], can generally not be implemented in primary oral health care programs due to practical reasons such as the illiteracy of the population involved. Emphasis should be placed however, on the applicability of a simple diagnostic tool, for example the visual analogue scale of facial expressions [4, 53], for the clinical observational assessment of dental pain within the perspectives of primary oral health care. The age of the patient and his or her cognitive abilities should be encountered.

In chapter 3 it has been described that, with respect to the oral health of children, a comprehensive dental treatment was preferred. Appropriate oral health care should at least comprise the prevention of new dental decay, arrestment of existing carious lesions, prevention of pain and discomfort for children, and prevention of early loss of deciduous teeth. When caries has already progressed into the dental pulp of primary teeth, the latter objective can generally not be fulfilled. Especially under field conditions, extraction of deeply carious teeth is often inevitable. Moreover, when dental infection has led to the formation of dental abscesses and/or fistulae, extraction should not be left undone, with respect to the serious consequences these infections can have. Besides damage on the developing permanent teeth, brain abscesses, orbital cellulitis and recurrent fever have been ascribed to chronic dental abscesses [39].

However, when the pulp has not yet been infected, many other treatment options are available, even under field conditions.

Atraumatic Restorative Treatment (ART) is suggested as the restorative treatment method of choice within the BPOC. Therefore, ART was also included in the current study. This minimal invasive treatment strategy has been proven a valuable restorative method and since its introduction in the mid-1980s, it has saved many carious teeth from early extraction [17-19, 22, 30, 38]. However, in the current study, the success of ART appears to be very low. Children that
receive ART restorative care are somehow prone to develop more new dental decay [chapter 4] and ART restorations perform extremely bad under the Suriname conditions [chapter 3]. Apparently, ART seems to be not suitable in every situation. The variable success of ART limits its indication area and should initiate further discussion about alternative treatment strategies, especially in those situations where choices have to be made with respect to a well-balanced cost-effective package of basic oral care.

A widely accepted treatment method for carious primary molars involving two or more surfaces is the placement of preformed metal crowns [15, 41, 42]. The novel variant to this method is the Hall technique: preformed metal crowns are cemented, using Glass Ionomer, directly over the carious primary molar without local anaesthesia, and without caries removal or tooth preparation. The Hall technique offers an effective treatment option for managing dental caries in primary molars and clinical trials have shown the technique to be effective, and well accepted by the majority of children, parents and clinicians [23-25].

Non-operative treatment strategies should also be considered. Although it might not be possible to predict dental caries, studies have indicated that it is possible to control the disease by the single use of preventive measures [1, 2, 8, 32, 35]. New knowledge of caries progression rates has led to substantial modification of restorative intervention thresholds and further handling of the disease. New diagnostic tools for caries lesion detection, caries risk assessment and focussed preventive treatments have decreased the need for early restorative interventions [9, 12, 13, 36, 54]. Overall, dentists are encouraged to use a more conservative and biological approach which means that secondary prevention and treatment should focus on management of the caries process over time for individual patients, with a minimally invasive, tissue-preserving approach [44].

Primary prevention
Based on the results of this study, it might be concluded that, although dental treatment is beneficial to oral health [Chapter 4], regarding general health there seems to be no evidence that general health conditions improve by dental intervention [Chapter 5 and 7]. Dental caries is a chronic infectious disease that can be controlled but not be eradicated, at least not with the treatment strategies that were applied in this particular project. The only way to rule out possible systemic effects of dental decay seems to be the primary prevention of dental caries. Dental caries should not be given a chance to develop. Oral health education should be given prior to the eruption of the primary teeth. In other words, parents, and mothers in particular, should be educated in maintaining good oral health for their children and receive adequate dietary advices. This finding is in line with other studies. Thylstrup and co-workers concluded that early diagnosis of dental caries followed by appropriate non-operative treatment was the key to better oral health [47, 48]. An individualized, non operative caries treatment strategy that was implemented in Nexø in 1987/91, based on these principles, proved
to be highly effective [11]. A significant caries preventive effect of parental, and in particular maternal, education has been found in this Nexø-project and was confirmed in other studies [28, 29]. Within the Nexø-project, children receive individualized non-operative dental care, according to their individual caries risk. However, when high caries risk populations are involved, individual caries risk assessments are less important. Primary preventive measures should then be community-based and integrated into other health prevention programs based on the common risk factors of oral and other non-communicable chronic diseases. Oral hygiene could be implemented together with general hygiene measures such as cutting nails and washing hands. The WHO has designed approaches for the integration of oral disease prevention within the prevention of non-communicable chronic diseases, and global strategies are currently being implemented in all regions of the world [37]. Dietary advice and oral health instructions should be given, taking local environmental conditions, dietary habits and available materials, into account.

Relationship oral and systemic health and disease

In the current study, it was found that children with high levels of dental caries were significantly shorter than children with lower caries levels [Chapter 5]. Moreover, in children that showed severe dental decay with concomitant signs of dentogenic infection, a systemic response was observed in terms of elevated serum levels of C-reactive protein and neopterin [Chapter 7]. The finding that dental intervention did not bring about an improvement in general health, according to the outcome measures of this study, underlines that other factors are co-determining general health conditions. General health is a multifactorial construct. In this study, only a few parameters were included. These parameters were chosen on the basis of earlier studies and with regard to the feasibility within the limitations of the rural conditions. A possible bias from, for example, co-occurring infectious diseases or malnutrition cannot be ruled out. However, it is questionable if any future study would be able to determine systemic effects that can exclusively be ascribed to the occurrence of dental decay.

In the current study, a genetically determined susceptibility for the formation of abscesses and/or fistulae as a result of dental caries was found. In chapter 7 it was described that the presence of a CD14-260:TT genotype was protective for the formation of abscesses and/or fistulae. It was therefore suggested that infection of the dental pulp would benefit from an up-regulation of immune factors such as CD14, resulting in a faster clearance of the bacterial products. Children who have the genotype CD14-260:TT are genetically protected to the formation of abscesses or fistulae as a consequence of severe dental caries compared to the CD14-260:CC or CT genotypes. Nowadays dentistry follows the principles of evidence-based practice whereby risk assessment is an important component [20]. Based on scientifically determined risk factors, an individual’s probability of acquiring a disease could be assessed. Apart from environmental factors, genetic
factors are found to have an important contribution to dental caries progression and severity [5, 6, 21, 45]. Further studies on this subject should be undertaken.

In understanding the potential effects of oral disease on systemic health, it is important to consider a broader construct of health beyond that defined by just biomedical status [20]. The health-related quality of life of patients, comprises both clinician-based, and patient’s own subjective, assessments of his or her well-being and daily functioning. Thomas et al. [2002] failed to prove a relation between rampant caries and body growth, but reported a significant improvement, as reported by their parents, in the quality of life of the children after dental treatment. This finding is supported by other studies [31, 50]. However, due to a lack of consistency in the definition and measurement, literature shows a fragmented vision of the relation between oral health and quality of life [34]. Future studies should elaborate this subject before final conclusions can be drawn regarding the priority of oral care within general health care programs.

Conclusions

The aim of this thesis was to establish the relation between dental caries and general health in children. Primary outcome measures were systemic immune response and body growth. Based on the current study, the following conclusions can be drawn:

- **Atraumatic Restorative Treatment (ART)** is a valuable, minimal invasive treatment method for dental caries. It renders less discomfort to the children, compared to minimal intervention methods whereby rotary instruments are used. However, the success of the ART restorations is very variable. In this Suriname study, extremely low survival rates for single- and two-surface ART restorations in the primary and permanent dentitions were found. Furthermore it was found that children that received only restorative care (ART), showed a significantly higher caries increment, compared to children that were treated according to other strategies. The variable success for ART should initiate further discussions about alternative treatment strategies, especially in those situations where choices have to be made with respect to a well-balanced, cost-effective package of basic oral health care.

- Regarding **Oral Health**, full dental treatment (prevention, restorative care and extractions) should be the strategy of choice whenever Oral Health Care programmes are developed. However, when priorities are required due to situational, practical or economical reasons, extraction of severely decayed teeth is an effective treatment strategy.
Instead of ART restorative care, other minimal invasive or non-operative treatment options should be considered, thereby taking environmental conditions, patient related factors, and cavity size or location into account.

- Regarding **General Health**, severe dental caries can generate a systemic immune response. Moreover, dental caries was found to be inversely correlated with body proportions in this Surinamese child population. No significant effect of dental caries treatment was found on serum parameters and invasive dental treatment did not show a significant influence on the growth pattern of the Suriname children either. With respect to these results, it is suggested that caries activity is a negative predictor for body growth in children. Based on this, it is hypothesized that caries prevention, rather than caries treatment, benefits general health.

Indications for a genetically determined susceptibility for the formation of abscesses and/or fistulae as a result of dental caries are found in this study. These results can have substantial implications for an individual risk assessment regarding the systemic impact of dental decay and could thus be decisive in the determination of a suitable treatment strategy.

**Overall Conclusion**

It has been well established in earlier studies that oral health has an impact on general health and vice versa. The results of the current study do not invalidate this statement. Treatment of dental decay does not only favour the oral health of children, as described in this thesis, it also improves their quality of life. Therefore, it is of prime importance that oral health care is integrated into primary health care. However, based on the outcome parameters used in this thesis, caries treatment does not seem to benefit general health, from a merely biomedical point of view. Therefore, the (Basic) Oral Health Care Programs should focus on the prevention of dental disease rather than on its cure. However, as long as there is no clear evidence that teeth with abscesses or fistulae can be left in the mouth without negative consequences, they should better be removed.

**Directions for future research**

- Future studies upon the relationship between dental caries and systemic health should focus on different populations; varying in ethnic background, dietary habits and caries experience. Particularly on populations with higher caries prevalence and incidence.
- Include pain assessment instruments.
- Include valid Quality of Life measurements.
- Include other, or more, systemic parameters and genetic factors.

The collective outcomes of these studies, could serve as an evidence-based foundation to plan adequate, efficient and effective oral health care for children.
References


Summary
Samenvatting
Summary

The fact that oral diseases can adversely affect human’s general health and well being, is not new. Particularly in periodontology, an association has been described between periodontal diseases and certain systemic conditions, such as cardiovascular diseases, respiratory diseases, diabetes mellitus, low birth weight and preterm birth. Possible systemic effects of dental caries have not been investigated as thoroughly as the systemic effects of periodontal diseases. However, similar outcomes may be expected, since dental caries is, like periodontitis, a chronic multifactorial infectious disease. Dental caries has been found to be associated with a deviant growth pattern in children. Children’s body growth has widely been accepted as a valid clinical indicator of general health and well being. In general, growth is influenced by genetic, constitutional and environmental factors, including malnutrition and the occurrence of infectious diseases. Dental caries is one of the most prevalent infectious diseases worldwide and it could thus be hypothesized that the possible systemic effects of dental caries could indeed be reflected in a deviant growth pattern.

If body growth in children is adversely affected by dental decay, the global increase in caries prevalence should raise major concerns, especially in those countries where access to oral health services is limited and where dental health care is of low priority. Further exploration of this relationship seems thus be necessary. Moreover, more insight in the possible systemic effects of dental caries could have important implications for the general discussion that is brought up widely on the question about what treatment strategy should be preferred to treat the carious primary dentition.

The aim of this thesis was to establish the relation between dental caries and general health in children of a certain population. The interior of Suriname was chosen as the goal area for the project, based on the need for dental care that was expressed by the Director of the Medical Mission and on the positive attitude of the Government, regarding the current study. Primary outcome measures were systemic immune response and body growth. The thesis was divided into seven sub studies that are described in separate chapters.

In Chapter 1, an epidemiological survey that was carried out in Suriname, prior to the launch of the project, was described. The study aimed at obtaining more insight in the oral health status of children living throughout the Interior of Suriname in order to be able to plan or define the need for dental care in the future. In this cross sectional study, dental caries was recorded according to the criteria of the World Health Organization (WHO). Decayed, missing and filled (DMF)-teeth (T) and surfaces (S) indices for caries prevalence were used. A total of 951 children from four different regions and between 5-15 years of age, was examined. The mean dmfs in
the youngest children (5-7.5 yrs) was 11.81 (±11.19) and the mean dmft 5.16 (±3.93). Regional, racial and gender differences were found regarding the caries prevalence of these children. Caries prevalence in the middle age category (7.5-10 years) was lower compared to the youngest children; a mean dmfs of 5.37 (±6.42) and a mean DMFS of 0.84 (±1.30) were observed. A mean DMFS of 2.31 (±4.97) was recorded in the oldest children.

The results of this study indicated that caries prevalence in young children in the Interior of Surinam is high according to the criteria of the WHO. Children in older age groups seem to experience low to moderate caries levels.

This epidemiological survey concerned four different areas in the Suriname rainforest. The intervention study-project was, mainly for practical reasons, conducted in only two of these regions.

In **Chapters 2 and 3**, the Atraumatic Restorative Treatment (ART) method was evaluated. ART is a method of minimal caries intervention that uses only hand instruments. It has been described to be applicable in outreach circumstances and was thus chosen as the restorative treatment method of choice within this project.

**Chapter 2** outlines the suitability of ART for the target population. ART claims to be atraumatic for both patient and the tooth in question. In this preliminary study, performed in Indonesia, 403 children were randomly divided in two groups. In each child one class-II- restoration in a deciduous molar was made. One group received treatment, using rotary instruments (750 rpm). The other group was treated according to the ART approach. It was found that that children treated according to the ART approach using hand instruments alone, experienced less discomfort than those treated using rotary instruments. Discomfort scores were determined using both physiological measurements (heart rate) and behavioral observations (Venham) on specific moments during the treatment.

In **Chapter 3**, the survival of the single- and two-surface ART restorations, performed during the course of the study in Suriname, was evaluated. 475 ART restorations were placed in the primary dentition and 54 in first permanent molars of 194 children (mean age 6.09 ±0.48 years). Evaluations took place after six months, one, two and three years. Three-year cumulative survivals of single- and two-surface ART restorations in the primary dentition were 43.4% and 12.2%, respectively. Main failure characteristics were gross marginal defects and total or partial loss. Three-year cumulative survival for single-surface ART restorations in the permanent dentition was 29.6%. Main failure characteristics were secondary caries and gross marginal defects. An operator effect was found only for two-surface restorations. The results show extremely low survival rates for single- and two-surface ART restorations in the primary and permanent dentitions. The variable success for ART may initiate further discussion about alternative treatment strategies, especially in those situations where choices have to be made with respect to a well-balanced, cost-effective package of basic oral health care.
In **Chapter 4**, the effect of four different dental treatment strategies on the oral health of Suriname children, was established. Three hundred and eighty schoolchildren, mean age 6.1 years (±0.5, range 5.1–7.1 years), were randomly assigned to four different groups: full dental treatment, only extractions, only restorations (ART) and no invasive treatment. Parameters for oral health were defined as caries prevalence, caries incidence, sequela to dental caries, and dental pain. Restorative dental care of the primary dentition, by means of ART, resulted in an increase in dmft. Extensive dental treatment, performing only extractions or no treatment did not render significant changes in the caries prevalence of children. From the results of this sub study, it was concluded that full dental treatment should be the strategy of choice whenever oral health care programmes are developed. However, when priorities are required due to situational, practical or economical reasons, extraction of severely decayed teeth is also an effective treatment strategy.

In **Chapter 5**, the effects of dental decay and dental treatment on, respectively, body proportions and body growth, have been assessed. The relation between dental caries and body proportions has been analyzed cross sectionally, the effect of dental treatment on body growth was analyzed in a randomized controlled trial using different treatment strategies. Three hundred eighty 6-year old Suriname children with untreated dental decay participated in the study. Caries prevalence and presence of dentogenic infections were recorded. Study population and randomisation were described above (Chapter 4 section). Body growth was evaluated by children’s height, weight and body mass index. Participants were evaluated after six months, one, two and three years. Negative correlations were observed between anthropometric measures and the number of untreated carious surfaces and caries experience of the children. No significant differences in growth pattern between the treatment groups were observed. Based on these results it is suggested that caries activity is a negative predictor for body growth in children and that dental intervention does not show significant improvement within 3 years.

In **Chapter 6**, a pilot study was described aiming to determine whether dental caries is associated with induction of the systemic immune system or cytokine response. The study was undertaken in Bali, Indonesia. Eighty five children from Den Pasar, aged 6-7 years, were included in this study. Caries prevalence and dentogenic infections were recorded and blood plasma was obtained via finger puncture. The concentrations of the acute-phase protein alpha(1)-acid glycoprotein (AGP), total IgG and the specific IgG and IgM immunoglobulins against *Streptococcus mutans* were determined. Immuno-electrophoresis was used for the determination of the AGP concentration and ELISA for IgG and IgM detection. The mean dmft of the whole group was 8.8 ±2.9. The plasma concentration of AGP ranged between 0.13 and 1.6 mg/ml serum (mean 0.86 ±0.26 mg/ml). Regression analysis revealed that the concentration of IgG against *S. mutans* was significantly correlated with dmft (adjusted $r^2=0.083$, standardized $\beta$-coefficient=0.31, $p=0.008$). When the concentration AGP was included, the correlation improved significantly (for IgG: adjusted $r^2=0.157$, standardised $\beta$-coefficient =0.36, $p=0.002$; for AGP: $\beta$-coefficient=-0.30, $p=0.009$).
The results suggest a relationship between caries and systemic parameters of inflammation. On the basis of this, severe caries might have consequences on the general health of the subject. The results of this study were applied to the Suriname project.

In Chapter 7, the oral-systemic relationship within the Suriname project population, focussing on the systemic immune response, is discussed. As parameters to monitor general health the acute phase proteins AGP, CRP and the cytokine neopterin were chosen. Also a polymorphism in the bacterial ligand CD14 (-260) was studied to investigate a relationship between genotypical sensitivity for bacterial infections and the presence of dental sepsis, in terms of abscesses or fistulae. Surinam children aged 6 years were recruited and randomly assigned to 4 groups with different treatment strategies. The children were and monitored longitudinally. 348 children were included in the present study. Blood and saliva samples were taken at baseline and after 1 year. Concentrations of serum AGP, CRP, neopterin, salivary Streptococcus mutans and CD14-260 C>T polymorphism were determined. There was no significant association between different treatment strategies and the serum parameters. Binary logistic regression analyses revealed a significant association between AFF as outcome variable and the CD14 genotype, the concentrations of CRP and of neopterin as factors (p<0.05). A significant negative association was found between the CD14-260 TT and AFF (p=0.035, chi square, OR=3.3) for the whole population. For children who had 4 or more carious lesions at baseline, the significance increased (p=0.005, OR=4.8).

From the results of this study, it was concluded that, based on the serum factors studied in this paper, general health was not significantly affected by dental caries treatment in Creole children. Children who have the genotype CD14 -260: TT were genetically protected to the formation of abscesses or fistulae as a consequence of severe dental caries.

In the General Discussion, the results of the seven sub studies were compiled and considered in the light of the existing literature. The conclusions that can be drawn, based on this thesis, should be interpreted carefully because they account for the Suriname child population that was included in the study but they may not be extrapolated to every other child population.

Based on the results of this thesis, it might be stated that with regard to the oral health of children, a comprehensive dental treatment is preferred. However, with regard to the general health of the children, it was found that, although dental caries was suggested to be a negative predictor for body growth, dental treatment did not seem to render any improvement. Based on the serum factors that were studied, no significant systemic effects of caries treatment were found either.

The clinical implication of this thesis is that (Basic) Oral Health Care Programs should focus on the primary prevention of dental caries rather than on its cure. However, as long as there is no clear evidence that teeth with abscesses or fistulae can be left in the mouth without negative consequences, they should better be removed.
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Reeds lange tijd bestaat de overtuiging dat mondgezondheid en algemene gezondheid nauw met elkaar verbonden zijn. Voornamelijk vanuit de parodontologie zijn er diverse studies bekend waarin ook een duidelijke associatie aangetoond wordt tussen parodontale aandoeningen en bepaalde systemische ziektebeelden zoals cardiovasculaire ziekten, ademhalingsstoornissen, diabetes mellitus, laag geboortegewicht en vroegegeboorte. Mogelijke systemische gevolgen van cariës zijn niet zo uitgebreid onderzocht als de systemische gevolgen van parodontale infecties. Soortgelijke bevindingen worden echter verwacht omdat ook cariës, evenals parodontitis en gingivitis, een chronische, multifactoriële infectieziekte is. In een aantal studies is beschreven dat cariës geassocieerd zou zijn met achterblijvende lengtegroei bij kinderen. Lengtegroei is wereldwijd geaccepteerd als zijnde een valide indicator voor algemene gezondheid. Over het algemeen wordt groei beïnvloed door genetische, constitutionele en omgevingsfactoren, waaronder kwalitatieve of kwantitatieve ondervoeding en infectieziekten. Cariës wordt beschouwd als één van de meest voorkomende infectieziekten en deze wetenschap leidt aldus tot de hypothese dat mogelijke systemische gevolgen van cariës af te lezen zouden kunnen zijn uit een afwijkend groeipatroon bij kinderen.

Wanneer lichaamsgroei van kinderen inderdaad negatief beïnvloed wordt door cariës, is de stijgende cariës prevalentie die er de laatste jaren in veel landen gesignaleerd wordt, op zijn minst zorgwekkend te noemen. Dit geldt in het bijzonder in die landen of gebieden waar de tandheelkundige gezondheidszorg niet voor iedereen toegankelijk is en bovendien vaak een lage prioriteit heeft. Nadere exploratie van de gesuggereerde associatie tussen cariës en groei bij kinderen lijkt dus noodzakelijk. Een beter inzicht in de mogelijke systemische gevolgen van cariës kan bovendien belangrijke implicaties hebben voor de discussie die hedentendage binnen de verschillende geledingen van de (tandheelkundige) zorgverlening gevoerd wordt betreffende de meest optimale behandelstrategie voor het carieuze melkgebit.

Het doel van dit proefschrift was het bepalen van de relatie tussen cariës en algemene gezondheid bij kinderen. Primaire uitkomstmaten waren systemische immuunrespons en lichaamsgroei. Het onderzoek werd uitgevoerd in de binnenlanden van Suriname. De keuze voor dit specifieke projectgebied was gebaseerd op de vraag naar tandheelkundige zorgverlening die door de Medische Zending van Suriname was geponeerd en op de positieve houding die de Surinaamse regering bezigde jegens het projectvoorstel. Het proefschrift is onderverdeeld in zeven deelstudies welke werden beschreven in zeven afzonderlijke hoofdstukken.
In **Hoofdstuk 1**, werd een epidemiologische studie beschreven die in Suriname was uitgevoerd, voorafgaand aan de lancering van het project. Doel van deze studie was om meer inzicht te verkrijgen in de mondgezondheid van kinderen uit het binnenland van Suriname en om, op basis daarvan, meer inzicht te verkrijgen in de planning en vraag van en naar tandheelkundige zorg in de toekomst.

In deze cross sectionele studie werd de aanwezigheid van cariës beoordeeld volgens de criteria van de Wereld Gezondheidsorganisatie (WHO). De prevalentie van cariës wordt aangegeven met behulp van de DMFT (dmft)- of DMFS (dmfs)-getallen (Decayed, Missing, Filled Teeth of Surfaces; hoofdletters voor cariës prevalentie in het blijvende gebit, kleine letters voor het melkgebit). In totaal werden 951 kinderen uit 4 verschillende regio’s, in de leeftijdscategorie tussen 5 en 15 jaar, onderzocht. In de jongste leeftijdscategorie (tussen 5-7.5 jaar) was het gemiddelde dmfs getal 11.81 (±11.19) en dmft 5.16 (±3.93). Er waren significante sexe verschillen in cariës prevalentie, alsmede etnische verschillen en verschillen tussen de vier regio’s. Cariës prevalentie in de middelste leeftijdscategorie (7.5-10 jaar) was lager vergeleken met de jongste kinderen. De kinderen in de hoogste leeftijdscategorie (>10 jaar) lieten een gemiddelde DMFS van 2.31 (±4.97) zien.

Op basis van deze resultaten mag geconcludeerd worden dat jonge kinderen in het binnenland van Suriname, een hoge cariës prevalentie hebben volgens de criteria van de WHO. Oudere kinderen tonen een lage tot gemiddelde cariës prevalentie.

Deze epidemiologische studie betrof 4 verschillende gebieden in het binnenland van Suriname. Vanwege praktische redenen, zijn slechts 2 gebieden geïncludeerd in de verdere studie.

In **Hoofdstuk 2** en **3** werd de Atraumatic Restorative Treatment (ART) methode geëvalueerd. ART is een methode van minimale cariës interventie waarbij louter handinstrumentarium gebruikt wordt. Mede omdat ART onder alle (veld)omstandigheden kan worden toegepast, werd het als restauratie methode van eerste keus opgenomen in deze studie.

**Hoofdstuk 2** beschrijft één van de redenen waarom ART geschikt werd bevonden voor toepassing binnen deze patiëntenpopulatie. ART pretendeert “atraumatisch” te zijn voor zowel de tanden als ook voor de patiënten. In een preliminaire studie in Indonesië werden 403 kinderen gerandomiseerd over 2 groepen. Bij elk kind werd een tweevlaks restauratie vervaardigd in een melkmolaar. Kinderen in groep 1 werden behandeld met behulp van roterend instrumentarium (750 rpm) en kinderen in groep 2 werden behandeld middels ART, bij gebruikmaking van louter handinstrumenten. Kinderen die volgens de ART methode behandeld werden ondervonden minder discomfort ten opzichte van de kinderen die met behulp van roterend instrumentarium behandeld werden. Discomfort werd fysiologisch (hartslag) gemeten alsmede beoordeeld aan de hand van psychologische gedragsobservaties (Venham) op verschillende momenten tijdens de tandheelkundige behandeling.

In **Hoofdstuk 3** werd de overleving van één- en tweevlaks ART restauraties, die gemaakt werden tijdens de Suriname-studie, beoordeeld. 475 ART restauraties werden vervaardigd in het
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melkgebit en 54 in de eerste blijvende molaren van 194 kinderen (gemiddelde leeftijd 6.09 ±0.48 jaar). De restauraties werden na 6 maanden, 1, 2 en 3 jaar geëvalueerd. De 3-jaarsoverleving van één- en tweevlaks ART restauraties in het melkgebit was respectievelijk 43.4% en 12.2%. Voornaamste redenen voor mislukking waren grote randdefecten en geheel of gedeeltelijk verlies van de restauratie. De 3-jaarsoverleving van éénvlaks restauraties in het blijvende gebit was 29.6%. Voornaamste redenen voor mislukking waren secundaire cariës en grote randdefecten. Voor de tweevlaks restauraties werd een operateureffect gevonden. De resultaten van deze studie laten een extreme lage overleving zien van één-en tweevlaks ART restauraties in zowel het melk als het blijvende gebit. De hoge variatie in het succes van de ART methode zou de toepasbaarheid van de methode ter discussie kunnen stellen. Zeker in die situaties waar door gebrek aan middelen, mogelijkheden en mankrachten, prioriteiten gesteld moeten worden met betrekking tot de mondgezondheidszorg.

In Hoofdstuk 4 werd het effect van 4 verschillende behandelingen op de mondgezondheid van Surinaamse kinderen beoordeeld. 380 Schoolkinderen, gemiddelde leeftijd 6.1 jaar (±0.5, range 5.1–7.1 jaar), werden gerandomiseerd toegewezen aan 4 verschillende behandelgroepen: (1) volledige behandeling, (2) alleen extracties, (3) alleen restauraties (ART) en (4) geen invasieve behandeling. Parameters voor mondgezondheid waren cariës prevalentie, cariës incidentie, aanwezigheid van abcessen en/of fistels en aanwezigheid van pijn (zelfrapportage). Het uitvoeren van louter restauratieve behandeling (ART) resulteerde in een significante cariës incidentie. Uitgebreide tandheelkundige behandeling, het uitvoeren van enkel extracties, of het doen van geen invasieve behandelingen bracht geen significante veranderingen in de cariës prevalentie teweeg. Op basis van de resultaten van deze studie mag geconcludeerd worden dat, met het oog op de mondgezondheid van kinderen, volledige tandheelkundige behandeling, bestaande uit preventie, extractie en restauratie, de voorkeur geniet. Echter, indien er, op basis van situationele omstandigheden, keuzes gemaakt moeten worden of prioriteiten gesteld, dan is enkel extractie van ernstig carieuze elementen eveneens een effectieve behandelstrategie.

In Hoofdstuk 5 werden de effecten van cariës en tandheelkundige behandeling beschreven op, respectievelijk, lichaamsheight (lengte/gewicht/body mass index, BMI) en lichaamsgroei. De relatie tussen cariës en lichaamsgroei werd cross sectioneel beoordeeld en het effect van tandheelkundige behandeling op lichaamsgroei werd in een randomized controlled trial geëvalueerd waarbij 4 verschillende behandelstrategieën werden toegepast. Onderzoekspopulatie, mondgezondheid parameters en behandelstrategieën werden reeds beschreven in het voorafgaande hoofdstuk. Lichaamsgroei werd geëvalueerd aan de hand van lengte, gewicht en BMI van de kinderen. Evaluaties hadden plaats na 6 maanden, 1 jaar, 2 jaar en 3 jaar. In deze studie werden negatieve correlaties gevonden tussen lichaamsgroei en het aantal onbehandelde cariës lasies (ds) en de cariës ervaring (dmfs) van kinderen. Tandheelkundige behandeling was niet van invloed op het groeipatroon. Op basis van deze resultaten mag gesuggereerd worden
dat, bij Surinaamse kinderen, cariës activiteit een negatieve voorspeller is voor lichaamsgroei en dat tandheelkundige behandeling daar geen significante verbetering in kan brengen in een tijdsbestek van 3 jaar.

In **Hoofdstuk 6** werd een pilot studie beschreven die tot doel had te beoordelen of cariës geassocieerd is met een inductie van het immuunsysteem of cytokine response. De studie werd uitgevoerd rondom Den Pasar, Bali, Indonesië. 85 Kinderen in de leeftijd van 6-7 jaar werden geïncludeerd. Cariës prevalentie en de aanwezigheid van dentogene infectie werd geregistreerd. Via een vingerprik werd bloed afgenomen. De concentraties van het acuut-fase eiwit alpha(1)-zuur glycoproteïne (AGP), de totale IgG en IgG en IgM specifiek tegen *Streptococcus mutans* werden bepaald. Immuno-electrophorese werd toegepast om de AGP concentratie te bepalen, ELISA werd gebruikt voor de IgG en IgM bepalingen. Binnen de totale groep was de gemiddelde dmft 8.8 ±2.9. De plasma concentratie van AGP varieerde tussen 0.13 and 1.6 mg/ml serum (gemiddelde 0.86 ± 0.26 mg/ml). Regressie analyse wees uit dat de concentratie IgG, specifiek tegen *S. mutans* significant correleerde met cariës prevalentie (adjusted r²=0.083, standardized β-coëfficiënt=0.31, p=0.008). Wanneer de AGP concentratie in de analyse werd opgenomen, nam de correlatie toe (voor IgG: adjusted r²=0.157, standardised β-coëfficiënt=0.36, p=0.002; voor AGP: β-coëfficiënt=-0.30, p=0.009). De resultaten van deze studie suggereren een relatie tussen cariës en systemische parameters voor ontsteking. Op basis hiervan kan gesteld worden dat ernstige cariës mogelijkerwijs consequenties heeft voor de algemene gezondheid van de patiënt. De resultaten van deze studie zijn toegepast op de Suriname studie.

In **Hoofdstuk 7**, werd de oral-systemische relatie, gefocust op de systemische immuun respons, onder de loep genomen. Als parameters voor algemene gezondheid werden gekozen: de acuut fase eiwitten AGP en CRP en het cytokine Neopterrine. Bovendien werd een polymorfisme van het bacteriële ligand *CD14* (-260) bestudeerd teneinde een relatie te onderzoeken tussen genotypische sensitiviteit voor bacteriële infecties en de aanwezigheid van dentogene infectie, in de zin van abcessen en/of fistels. Van de eerder beschreven Surinaamse onderzoekspopulatie werden 348 6-jarige kinderen geïncludeerd en gerandomiseerd toegewezen aan 4 verschillende behandelgroepen. De kinderen werden longitudinaal vervolgd. Bloed- en speeksel monsters werden genomen op de baseline and na 1 jaar. Concentraties serum AGP, CRP, Neopterrine, speeksel *Streptococcus Mutans* en *CD14*-260 C>T polymorfisme werden bepaald. Er werd geen significante associatie aangetoond tussen de verschillende behandelstrategieën en de serum parameters. Wel werd een significante associatie gevonden tussen de aanwezigheid van dentogene infectie en het *CD14* genotype, de concentraties CRP en Neopterrine (p<0.05). Een significante negatieve associatie werd aangetoond tussen *CD14*-260 TT en de aanwezigheid van dentogene infectie (p=0.035, Chi square, OR=3.3) voor de hele populatie. Wanneer de kinderen met 4 of meer carieuze laesies in de mond geselecteerd werden, nam dit significant toe (p=0.005, OR=4.8). Op basis van de resultaten van deze studie werd geconcludeerd dat, met het oog op de
serum factoren die in dit onderzoek geïncludeerd werden, algemene gezondheid niet significant beïnvloed wordt door tandheelkundige (cariës) behandeling in Creoolse kinderen. Kinderen met het genotype CD14 -260: TT waren genetisch beschermd tegen de productie van abcessen en/of fistels tengevolge van diepe cariës.

In de Algemene Discussie worden de resultaten van de zeven afzonderlijke deelstudies kritisch beoordeeld en beschouwd tegen het licht van de bestaande literatuur. De conclusies die op basis van dit proefschrift getrokken kunnen worden moeten met enige voorzichtigheid worden beschouwd omdat ze voornamelijk gelden voor de Surinaamse onderzoekspopulatie en niet onherroepelijk geëxtrapolereerd kunnen worden naar elke willekeurige andere populatie.

Op basis van de resultaten van dit proefschrift mag gesteld worden dat, met het oog op de mondgezondheid van kinderen, een volledige tandheelkundige behandeling, bestaande uit preventie, restauratie en extractie, de voorkeur verdient. Ondanks het feit dat cariës gesuggereerd wordt een negatieve voorspeller van lichaamsgroei te zijn, lijkt tandheelkundige behandeling geen enkele invloed te hebben op het groeipatroon van kinderen. Op basis van de bestudeerde serum parameters wordt eveneens geen invloed van tandheelkundige behandeling op de algemene gezondheid gevonden.

De klinische implicatie van dit proefschrift behelst dan ook dat (basale) mondgezondheidsprogramma’s zouden moeten focussen op primaire preventie van cariës op zeer jonge leeftijd, in plaats van op de invasieve behandeling van de carieuze laesies op latere leeftijd. Zo lang er nog geen onomstotelijk bewijs is dat tanden en kiezen met abcessen en/of fistels onbehandeld kunnen blijven zonder negatieve consequenties, verdient het aanbeveling deze elementen te extraheren.
Appendix

Flow chart study population

Assessed for eligibility (n=490)

Enrollment; excluded (n=76)
Cariesfree children

Allocation

T0 Group 1
Full Treatment
Allocated to intervention (n=104)
Received allocated intervention (n=96)
Did not receive alloc. intervention (n=8)

Absent at ev. 1 (n=8)
Absent at ev. 2 (n=11)
Absent at ev. 3 (n=16)
Absent at ev. 4 (n=20)

Definite Lost to follow-up (n=8)

Analysed (n=88),
No children excluded

T0 Group 2
Extraction
Allocated to intervention (n=104)
Received allocated intervention (n=91)
Did not receive alloc. intervention (n=13)

Absent at ev. 1 (n=9)
Absent at ev. 2 (n=9)
Absent at ev. 3 (n=18)
Absent at ev. 4 (n=25)

Definite Lost to follow-up (n=6)

Analysed (n=85),
No children excluded

T0 Group 3
ART
Allocated to intervention (n=103)
Received allocated intervention (n=96)
Did not receive alloc. intervention (n=7)

Absent at ev. 1 (n=6)
Absent at ev. 2 (n=10)
Absent at ev. 3 (n=14)
Absent at ev. 4 (n=17)

Definite Lost to follow-up (n=7)

Analysed (n=89),
No children excluded

T0 Group 4
No Treatment
Allocated to intervention (n=103)
Received allocated intervention (n=97)
Did not receive alloc. intervention (n=6)

Absent at ev. 1 (n=5)
Absent at ev. 2 (n=8)
Absent at ev. 3 (n=9)
Absent at ev. 4 (n=17)

Definite Lost to follow-up (n=4)

Analysed (n=93),
No children excluded
Dankwoord
Dankwoord

En dan is het einde ineens in zicht... Na zoveel jaar studie en nog eens een heel aantal jaar onderzoek heb ik mezelf nog steeds niet aan kunnen leren om dingen niet tot het allerlaatste uit te stellen. Een eigenschap die ik waarschijnlijk levenslang mee zal dragen maar waar ik inmiddels wel goed mee heb leren functioneren. Misschien dat ik het schrijven van dit dankwoord ook wel zo lang heb uitgesteld omdat ik het eigenlijk een ontzettend lastige klus vind, zo niet de moeilijkste van het hele boekje. Terwijl de woorden me zo hoog zitten, verlamd het idee iemand te vergeten me bij het uitstorten van die vloed van erkentelijkheid.

Prof. Dr. J.M. ten Cate. Beste Bob, je hebt me door de jaren onderzoek heen ontzettend veel geleerd. Ik heb een hoge pet van je op, die ik ook weer graag voor je afneem. Ik zal nooit begrijpen hoe jij de meest uiteenlopende functies en werkzaamheden schijnbaar moeiteloos weet te combineren. Een kwestie van prioriteiten stellen wellicht maar dan is het wel de kunst om een ieder het idee te geven dat hij of zij de hoogste prioriteit heeft. Die kunst bezit je zeer zeker. Je had altijd tijd voor me en was overal ter wereld bereid mijn manuscripten te reviseren. Ondanks je volhardende pogingen ben je er niet in geslaagd me mijn, naar jou zeggen "wollige en haast filosofische" schrijfstijl te ontnemen...maar je hebt me er wel bewust van gemaakt! Je hebt me begeleid in de wereld van de wetenschap en kennis laten maken met veel van haar facetten. In meerdere of mindere mate heb ik mij met deze wereld weten te vereenzelvigen en daar ben ik je erkentelijk voor.

Dr. W.E. van Amerongen. Lieve Evert, bedankt...je weet wel waarom...
Ongeveer 12 jaar geleden maakte ik kennis met je, als zijnde onze stagebegeleider. Caroline en ik waren de eerste pioniers die onderzoek in het buitenland gingen doen. Je corrigeerde me hartgrondig omdat ik "u" tegen "jij" zei, het begin van een lange weg samen. Naast de wetenschappelijke missie splitste je ons de opdracht in de maag om een foto te maken van die ene ultieme "hoop olifantenstront met gele vlinders" en liefst ook een close-up van een wrattenzwijn. Wij kwijtten ons goed van onze taak en ik ontdekte dat je zo je eigenaardigheden had/hebt... Na Zimbabwe kwam Bandung, Indonesië. Mijn eerste zelfstandige project dat we samen gingen opstarten. We maakten er ons onsterfelijk door de polonaise in te zetten op een officieel feestje en daarmee was de toon gezet. Het project werd een succes en de contacten waardevol. We bleken gewaagd aan elkaar en werden een team. Ananassap deed haar intrede en daarmee hadden we een wapen in handen om ongenoegens te uiten. Pas op Bali heb ik, op jouw aandringen, die daad bij het woord gevoegd en dat luchtte op na de grote decepie van het gestrande project. De herkansing voor het project, waar ik aanvankelijk nogal sceptisch tegenover stond, kwam in Suriname: het mooiste wat je me ooit gegeven hebt en zult kunnen geven. Het valt volgens mij niet mee om iemand als ik te begeleiden op een promotietraject. Ik
heb een erfelijk bepaalde eigenwijsheid, passeer deadlines om altijd uiteenlopende maar steeds weer begrijpelijke redenen, hou hardnekkig vol dat ik het allemaal zelf wel doe, ben wars van politiek en neig naar recalciitrantie wanneer er verwacht wordt in de maat te lopen. Kortom, je hebt wel wat met me te stellen gehad. Gelukkig heb jij ook een gebruiksaanwijzing en door de jaren heen hebben we die van elkaar goed leren lezen. Wat we samen aanpakken krijgt goed gevolg en daarom weet ik ook dat het einde van dit promotietraject vast weer het begin van wat anders inluidt. De “klik” die wij samen hebben is inmiddels ook op de volgende generatie overgeslagen en dat is reden temeer om onze waardevolle vriendschap tot in lengte der dagen te koesteren.

Dr. I.H.A. Aartman. Beste Irene, in beginsel was het de bedoeling dat je me alleen op het vlak van de methodologie bij zou staan in dit onderzoek maar het werd veel meer dan dat. Ik herinner me de wanhoop die me bekroop als ik bij je vandaan kwam nadat je me weer de nodige statistische handgrepen had voorgedaan. Ondanks het feit dat ik ervan overtuigd was dat ik het nooit zou kunnen reproduceren heb je me toch geleerd op eigen benen te staan. Je didactische vaardigheden schaal ik daardoor ernstig hoog in! Daarnaast was het altijd weer prettig om met je van gedachten te wisselen en we schakelden moeiteloos over van serieuze wetenschap naar evenzo importante en veelal hartverwarmende alledaagse beslommeringen. Ik hoop dat onze paden elkaar nog lange tijd blijven kruisen.

Dr. J.J. de Soet. Beste Hans, de bloedjes, de bloedjes!!! In Indonesië heb je me brommer leren rijden, op het lab heb je me leren pipetteren en me met allerhande andere analyses kennis laten maken. Je hebt me “tijdschrift-gericht” leren schrijven, althans je hebt me met de principes daarvan kennis laten maken. Vervolgens heb je me in mijn eigenwijze waarde gelaten door mijn soms wat minder-wetenschappelijke, prozaïsche schrijfstijl te gedogen. Na thuiskomst van weer een lange Suriname reis was het stevast eerst een ritje VU om bij jou de zenuwslopende doos met “infectious material” af te leveren die dan net weer ternauwernood de douane gepasseerd was. Je hebt een geweldige bijdrage geleverd aan dit onderzoek en hebt vaak je nek uit moeten steken omdat het onderzoek aan zoveel onzekerheden en onvoorspelbaarheid onderhevig was. Ik ben je daar ontzettend dankbaar voor maar bovenal dank ik je voor de haast vaderlijke zorgzaamheid en de oprechte persoonlijke betrokkenheid die je steeds weer aan de dag legde. Op deze plaats wil ik ook de afdeling Orale Microbiologie in het algemeen bedanken voor het vertrouwen in het project en alle medewerking die ik heb mogen ontvangen. In het bijzonder dank ik Malika Dahmaza voor haar geduldige analysewerk en Marja Laine voor haar betrokkenheid en suggesties.

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hartverwarmende glimlach aan de hand genomen en me kennis laten maken met een prachtig vakgebied: de kindergeneeskunde. Je enthousiasme is, evenals je glimlach, aanstekelijk en ik verliet altijd weer licht euforisch het Lucas Ziekenhuis. Ik ben ontzettend dankbaar voor al je medewerking, je geduld en je bevlogenheid. Je bent een ontzettend bijzonder mens en ik ben dankbaar dat ik je via deze weg wat beter heb mogen leren kennen.


De Suriname familie... Wat had ik zonder jullie gemoeten? Onze vriendschap is een levendig bewijs van het geslaagde project maar toch wil ik ieder van jullie een paar woorden van dank zeggen, al weet ik dat ik daarmee op voorhand al tekort schiet.

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Willemijn Oudhof. Lieve Willemijn, je verbindelaar stuurde je die eerste ronde bijzonder “well-equipped” op reis en daar hebben wij allemaal de vruchten van mogen plukken. Je Amsterdamse nuchterheid en humor hebben die prachtige ervaring voor ons allemaal extra kleur gegeven. “Mog” mag best met Scrabble, daar zal Slagerij van Campen het mee eens zijn!

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Mandee en Koos Oeloekanamoe. Vanuit een wederzijds respect hebben we ontzettend veel van elkaar geleerd zowel op professioneel als op het cultureel-persoonlijke vlak. Ik heb leren organiseren zonder klok en agenda en heb enige tolerantie ten opzichte van de bosspin ontwikkeld. Jullie hebben je ontwikkeld tot buitengewoon vaardige tandheelkundige zorgverleners, geleerd om brood mee te nemen naar je werk en kennis gemaakt met kabouters en hun dans! Het was een geweldige ervaring om dit avontuur met jullie te mogen beleven en om op deze manier kennis te mogen maken met jullie warme, gastvrije en innemende cultuur.

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op de voet gevolgd en me veelvuldig gevraagd of ongevraagd van advies bediend. Vaak met een professionele insteek maar ook heel vaak slechts gestoeld op de bodemloze humor die u zo kenmerkt en die ik zo ontzettend in u waardeer. Ik vind het heel bijzonder dat u mij straks als paranimf wilt bijstaan en het geeft me een absoluut gevoel van vertrouwen. Ik ben ervan overtuigd dat u zich tot in detail in deze rol zult verdiepen en ik heb zo’n vermoeden dat dat ook zeker weer tot een hilarische voorpret kan gaan leiden.

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Veel liefs, Martine
List of Publications


Curriculum Vitae

Martine Christine Maria Schriks was born on September 9th, 1974, in Tilburg, the Netherlands. She finished the secondary school at the Cobbenhagen College in Tilburg in 1992 and started to study dentistry at the Academic Centre for Dentistry Amsterdam (ACTA) in the same year. During the final stage of her study, she participated in a research project in Zimbabwe, focusing on the refinement of the Atraumatic Restorative Treatment (ART) technique.

After her graduation in May 1998, she started working as a general practitioner in a dental practice in Tilburg and in Hilversum. In September 1998, she started her postgraduate education (MSc) Paediatric Dentistry at the Department of Cariology Endodontology and Pedodontology of the ACTA. She completed this MSc successfully in July 2001. During this education period she worked parttime in general dental clinic.

As part of the postgraduate education she completed a clinical study upon the degree of discomfort experienced by children during ART and this resulted in a publication which has been included in this thesis. These “preliminary” research activities stimulated her to start her PhD program in September 2001 at the Department of Cariology Endodontology and Pedodontology of the ACTA. The results of the years of research that followed are described in this thesis. The present work resulted in several publications and a number of presentations at (inter)national conferences.

During her PhD study, she worked parttime as a paediatric dentist in the Special Dental Care clinic in Amsterdam (SBT).

In 2004 she joined the board of the Dutch Association of Paediatric Dentistry (NVvK), of which she is now the general secretary.

Martine Schriks is married to Jan van Gemert and they have two children, Haye (2006) and Martijn (2007).
UITNODIGING

Voor het bijwonen van de openbare verdediging van het proefschrift

Effect of dental caries and treatment strategies on oral and general health in children

Op woensdag 3 september 2008 om 12.00 uur in de Aula van de Universiteit van Amsterdam, de Oude Lutherse Kerk aan het Spui te Amsterdam

Receptie na afloop

Paranimfen
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Cees Schoofs

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