Centre for International Health

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Dental caries, oral-health-related quality of life and atraumatic restorative treatment (ART): a study of adolescents in Kilwa district of Tanzania

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Dedication

To my father, the late Obed Kimazi Daniel Mashoto and my children Jack, Obed and Faith Lianne

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Abstract

Background: To effectively plan and implement oral-health education and treatment programs targeting school students, information on the social and behavioral correlations of caries and subsequent ailments is important. Such information is limited in developing countries in general and in Tanzania in particular.

Objective: This study examined the prevalence of dental caries, its socio-behavioral distribution and its impact on daily life activities in adolescents attending primary schools in Kilwa district, Tanzania. This study also extends the existing literature on OHRQoL by examining for the first time the evaluative properties, in terms of responsiveness and longitudinal validity, of a quality-of-life assessment scale, the Child OIDP, following the implementation of a minimally invasive procedure of ART, extraction and oral health education.

Methods: Pre- (2008) and post-treatment (2009) surveys were conducted among 10 – 19-year-old adolescents in the Kilwa district using a stratified one-stage cluster sample design with rural wards as the primary sampling unit. A total of 8 rural wards were selected from a sample frame of 18 rural wards. In addition, 2 urban wards were included in the sample. All sixth graders in all primary public schools that were accessible in the urban and selected rural wards were included in the sample. Data were collected by clinical examination and face-to-face interviews. The structured questionnaire captured information on socio-demographics and oral-health behaviors. Oral-health-related quality of life was measured by the Child-OIDP inventory. DMFT was measured according to WHO criteria.

Results: An interview was completed by 1,780 (72.1%) students at baseline survey. Out of this number, 1,306 (73.8% follow-up rate) also completed an identical 6-month follow-up interview. The crude prevalence of caries (DMFT>0) was 19.2% (20.4% weighted prevalence estimate). The significant caries index (SiC), which gives the mean DMT of one-third of the

most severely affected group, was 1.03. Thirty-six percent of adolescents (41.3% urban and 31.4% rural, $p<0.001$) reported at least one OIDP. Dental pain, dental caries and oral problems impacted negatively on adolescents' daily performances. Stepwise logistic regression analyses revealed that social and behavioral variables varied systematically with caries experience, high need for dental treatment and poor self-rated oral health. Socio-demographic disparities in oral-health outcomes persisted after adjusting for oral-health-related behaviors. The mean changes in the OIDP total and sub-scale scores were negative within those who reported worsened oral health and positive in subjects reporting improved oral health. Thus, the Child OIDP showed promising evaluative properties and responsiveness to change following treatment with ART fillings, ART fillings and extraction and OHE only.

Conclusion: Substantial proportions of students suffer from untreated dental caries, oral impact on daily life and perceived need for dental care. Socio-demographic disparities in oral health and oral-health-related behaviors exist, but the social gradient in subjective and objective measures of oral health has not been fully accounted for by socio-demographic disparities in oral-health-related behaviors. Our results indicate that the Child OIDP inventory is able to detect the oral impact for school-going adolescents with pain-associated dental caries and is responsive to the change following treatment, particularly for tooth extraction. Developing policies targeting social and individual determinants of oral health is an urgent public-health strategy in Tanzania.

List of abbreviations

ART	Atraumatic Restorative Treatment
BPOC	Basic Package of Oral Care
Child-OIDP	Child Oral Impact on Daily Performance
CI	Confidence Intervals
COHU	Central Oral Health Unit
CS-Child-OIDP	Condition Specific Child-Oral Impact on Daily Performance
DMFS	Decayed Missed and Filled Surfaces (permanent dentition)
DMFT	Decayed, Missed and Filled Teeth (permanent dentition)
GIC	Glass Ionomer Cements
HIV/AIDS	Human Immunodeficiency Virus/Acquired Immunodeficiency Syndrome
ICDAS	International Caries Detection and Assessment System
ICIDH	International Classification of Impairment, Disability and Handicaps
MID	Minimally Important Difference
MoHSW	Ministry of Health and Social Welfare
MUHAS	Muhimbili University of Health Allied Sciences
NBS	National Bureau of Statistics
OHE	Oral Health Education
OHRQoL	Oral Health Related Quality of Life
OIDP	Oral Impact on Daily Performance
OR	Odds Ratio
SES	Socio-economic status
SiC	Significance Caries Index
SPSS	Statistical Package for the Social Sciences
RCT	Randomized Controlled Trials
WHO	World Health Organization

List of papers

Paper I

Mashoto KO, Åstrøm AN, Jamil D and Masalu JR. Dental pain, oral impacts and perceived need for dental treatment in Tanzanian school student: a cross sectional study. Health Qual Life Outcomes 2009; 7: 73.

Paper II

Kijakazi Obed Mashoto, Anne Nordrehaug Åstrøm, Marit Slåttelid Skeie and Joyce Rose Masalu. ·Socio-demographic disparity in oral health among the poor: a cross sectional study of early adolescents in Kilwa district, Tanzania. BMC Oral Health 2010; 10: 7.

Paper III

Kijakazi Obed Mashoto, Anne Nordrehaug Åstrøm, Marit Slåttelid Skeie,

Joyce Rose Masalu. Changes in the quality of life of Tanzanian school children after treatment interventions using the Child-OIDP. Eur J Oral Sci 2010; 118: 626 – 634.

1. Introduction

Oral health is defined as a comfortable and functional dentition that allows individuals to continue in their desired social role [3]. Apart from oropharyngeal cancers and human immunodeficiency virus/acquired immunodeficiency syndrome (HIV/AIDS)-related oral disease, oral diseases such as dental caries, periodontal disease, dental erosion, tooth loss, oral mucosal lesions and oro-dental trauma, though not life-threatening, constitute major public health problems worldwide [2, 4]. This fact is due to their high public demand and impact on the quality of life of individuals and communities. Although great improvements have been made in the oral health of populations in several countries, problems still persist, particularly among the underprivileged in developed and developing countries [5].

This thesis concerns dental caries, one of the most preventable diseases in childhood and adolescence, and its socio-behavioral predictors and perceived consequences among school-going adolescents in a rural district of southern Tanzania. The perceived consequences of caries here are oral pain and impaired oral-health-related quality of life (OHRQoL). The effect of dental caries on overall quality of life and well -being has not been extensively studied in the context of developing countries. This disease and its subsequent ailments can cause significant pain. In developing countries, the disease is too expensive to manage with conventional invasive treatment procedures. According to WHO, the cost of conventional treatment of dental caries in developing countries would exceed the total health care budget for children, if available [5]. In light of this situation, the ultimate goal of the empirical work presented in this thesis was to provide information for the planning, implementing and evaluating of feasible oral-health-care interventions targeting young people living in a rural district of Tanzania.

The World Health Organization (WHO) defines ″young people″ as those in the age range of 10-24 years, comprising both adolescents (10-19 years) and youth (15-24 years). The term ″adolescents″ is used in this thesis with the above definition in mind [6]. Young people are of great concern during the rapid socio-economic and cultural changes taking place in sub-Saharan Africa. Such changes are likely to impact their overall and oral health. Adolescence is an important period of maturing in which a variety of health behaviors are adopted and established. Although primary school is available for all children in Tanzania, in-school adolescents may constitute an affluent subgroup who might serve as role models for younger peers as well as for their out-of-school counterparts. In addition, the majority of children attending school are engaged in early sexual activities before age 15 [7]. Three out of four mothers begin child-bearing during their adolescence [8]. In light of the possibility of soon becoming responsible for maintaining good oral health for other children, primary school provides a unique opportunity for health and oral health education.

1. 1. *Trends of dental caries in young people in middle- and high-income countries*

Globally, dental caries affect 60-90% of school-aged children and most adults [9]. Over the years, evidence has suggested a decline in the prevalence of dental caries, particularly among children, adolescents and young adults in developed countries [10-13]. A Belgian study of 12-year-olds revealed that the prevalence of caries improved significantly from the early 1980s to the late 1990s, showing an increase in caries-free children from 4% to 50% and a reduction in DMF scores by 78% [11]. In Hungary, a study of 12-year-olds showed a decline in the number of DMFTs from 5.0 in 1985 to 3.8 in 1996 [13]. In Lithuania, a series of cross-sectional studies conducted between 1993 and 2001, involving 12- and 15-year-olds, revealed a decrease in the mean DMFT scores of both age groups in both high- and low-fluoride areas. In low-fluoride areas, the DMFT among 12-year-olds declined from 5.8 to 4.5, whereas in

high-fluoride areas, the mean DMFT declined from 2.6 to 1.9 [10]. In the former East Germany, caries reductions amounting to 77.2% for 8/9-year-olds, 59.5% for 12/13-year-olds and 49.1% for 15/16-year olds were observed between 1981 and 1993 [12]. The observed caries decline has been ascribed to improved dental-health-care habits [10, 11, 14], regular use of topical fluoride in one or more forms [15] and the establishment of school-based preventive care and oral-health education programs [13]. A substantial dental caries decline has also occurred in areas without drinking-water fluoridation and without organized preventive programs [16].

The decrease in dental caries is encouraging but should be considered in the context of high levels of disease in the 1960s [17]. Contrary to the optimistic view that caries is disappearing, stabilization in caries experience has been reported in some countries. In Finland, the mean DMFT among 15-year-olds declined sharply from 12.1 in 1976 to 3.6 in 1990 and then stabilized at 3.0 in 1993 [18]. In Norway [19], a stabilization at about 1.6 D_3MFT among 12-year-olds was observed between 1997 and 2004. The mean D_3MFT score of 3.4 in 1985 declined steadily to 1.5 in 1999 and 2000 and increased to 1.7 D_3MFT thereafter. A national survey conducted among 6-, 12- and 15-year-olds in the school year 2004-2005 in Iceland indicated a slight increase in caries rates when compared to another Icelandic national dental survey conducted in 1996 [20]. The two Icelandic studies used different indexes to measure caries, which might explain the slight increase in caries rates observed in the 2004-2005 survey. The 2004-2005 survey used International Caries Detection and Assessment System (ICDAS) [21, 22], while the 1996 survey used the World Health Organization (WHO) criteria [23]. Using the Significance Caries Index in quantifying the changes in caries prevalence in Switzerland from 1964 to 2000, Marthaler and co-workers [24] reported a decline of SiC in

12-year-old children by 81.3% from 1964 to 1996. Since 1996, the SiC has remained below the upper limit of 3.0 proposed by Bratthal [25].

1. 2. *Dental caries trends of young people in sub-Saharan Africa*

Due to increasing exposure to commercialized sugar products, inadequate supply of fluoride and less availability to dental-health-care services, dental caries has been assumed to be on the increase in developing countries. Nevertheless, a systematic review of Latin American and Caribbean 5-6- and 11-13-year old children showed a statistically significant downward trend in dental caries between 1970 and 2000 [26]. Further evidence supporting a downward trend in dental caries has been provided by a recent systematic review covering 130 epidemiological studies published between 1970 and 2004 [27]. All studies included in this review used WHO criteria to diagnose caries. According to this review, the mean prevalence and mean DMFT in 11-13-year-olds were lower in Sub-Saharan Africa compared to Latin American and Caribbean countries.

In Africa, the caries prevalence of adolescent populations has generally remained stable at low levels by international standards [28]. However, both an increase and a decline seem to have occurred in different parts of Africa [29]. The belief that caries is on the rise in mainland Africa has not been supported by systematic reviews [30, 31]. In the past 20 years, South Africa has reported a significant caries reduction among 12-year-old adolescents. The prevalence of caries (DMFT>0) declined from 64.4% in 1982 to 41.7% in 1999/2002. The mean DMFT score declined significantly from 2.54 in 1982 to 1.17 in 1999/2002 [32].

A number of cross-sectional epidemiological studies conducted over the last decade have found a low prevalence of dental caries in Tanzanian child populations [33-40]. Longitudinal studies on the progression of dental caries conducted in Tanzania and elsewhere have shown that many caries lesions progress much more slowly than previously assumed [41-44].

Results from studies published in sub-Saharan Africa between 1995 and 2010 regarding caries experience in adolescents are shown in Table 1.

Table 1: Studies of dental caries in permanent dentition of adolescents emanating from Sub-Saharan Africa, published between 1995 and 2010 using WHO criteria for caries diagnosis

Reference	Country	Area	Year examined	Age (years)	Sample size	Mean	DMFT>0 (%)
[45]	Zimbabwe	Urban/Rural	1991	15	736	0.92-3.05	44-75
[46]	Nigeria	Urban/Rural	1990/91	15-19	794	1.5	46.2
[47]	Tanzania	Urban/Rural	1988/89	12	98	< 1	30
[48]	Zimbabwe	Urban/Rural	1994	13.9*	569	1.1	42.3
[49]	Senegal	Urban/Rural	1994	12	300	1.2	27.5
[50]	Zimbabwe	Urban/Rural	1995	15-19	625	1.2	45
[51]	Uganda	Urban/Rural	1996/97	10-14	481	0.34	15.8
[52]	Tanzania	Rural	1998	7-15	1293	0.41	23.4
[53]	Tanzania	Urban/Rural	1996	9-14	256	0.22	14
[54]	Ghana	Peri-urban	Not reported	4-16	1851	0.79	31
[55]	Uganda	Urban/Rural	2001	13-19	372	2.9	80**
[56]	Burkina Faso	Urban/Rural	1999	12	505	0.7	28.5
[57]	Nigeria	Sub-urban	2003	12	402	0.14	13.9
[58]	South Africa	Urban/Rural	1999-2002	12	5411	1.19	40.1
[59]	Nigeria	Urban	Not reported	1-16	269	3.2	44.8
[60]	Sudan	Urban	2008	12	1109	0.42	24
[61]	Tanzania	Urban	2006	12-14	1601	0.38	22
[62]	Tanzania	Urban/rural	2009	14.9*	1077	1.2	43.5

*Mean age; **1997 WHO criteria was not used

1. 3. Risk factors of dental caries

Dental caries results from interactions over time between bacteria that produce acid, a substrate that the bacteria can metabolize, and many host factors that include teeth and saliva [63]. Risk factors for dental caries include physical and biological factors (e.g., a high number of cariogenic bacteria and immunological components) and behavioral factors (poor oral hygiene, poor dietary habits, frequent use of oral medication containing sugars, insufficient exposure to fluoride and inadequate use of dental-health-care services). Other risk factors include poverty, deprivation and social status [63]. Strictly speaking, by definition, a risk factor must establish that the exposure has occurred before the outcome. Thus, longitudinal studies are necessary to establish risk factors for dental caries, whereas a cross-sectional study can only provide evidence of risk indicators. Factors that may be implicated in giving rise to caries in school children have been described in a number of review papers [63]. Of particular

concern in this thesis are behavioral and socio-demographic correlations of dental caries among adolescents.

Socioeconomic status, SES, has been recognized as a contributor to inequalities in oral health worldwide [64]. The existence of a social gradient in dental caries prevalence as measured by the association between dental caries indicators and socioeconomic status has been documented across countries and oral-health systems, even in countries with a long tradition of oral-health promotion, preventive oral care, outreach dental-health services and high utilization rates [2]. Socio-economic disparity in adolescents' oral-health behaviors have been confirmed and disconfirmed in various studies globally [65-67]. The quality of evidence supporting the inverse relationship between SES and caries in 12-year-olds is relatively weak [68]. The choice of SES measures may explain the conflicting evidence regarding the exact role of SES in determining adolescents' oral-health outcomes [69]. In the United States, using family income and parental educational attainment as SES indicators, higher SES was associated with a lower likelihood of having caries experience (DMFT>0) and severe dental caries [67]. Similar results have been reported among adolescents in Northern Ireland, Australia and Sweden [70-72]. Using an array of social indicators, including parental level of education, family-affluence scale and the wealth index, a study from Sri-Lanka reported that caries prevalence and mean DMFS decreased as the SES level increased [73]. Studies from sub-Saharan Africa have reported mixed results with respect to the direction of the social gradient in adolescents' dental-caries experience. In a study of Ugandan students, no significant association was identified [55]. On the contrary, in a recent Sudanese study of 12-year-olds in Khartoum, subjects from middle SES groups were more likely to have caries experience than their counterparts from low SES groups [60].

Girls are often found to be more seriously affected with dental caries than boys [70]; however, numerous studies have reported no sex differences in dental caries experience [55, 60, 74]. Studies investigating the relationship between dental caries and place of residence have shown discordant results as well, with some reporting higher caries prevalence in urban than in rural societies [45, 75, 76] and others reporting the opposite trend [74, 77].

Oral-health-related behaviors (sugar consumption, household-member smoking, dental visits, and irregular toothbrushing at night, insufficient access to topical fluoride and dental fear or anxiety) are important risk factors for dental caries in adolescents [71, 78-80]. The role of sugars in caries etiology is well-known, and there is overwhelming evidence that both the amount and frequency of consumption of fermentable carbohydrates are associated with the development of caries [81, 82]. Although sugars, both naturally occurring and added, and fermentable carbohydrates stimulate bacteria to produce acid and lower the pH, several dietary factors affect the caries risk of the associated fermentable carbohydrates [83]. The contribution of decreased sucrose consumption to the decline in caries prevalence is often discussed because, in many European countries, sucrose consumption has not declined in parallel with the decline in caries prevalence [84-86]. In addition, some studies have not provided empirical evidence for a relationship between dental caries and sugar consumption [87]. Nevertheless, where there is good fluoride exposure, sugar consumption has shown to be a moderate to mild risk factor for caries [88].

A low frequency of toothbrushing (once or less than once per day versus twice or more per day) has been found to be associated with a higher number of carious permanent teeth [76]. Studies from developing countries have not provided similar results [60, 89]. Evidence from cross-sectional studies have shown that, whereas use of dental care services is associated with

lower caries prevalence in developed countries [71, 74], the use of dental services has been related to increased probability of having dental caries in developing countries [55, 89]. The latter results suggest that dental caries experience is a precursor rather than an unexpected outcome of the use of dental-health-care services in developing countries.

Conceptually, oral-health-related behaviors might be considered as proximal risk factors, whereas socio-economic status might be considered a distal risk factor or an indicator of an individual's dental-caries experience [2] (see Figure 1). The dual relationship of oral-health-related behaviors with socio-economic position on one hand and oral-health outcomes on the other suggests that oral-health-related behaviors play an important role when it comes to socio-economic disparities in oral health. A number of studies indicate that oral-health-related behaviors explain parts of the SES disparities in oral-health outcomes [90-92]. Other studies have shown that the effects of SES on oral-health outcomes are not mediated by oral-health behaviors. Rather, SES has a direct effect on oral-health outcomes, independent of the proximal determinants of oral-health-related behaviors [67].

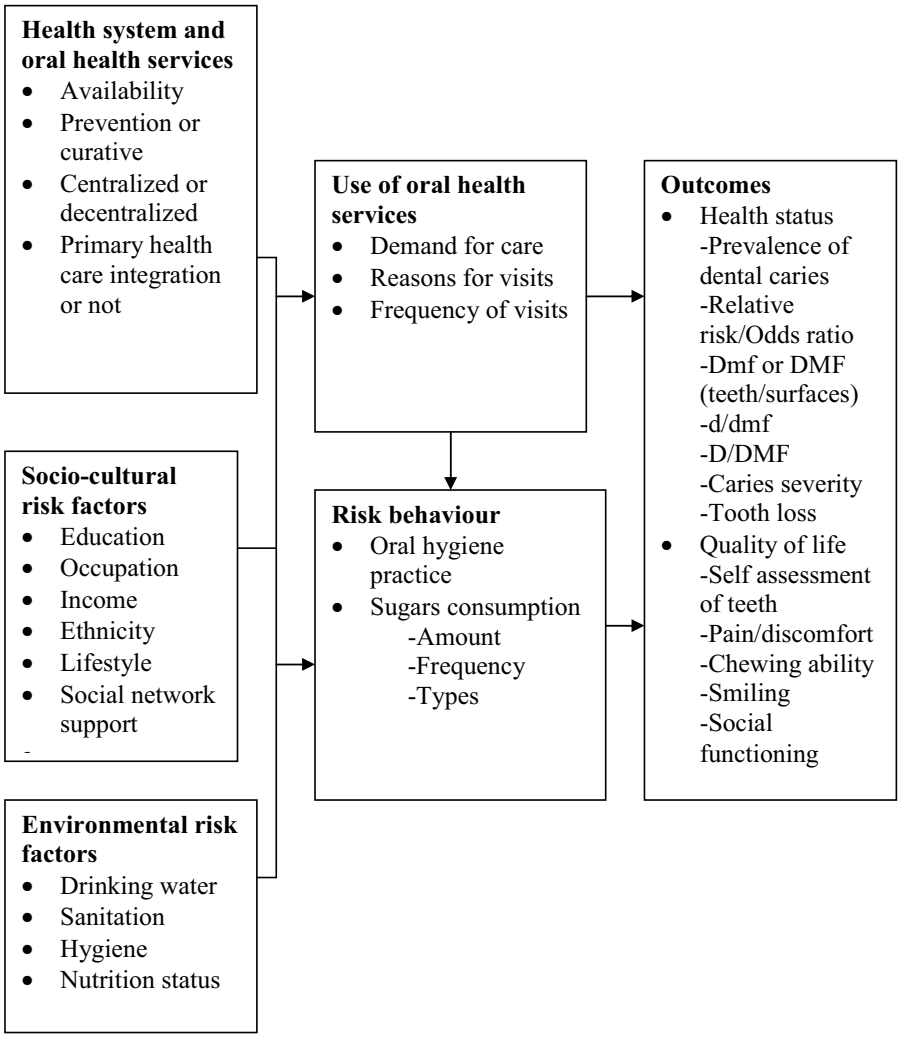

Figure 1 Caries risk-factor model adapted from Petersen [2]

1. 4. Dental caries and impact on quality of life

The concept of oral-health-related quality of life, OHRQoL, appeared in the early 1980s [93] and was defined as the impact of oral disorders on an individual's life as measured from their own point of view, thus suggesting that people assess their OHRQoL by comparing their

expectations and experiences [94]. Since the 1990s, instruments to assess OHRQoL have been developed to supplement, rather than substitute, conventional clinical oral indicators [95-99]. Oral Impact on Daily Performances (OIDP) [99] is an OHRQoL instrument commonly used in the empirical literature. The OIDP has gained international recognition and has been shown to be valid and reliable across populations in occidental and non-occidental cultural settings [61, 100]. This inventory is based on the conceptual framework derived from the World Health Organization's (WHO) International Classification of Impairment, Disabilities and Handicaps (ICIDH), which has been amended for dentistry by Locker [101] (Figure 2). The ICIDH provides a basis for the empirical exploration of the links between different dimensions or levels of consequence variables and consists of the following key concepts: impairments, functional limitations, pain, discomfort, disability and handicap. Impairments (first level) refer to the immediate biophysical outcomes of disease, commonly assessed by clinical indicators. In additional to dissatisfaction with dental appearance, functional limitations, pain and discomfort (second level) refer to the experiential aspects of oral conditions in terms of symptoms assessed through self report procedures. Any of the dimensions mentioned at the first and second levels may lead to the third level, which refers to any difficulties in performing activities of daily living and to the broader social disadvantages, called ultimate impacts (third level), thus corresponding to the WHO's and Locker's concepts of disability and handicap [1, 101].

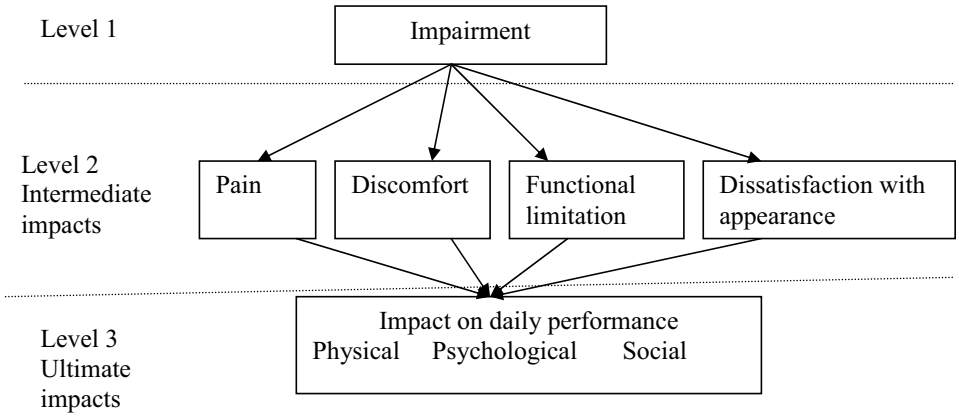

Figure 2 Theoretical framework of the consequences of oral impact (modified from WHO's International Classification of Impairment, Disabilities and Handicaps) [1]

In recent years, a number of OHRQoL instruments have been developed for use with children and adolescents [102-110]. The Child-OIDP was originally developed in Thailand, focusing on the ultimate impacts of disabilities and handicaps [104]. The Child-OIDP has been found to be a valid and reliable measure when applied to young people in different cultural settings [111-118].

Both the adult and child versions of the OIDP can be used as either a *generic* or *condition-specific* OHRQoL measure. In contrast to other OHRQoL measures, the Child-OIDP was designed to assess the specific oral problems causing impacts, thereby linking the impacts to the specific oral condition or problem that may need attention [99]. This unique characteristic has permitted the condition-specific Child-OIDP (CS-Child-OIDP) to be used in the assessment of oral health needs and in prioritizing dental-health-care services [119-121]. A

comparison of generic and condition-specific forms of the Child-OIDP has revealed that the CS-Child-OIDP is better able to discriminate between groups with and without normative dental treatment needs for caries, malocclusion, periodontal disease and traumatic dental injuries [122].

A first step in selecting an appropriate socio-dental indicator is to specify the exact purpose of use in terms of being descriptive, discriminative or evaluative [123]. The second step is to identify a measure with properties that satisfy the intended study aims. It cannot be assumed that a measure proven to be reliable and valid in cross-sectional population surveys is suitable for detecting meaningful clinical changes. The latter purpose needs instruments with properties such as responsiveness, longitudinal validity and interpretability [123]. Few of the available OHRQoL instruments have been tested for the psychometric properties required to be an appropriate measure for use in clinical trials and evaluative research [124-130].

Oro-facial pain can be defined as pain related to the face and/or mouth and may involve both hard and soft tissues in these anatomical regions [131]. Dental caries is one of the main causes of dental pain; however, the caries-pain association is found to be strongest in populations with reduced access to dental care, in lower socioeconomic status groups and in populations where dental caries is largely untreated [132]. A review of the epidemiology of dental pain and dental caries in child populations has shown that dental pain is prevalent among children, even in contemporary populations with historically low levels of caries experience [132]. Epidemiological studies in the developed countries have shown that the prevalence of dental pain in child and adolescent populations ranges from 5% to 47.5% [133-135]. In developing countries, the prevalence and severity of children's dental pain is usually higher than the figures presented in the UK, the USA and Europe. A prevalence of oral pain of 49% and 53%

as reported by children themselves and their parents, respectively, have been found in 8-year-old Sri Lankan children [136]. In the Western Cape of South Africa, 70% of 8-10-year-olds reported dental pain within the past two months [137]. The corresponding prevalence in 12-14-year-olds in Uganda was 47.6% [138].

Dental caries causes deterioration in the OHRQoL of children and adolescents [108, 111, 118, 139, 140]. Children with higher levels of dental caries are at risk for loss of school days and experiencing days with restricted activity [89, 141]. Untreated dental caries affects the quality of life expressed through pain, discomfort and functional disability [74, 142]. In Australia, 32% of 7-year-old children experienced disturbed sleep because of dental pain [135]. For Brazilian adolescents, concentration in school and interference in sports and home activities were the main consequences of dental pain [142]. Adolescents with untreated dental caries have been found to be more likely than those without to report impacts on their daily performances [143]. It has also been shown that caries negatively impacts children's self-confidence [140].

Table 2: An overview of studies published globally between 2000 and 2010 focusing on the impact of caries on oral-health-related quality of life (OHRQoL) in children and adolescents

Author(s)	Country	Sample size	Age (years)	OHRQoL impact %	Caries-OHRQoL association	OHRQoL Index
[108]	New Zealand	430	12-13	Not reported	Confirmed *	CPQ
[140]	United Kingdom	3342	5-15	22-34%	Confirmed *	Modified OHIP
[111]	Tanzania	1601	12-14	28.6	Not confirmed	Child-OIDP
[144]	Australia	677	5-15	Not reported	Not confirmed	CPQ/PPQ
[145]	New Zealand	924	32	23.4	Confirmed	OHIP
[146]	India	325	18-28	Not reported	Confirmed*	OHIP
[143]	Brazil	247	15-17	14.6	Marginally confirmed*	OHIP
[117]	Italy	530	11-16	66.8	Not confirmed	Child-OIDP
[118]	Sudan	1109	12	54.6	Not confirmed	Child-OIDP

*Did not control for confounders

1. 5. Oral-health-care services and treatment modalities for dental caries in Tanzania

Since independence, oral-health services in Tanzania have been part of the health-care delivery system and are provided by the public (60%) and the private (40%) sector [147]. Public-health services are delivered through a hierarchy of institutions: consultant hospitals at the top, followed by regional hospitals, district hospitals, health centers, dispensaries and, at the bottom, village health posts [148]. Patients treated at referral, regional and district hospitals share the cost of service, although some groups, such as pregnant women, children below the age of five years, people with chronic diseases and the elderly, are exempted [147].

Dental personnel categories in Tanzania are dental auxiliaries, dental assistants (dental therapists), dental officers, assistant dental officers and dental specialists. Although trained to work for the government in clinics, health centers, and districts hospitals, dental therapists are also able to work in private practices. They train in a 3-year program at either Tanga or Mbeya Dental Therapist School after secondary education. After gaining experience in practice for at least two years and passing an examination, a dental assistant can upgrade to assistant dental officer by undergoing 2 years of further training. The basic three-year training program emphasizes oral-health promotion, clinical examination, preventive dentistry and simple extractions, whereas the two additional years of training enables individuals to perform restorative care for carious lesions, extractions including impactions, initial periodontal therapy and fabrication of partial dentures. The ratio of dental therapists to the Tanzanian population is 1:254,667 [149].

Dental officers and dental specialists are essentially university graduates, with the specialists undergoing further university training in specific aspects of dentistry. Currently, there are 250 dentists in Tanzania, but only 100 of them are practicing dentistry. The ratio of dentists to the

population has never been calculated (verbal communication with former Dean of Faculty of Dentistry of MUHAS and assistant director of COHU-MoHSW). However, Nash et al. [150] used different sources of information to document this ratio for different countries. For Tanzania, a dentist-to-population ratio of 1:347,273 was documented, which is lower than that for other sub-Sahara African countries, such as Sudan 1:100,000 [151], South Africa 1:10,393, Zimbabwe 1:68,115 and Nigeria 1:46,151[150].

Oral-health services rendered at referral and regional/district hospitals includes preventive, curative and rehabilitative aspects [149]. However, the predominant mode of treatment for caries is extraction [152-155], and the contribution of restorative care is still negligible [40, 152, 154]. Failure of the country economy to support conventional restorative treatment is the reason given for the negligible amount of restorative treatment provided [156, 157]. To improve the management of dental caries, the Ministry of Health in Tanzania, in line with WHO African regional, endorsed Atraumatic Restorative Treatment (ART) [149, 158]. So far, the ART technique for caries management has been introduced in three regions only (Dar Es Salaam, Tanga and Morogoro) and reported to have significantly increased the restorative care in the piloted government clinics [159].

Oral-health education is considered to be an essential and basic part of dental-health-care services [160, 161]. It aims to improve oral health by providing information to raise awareness leading to the adoption of healthier lifestyles, positive attitudes and good oral-health behaviors [162, 163]. It is a powerful and successful tool in promoting oral health in adolescents [164, 165]. School provides a perfect setting for health-education programs. Positive outcomes regarding oral cleanliness, gingival health and oral-health knowledge following school-based oral-health education have been reported in both developing [166, 167] and developed countries [164, 168-170]. Other studies have shown temporary effects on

plaque accumulation, no discernable effect on caries increment, short-lived effects on attitude and a consistent positive effect on knowledge level [162, 171].

Oral-health education, a part of the primary-school curriculum in Tanzania, is an important means of dealing with the scarce number of dental professionals available in the country [172]. Since 1979, children up to 15 years of age have been the priority target group to prevent oral-health hazards before serious damage appears. The oral-health education program aimed at fostering proper oral-health behavior among school-age children started in 1982 and is implemented by teachers at primary schools [173]. However, most teachers responsible for implementation lack training and motivation for the task, and the program does not seem to be effective due to lack of adequate support for the implementers, the school teachers [174]. Poorly equipped teachers, a lack of leadership from government or the public and a lack of funds contribute to the ineffectiveness of the implemented oral-health education. It is argued that the provision of facilitating factors, such as appropriate material resources including books, pamphlets, films and guest speakers and overcoming inhibiting constraints in terms of time and money might lead to a more successful implementation of oral-health education by teachers in Tanzanian primary schools [175].

1. 6. Atraumatic restorative treatment (ART)

Atraumatic restorative treatment (ART) is a minimally invasive procedure that involves removing markedly softened carious enamel and dentine using only hand instruments and then restoring the resulting cavity and adjacent pits and fissures with an adhesive restorative material [176]. The removal of all infected dentin in deep carious lesions is not required for successful caries treatment provided that the restoration can effectively seal the lesion from the oral environment [177]. At present, the restorative material of choice for ART is high-

viscosity glass ionomer cement (GIC) [178]. GIC provides an adaptive seal by adhering to the enamel and dentine [179]. Due to its property of slowly leaching fluoride ions into the adjacent tooth tissue, GIC is capable of halting or slowing the progression of carious lesions [180]. Thus, the material can be applied in the very early stages of caries or in a large cavity.

The simplicity of ART, its independence from electricity and relatively low cost compared to treatment using rotary instruments are attractive advantages in non-occidental cultural settings [181]. To make preventive and curative oral care available to the majority of people in economically deprived countries, the World Health Organization (WHO) endorsed the ART approach as appropriate for public oral-health-care services in developing countries [182]. Trained dental allied personnel, such as dental therapists, can perform ART at a lower level of the health-care pyramid [161]. Research has shown high mean survival rates for single-surface ART restorations using high-viscosity GIC in both primary and permanent teeth [178]. Single surface ART restorations in permanent teeth have also been reported to survive longer than the traditional approach using amalgam after 6.3 years [183]. In comparison with conventional amalgam fillings of the same size, type of dentition, and follow-up period, ART restorations with high-viscosity GIC appear to be equally successful, and their survival rate may even exceed that of amalgam fillings [184].

1. 7. Rationale of the study

In Tanzania, exposure to topical fluoride in many areas of the country is inappropriate and access to oral care services is limited, particularly in rural areas. Although caries prevalence has remained low in the child population, dental pain and discomfort have been cited as common reasons for seeking dental care [52]. The primary mode of treatment is tooth extraction on an on-demand basis, leaving most of the decayed teeth untreated [52, 153, 185].

Because untreated dental caries might lead to dental pain and impact daily activities [132], it is necessary to investigate the extent, distribution and psychosocial impacts of dental caries, dental pain and oral symptoms. This information is important when assessing adolescents' burden of oral diseases and their perceived need for dental care.

Evidence suggests that oral diseases may not be distributed equally across socio-demographic groups. They are most common among those least able to access dental care and lead to pain and suffering. Improved understanding of this issue might have important policy and oral-health-program implications because national oral-health policy gives priority to children and adolescents as target groups for health-care services. In developing countries, very few studies have considered socioeconomic disparities in oral health and the influence of lifestyle factors on this disparity. Thus, it seems necessary to examine whether oral-health-related health behaviors might explain SES disparities in clinical indicators of oral health among adolescents.

Studies have shown that reduced OHRQoL is most commonly recorded in socially and economically disadvantaged groups [186]. Data on the aspects of OHRQoL outcomes in adolescents following dental treatment are lacking in Tanzania, indicating a need to provide outreach dental service and to assess its impact on OHRQoL. Whereas cross-sectional validity and test re-test reliability are desirable properties of evaluative measures, longitudinal validity, reproducibility and ability to detect minimally important clinical changes are even more important [187, 188]. Although the Child-OIDP has proven to be appropriate as a discriminative measure in cross-sectional study in Tanzania [111], it cannot be assumed that it is suitable for evaluative purposes. Thus, there is a need to assess the applicability of the Child-OIDP inventory as an evaluative measure in this particular socio-cultural context.

The Kilwa district was selected as a study site for this work because this district constitutes one of the most underserved segments of rural Tanzania with very low levels of fluoride in the drinking water (0.2 ppm). Access to oral-health-care services is severely limited. The entire district is served by one assistant dental officer (1:171,057). In addition, the oral health of the young population of this district has yet to be investigated.

2. Aims of the study

2. 1. Overall aims

This study examined the prevalence of dental caries, its socio-behavioral distribution and its impact on daily life activities in adolescents attending primary schools in the Kilwa district, Tanzania. This study also extends the existing literature on OHRQoL by examining for the first time the evaluative properties, in terms of responsiveness and longitudinal validity, of a quality-of-life assessment scale, the Child OIDP, following the implementation of a minimally invasive procedure of ART, extraction and oral-health education.

2.1. 1. Research questions

Paper 1: Dental pain, oral impacts and perceived need for dental treatment in Tanzanian school students: a cross-sectional study

Aim: Focusing on primary school children resident in Kilwa in southeastern Tanzania, this study aimed to assess the prevalence of dental pain and oral impact on daily performances (OIDP) and to describe the distribution of OIDP by socio-demographics, dental caries, dental pain and reported oral problems. The relationship of OIDP with children's perceived dental treatment need was investigated in an attempt to assess the predictive validity of the Child-OIDP frequency questionnaire in the context of primary schoolchildren in rural Tanzania.

Paper II: Socio-demographic disparity in oral health among the poor: a cross-sectional study of early adolescents in Kilwa district, Tanzania

Aim: Focusing on early adolescents attending primary school in Kilwa in southeastern Tanzania, this study aimed to assess socio-demographic disparities in caries experience, treatment need, self-reported oral-health status and a number of oral-health-related behaviors. The extent to which oral-health-related behaviors accounted for socio-demographic disparities in oral health status was also investigated.

Paper III: Changes in the quality of life of Tanzanian school children after treatment interventions using the Child OIDP

Aim: Focusing on primary school students in Kilwa in southeastern Tanzania, we aimed to examine the evaluative properties of the Child OIDP inventory in terms of its responsiveness to change, longitudinal validity and reproducibility using global ratings of oral-health change as a reference. Secondly, this study estimated treatment-associated changes in OHRQoL, as assessed in terms of Child OIDP, reported oral problems and oral-health satisfaction following ART and the provisions of oral-health education (OHE).

3. Materials and Methods

3. 1. Study area

Lindi, a coastal region located in southeastern Tanzania, is one of the most sparsely populated regions of mainland Tanzania with a population density of 12 persons per km sq. The land area for the region is 66,046 per square km [189]. The population was 787,624 as of the 2002 national census [189]. Lindi is mainly rural, divided into one urban and five rural districts;

Lindi urban (N = 41,075), Lindi rural (N = 214,882), Liwale (N = 75,128), Ruangwa (N = 124,009), Nachingwea (N = 161,473) and Kilwa (N = 171,057) (see Figure. 3).

The present thesis is based on pre- and post-treatment surveys conducted among adolescents in Kilwa district. The district has a total area of 13,347.50 square kilometers, of which 12,125.9 square kilometers is surface land and 1,221.52 square kilometers is ocean. The district is bordered on the north by the Coastal region, on the east by the Indian Ocean, on the south by the Lindi rural district and on the west by Liwale district. Only 2.6% of the Kilwa population uses electricity as the main source of energy for lighting. The net school enrollment rate is 47%, with over 50% of the population being illiterate. Health services are available but fall short of the actual demand and are also unevenly distributed. The imbalance in the distribution of services is attributed to the uneven population distribution, which is concentrated in the central and southern parts of the district, particularly in the wards surrounding the town of Kilwa [189].

Figure 3: Map of Tanzania and the Lindi region

3. 2. Study design

To address the stated research questions, a longitudinal school-based study was conducted in the Kilwa district in 2008 and 2009. A stratified one-stage cluster sample design with wards as the primary sampling unit was used for the baseline survey (Fig. 4). Data were collected at the baseline and follow-up, 6 months after the provision of ART and oral-health education, OHE.

3. 3. Sampling procedure

The study population was composed of adolescents attending grade six in public primary schools (N =8,609) in Kilwa district. Because this study included several outcomes, the size of the sample was calculated separately for each outcome, and the largest sample size required was adopted. A sample size of 2,000 grade six primary-school adolescents was calculated to be satisfactory, assuming that the percentage of primary school adolescents expected to have dental caries was 30%, using an absolute precision (d) of 0.03, 95% CI and a design factor of 2 [190]. Some of the schools in the selected wards were not easily accessed because the roads were muddy at the time of data collection. Moreover, the number of enrolled sixth-graders and attendance rates in rural schools were particularly low. To reach the estimated sample size, 8 rural wards (8/18=0.4) were selected at the first stage by systematic random sampling. In addition, both urban wards were included in the sample. At the second stage, sixth-graders in all primary public schools that were accessible in the urban and the selected rural wards were included in the sample (See Figure. 4). Thus, a disproportionately stratified one-stage cluster sample with the ward as the primary sampling unit was used, yielding a non-self-weighted sample. This design means that each participating student had a different probability of being selected into the study. An interview was completed by 1,780 (72.1%) students as a baseline, of whom 1,306 (follow-up rate 73.8%) also completed an identical 6-month follow- up interview.

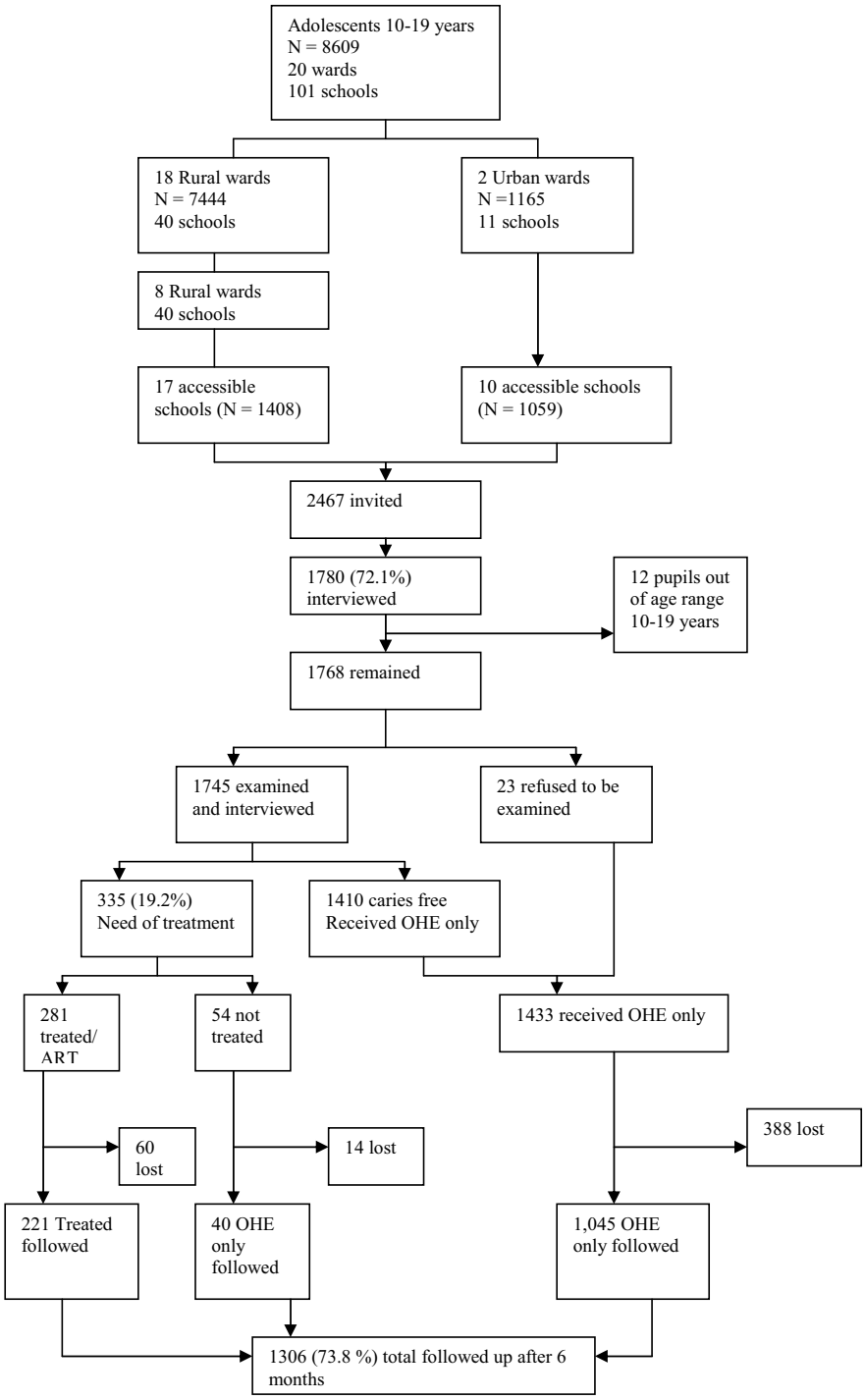

Figure 4 Sample profile for baseline and 6-month follow-up interviews

3. 4. Interviews

A structured questionnaire covering socio-demographics, oral-health behaviors and various aspects of oral health was administered by trained research assistants and completed by the pupils in face-to-face interviews at the baseline and at the 6-month follow-up. The questionnaire was originally constructed in English, translated to Kiswahili, the national language of Tanzania, and then back translated into English. The questionnaire was pilot tested prior to its use in the field. Each interview was conducted in a private, quiet place outside the classroom. Oral-health-related quality of life was measured using a Kiswahili version [111] of the eight-item Child OIDP inventory. A global transition rating pertaining to participants' perceived change in oral health following dental treatment was included in the follow-up questionnaire (Appendix 4).

3. 5. Clinical oral examination and assessment of treatment need

The clinical examination was carried out by a trained and calibrated dentist (KOM). The examination took place in the classroom, and the desk on which the examiner sat was placed strategically to face the window or door to capture the natural light. Caries experience was assessed under field conditions and scored according to the criteria described by the World Health Organization [23]. After a full-mouth clinical examination, a final overall judgment was made by the dentist as to the kind of treatment each participant needed according to the ART approach [176] (Appendix 5).

3. 6. ART and OHE interventions

After completion of interviews and clinical examinations, the participants in each school gathered in a classroom to receive oral-health education aimed at improving adolescents' oral-health-related knowledge, attitudes and behaviors. A team of one dentist, one assistant dental

officer, a dental therapist and a teacher conducted the educational sessions, allowing participants to ask questions where they needed clarification. In each school involved in the study, one teacher was trained by the dental staff to conduct oral-health education, which covered topics on the causes, symptoms and prevention of dental caries. The session lasted approximately thirty to forty-five minutes. Subsequent sessions of oral-health education were provided by the trained teachers. These sessions were conducted in the general assembly once a week for a period of 6 months and consisted of an interactive talk with pupils around key oral-health messages. The key oral-hygiene messages included the following: brush with fluoride toothpaste and use a pea-sized amount of it, brush for three minutes at least twice a day, and replace the toothbrush when the bristles start to get out of shape. Each participant was given a toothbrush. Information on the effect of frequent sugar consumption on caries development and progression was also provided during OHE.

Depending on the caries severity, ART, extraction or both were performed on schoolchildren diagnosed with caries. The assistant dental officer and dental therapist provided this service (see paper III for details of ART procedures). The treatment was carried out in the classroom.

3. 7. Data characteristics and statistical procedures

The same questionnaire was used at baseline (pre-treatment) and 6 months after the last scheduled treatment appointment (post-treatment) to generate data from interviews. *A global transition rating* pertaining to participants' perceived change in oral health following dental treatment was included in the follow-up questionnaire. In the analyses after the second survey, schoolchildren were grouped into three groups: Group A (only filling ART), Group B (extraction or both extraction and ART) and Group C (only oral-health education). Some variables were originally assessed as ordinal and nominal variables and then collapsed into

dichotomous variables. Adding responses to the scale items provided variables or indices measured on semi-continuous scales

Data were analyzed using the Statistical Package for Social Science (Version 15.0.1). The cluster effect was adjusted for using STATA 10.0. Table 3 summarizes the statistical methods for different papers. The P-value for statistical significance was set at 0.05.

Table 3: Statistical tests and methods that were used in papers I, II and III

Statistics and methods used	**Paper I**	**Paper II**	**Paper III**
Principal Component Analysis	+	+	+
Chi square statistics	+	+	+
Cronbach's alpha		+	+
Effect size statistics			+
Logistic regression	+	+	
Paired t-test			+
Cochrane's Q			+
One-way ANOVA			+
General linear models (repeated measures)			+
Wilk's Lambda statistics			+
GML ANOVA			+
Bonferoni post hoc analyses			+
Kappa	+	+	+

3. 8. Ethical considerations

Ethical clearance was granted by the National Institute for Medical Research in Tanzania, the Regional Committee for Medical Research Ethics in Norway and the Norwegian Data Inspectorate. Permission for students' participation was sought from school authorities and parents. Ministry of Education and Vocational Training through the District Council approved

the conduct of the study. Written and verbal informed consent to participate in the study was obtained from schoolchildren and their parents.

4. Results

Briefly, the general findings of this thesis and the main findings of individual papers are presented in this section. The results of Papers I and II are based entirely on data from the cross-sectional baseline survey, whereas paper III is based on data collected from the baseline and follow-up surveys.

4.1. 1. Paper I: Dental pain, oral impacts and perceived need for dental treatment: a study of schoolchildren in rural Tanzania

Thirty-six percent of adolescents (41.3% urban and 31.4% rural, $p<0.001$) reported at least one OIDP. The prevalence of dental caries was 17.4%, dental pain 36.4%, oral problems 54.1% and perceived need for treatment 46.8% for urban adolescents. The corresponding figures for rural adolescents were 20.8%, 24.4%, 43.3% and 43.8%. The adjusted ORs for reporting oral impacts are as follows: for those with dental pain, from 2.5 (95% CI 1.8 - 3.6) (problems smiling) to 4.7 (95% CI 3.4 – 6.5) (problems sleeping); for those with oral problems, from 1.9 (95% CI 1.3 – 2.6) (problems sleeping) to 3.8 (95% CI 2.7 – 5.2) (problems eating); and for those with dental caries, from 1.5 (95% 1.0-2.0) (problems eating) to 2.2 (95% CI 1.5 – 2.9) (problems sleeping). Adolescents who perceived a need for dental care were more likely to be females (OR = 0.8; 95% CI 0.6 – 0.9) and more likely to have an impact on eating (OR = 1.9; 95% CI 1.4 – 2.7) and tooth cleaning (OR = 1.6; 95% CI 1.6 – 2.5).

4.1. 2. Paper II: Socio-demographic disparity in oral health among the poor: a cross-sectional study of early adolescents in Kilwa district, Tanzania

The majority of adolescents were caries-free (79.8%) and presented low need for dental treatment (89.3%). Compared with their urban counterparts, rural residents and those from wealthier households more frequently presented caries experience (DMT>0), a high need for dental treatment and poor oral-hygiene behavior but were less likely to report poor oral-health status. Stepwise logistic regression analyses revealed that social and behavioral variables varied systematically with caries experience, a high need for dental treatment and poor self-rated oral health. Socio-demographic disparities in oral-health outcomes persisted after adjusting for oral-health-related behaviors

4.1. 3. Paper III: Changes in the quality of life of Tanzanian school children after three treatment interventions using the Child-OIDP.

The mean changes in the OIDP total and sub-scale scores were negative for subjects who reported worsened oral health and positive for those reporting improved oral health. The effect sizes for the total OIDP score ranged from -0.2 for the 'worsened' category to 0.4 for the 'improved' category. Changes following treatment were most extensive in Group B followed by Group C and then Group A. The child-OIDP showed promising evaluative properties and responsiveness to change following ART, ART and tooth extraction, and OHE.

5. Discussion

This section considers the methodological issues of importance for the present thesis and the main findings of its constituent papers. A more detailed discussion of the results is found in the individual papers included in this thesis.

5. 1. Methodological issues

The data used in this thesis were collected in a longitudinal sample survey before and after ART/OHE intervention. Data were collected by the use of interviews and a full-mouth oral clinical examination. Sample surveys are designed, by definition, to provide estimates of the characteristics of a defined population [191]. The study population consisted of 10- to 19-year-old adolescents attending public primary school in Kilwa district. The main strength of the present study, and one of the advantages of a sample-survey approach, is that it yields information on many variables of a large number of people at a relatively low cost [191]. However, it may be subject to various sources of error, which might bias the results and the conclusions [192]. The methodological problems associated with the present approach are discussed in detail in the individual papers. Some methodological issues are discussed below.

5.1. 1. Reliability

Reliability concerns the degree of consistency or accuracy with which an instrument measures an attribute [191, 193]. An instrument is recognized to be reliable when it maximizes the true component and minimizes the error component of the score. The stability aspect of reliability (precision) can be assessed by comparing the same measure for the same sample at two or more points in time and then translating it into convenient statistics [194]. For logistic reasons, a test-retest of the questionnaire was not applied in this study. Nevertheless, the test-retest reliability of the Child-OIDP when applied to Tanzanian primary-school children in Dar es Salaam was deemed to be satisfactory [61]. In addition, Cohen's Kappa was applied for test-retest reliability of the clinical variables (caries score) to examine measurement consistency. The interpretations of the Kappa values are as follows: 0.0-.0.2 = slight agreement, 0.21-0.40 = fair agreement, 0.41-0.60 = moderate agreement, 0.61-0.80 = substantial agreement, and 0.81-1.00 = almost perfect agreement [195]. With regard to clinical examination, the intra-

examiner reliability was perfect as the Kappa value for DMFT was 1.00 for 20 participants who were randomly selected and re-examined within two weeks.

Cronbach's alpha was used to assess the internal consistency reliability [196]. Internal consistency denotes the interrelation of items in a scale. The test was conducted on the 8-item Child-OIDP inventory. Alpha coefficients above 0.80 are rated as exemplary, those from 0.70 to 0.79 are rated as extensive, and those in the range 0.60 – 0.69 indicate only moderate internal consistency [197]. The value for Child-OIDP was 0.85 (95% CI 0.83 – 0.86) for the baseline and 0.87 (95% CI 0.79 – 0.92) for the follow-up survey.

5.1. 2. Validity

Validity is defined as the ability of a tool to measure what it is intended to measure [194, 197]. Internal validity deals with the question of whether a true measure is obtained for the subjects under study. Several types of bias or systematic errors might have influenced the internal validity of the results in the present study [198]. Dental caries is best diagnosed using adequate lighting and the use of visual, tactile and x-ray records. However, because the WHO standardized criteria for field studies recognize frank dentine caries only, these factors might have led to the under-reporting of caries prevalence and a certain amount of misclassification. To overcome misclassification regarding dental caries, the examiner was trained and calibrated before the main survey. This survey relied on self-reported data in the assessment of risk indicators and subjective oral-health status. A common threat to the validity of self-reports that can lead to information bias is social desirability and recall bias. There is a possibility that socially desired and undesired behaviors have been over- and under-estimated in this study, respectively. To minimize problems associated with socially desirable answers, the interviews were carried out before the clinical examination. The use of a three-month

recall period for the assessment of the Child-OIDP inventory might reduce recall bias and has proven to be successful in a number of studies [104, 111-113].

It cannot be assumed that a measure showed to be reliable and valid in cross-sectional population surveys is suitable for detecting meaningful clinical changes. The latter purpose requires instruments with properties such as responsiveness, longitudinal validity and interpretability [123]. Paper III tested, for the first time, the responsiveness to change and longitudinal validity of the Child-OIDP, which are the psychometric properties required for this measure to be used in clinical trials and evaluative research [107, 124, 126-130]. According to the results in Paper III, the Child-OIDP presented good reproducibility in terms of ICC, amounting to 0.85 (95% CI 0.83 – 0.86) and acceptable responsiveness and longitudinal validity. Similar findings have been reported in studies assessing the longitudinal validity of other OHRQoL instruments [125, 128, 129].

External validity relates to whether it is permissible to generalize the findings to a wider population. A comparison of the characteristics of the sample used in this study with the corresponding 10- to 19-year-old adolescent population in Kilwa district regarding markers of sex, age and place of residence suggests that rural adolescents were under-represented in the study group (Table 4). As far as sex is concerned, the sample was representative of the adolescent population (10-19 years) in Kilwa district. Selection bias might have occurred due to the low attendance rate in primary schools. Because the obtained estimates do not apply to the general Tanzanian adolescent population but are restricted to a selected but important group of school attendees in Kilwa, further data are required from different locations and from out-of-school adolescents to confirm, refute and/or extend the present findings. In this study, the sample used was non-self-weighted due to the unequal sampling fraction applied in the

rural and urban wards (i.e., disproportional sampling). Using an equal sampling fraction was impossible because the number of urban wards was limited to 2. Sample weights were applied to adjust the differential probability of the students being selected and to obtain unbiased estimates of the prevalence of caries, self-reported oral health and oral impact in the total population covering both rural and urban wards [191].

Table 4: Population and sample profiles

	10 – 14 yrs	15 – 19 yrs	Boys	Girls	Urban	Rural
Population						
Number (N)	22,077	17,944	20,184	19,837	3,386	36,635
Percent (%)	55.2	44.8	50.4	49.5	8.5	91.5
Sample						
Number (N)	1,183	561	867	878	837	908
Percent (%)	67.6	32.4*	49.3	50.7	49.9*	52.1*

Source for population profile: National Household Survey 2002 [199]

The use of the cluster-sampling design with wards as the primary sampling units simplified and cheapened the field work. However, including all sixth-graders in accessible schools of the selected wards resulted in having clusters with different sizes. To adjust for the cluster effect and avoid overestimating the precision of the results, data were transferred to STATA version 10. In statistical analysis, the point estimates were essentially unchanged after adjusting for cluster-design effect. The only changes observed were the broadening of the confidence interval after adjustment.

Although all grade-six adolescents in the selected schools were invited to participate in the study, the actual participation was volitional and relied on each adolescent. Initial differences due to self-selection attrition should make one attentive to the potential presence of a divergence between the targeted adolescent population and the studied one. A bias towards health-conscious participants is a well-known problem in studies where participation is voluntary [192]. The response rate of 72.6% for the baseline survey is acceptable, giving

support to the external validity of the study. Some adolescents (23) refused to be clinically examined for fear of dental instruments. Nevertheless, non-response might not be a random issue. Thus, because information about the non-respondents was lacking, any firm conclusion about the amount of selection bias in this study should be precluded.

Randomized controlled trial (RTC) is the most rigorous way of determining whether a cause-effect relation exists between treatment and outcome. Random allocation ensures no systematic differences between intervention groups in factors, known or unknown that may affect outcome. Although RCT is a powerful tool, it is also more costly and time-consuming, and use of such a tool is limited by ethical and practical concerns [200]. In Paper III, a multi-group before-and-after design was used because the present study was designed to satisfy the health authorities' ethical requirements that all subjects should potentially benefit from the study. Moreover, because available resources in terms of time and money were limited, this study could not include a true control group. It is worth noting that the main aim of the study was to assess the evaluative properties of the Child-OIDP inventory and not to assess the efficacy of the interventions (ART, extraction and OHE). A substantial proportion of adolescents (27%) were lost during the follow-up survey and non-response analysis revealed differences in age, gender, place of residence and socio-economic status between responders and subjects lost to follow-up. Nevertheless, the distribution of clinical groups with respect to baseline oral health measures was stable throughout the 6-month follow-up period, indicating limited bias caused by a differential non-response.

5. 2. Comments on the main findings

5.2. 1. Baseline oral-health status

Paper I highlighted the oral health status of Kilwa primary school attendees. Despite a moderate prevalence rate of untreated dental caries, dental pain, oral problems and oral

impacts affected a significant part of the subjects investigated. A low caries prevalence of 19.2% is consistent with the caries trends of younger groups in Tanzania [44, 52, 201] but lower than that of adolescents in other African countries [58, 60, 138]. SiC was introduced to draw attention to those individuals with the highest caries score because the caries distribution was generally skewed. The SiC of 1.03 is well below the upper limit of an SiC value of 3 set by WHO [15].

The 3-month-period prevalence of dental pain (including tooth sensitivity) and reported oral problems amounted to 30% and 48.5%, respectively. The present result agrees with those of similar age groups reported previously [142]. It is lower than that of 10- to 14-year-old adolescents in Uganda [138] and higher than that of 12- to 15-year-old adolescents in Brazil [202]. In these countries, the prevalence rates in children with caries experience were 50% and 54%, respectively. These data are similar to the rate reported in 10- to 14-year-olds from Uganda [138] and in 14- to 15-year-old Brazilian adolescents [203]. Compared with the prevalence rate of Child OIDP recently reported in primary school children in Dar es Salaam (28%) [111], the prevalence reported in Kilwa children was higher and amounted to 36%. Nevertheless, the prevalence of OIDP observed in this study was lower than those reported among similar age groups and adults of various ages in other cultures [117, 204, 205] and also lower than those observed in similar age groups in Sudan [118] and northern Tanzania [91].

The prevalence of perceived dental treatment need, amounting to 45%, clearly overestimated that of oral impacts (36%), dental pain (30%) and untreated dental caries (19%) and was almost in agreement with the prevalence rate of self-reported oral problems (48%). Consistent with results of previous studies in adults, the present findings suggest that normatively

assessed and perceived need for dental care differs among Tanzanian primary-school students [185, 206].

5.2. 2. Correlates and predictive validity of Child-OIDP

Paper I provides insight about the specific oral impacts that guide perceived need for dental care. Whereas dental caries and reported oral problems were useful predictors of child-OIDP, the child-OIDP in turn predicted perceived dental-treatment needs, accounting for between 8% and 14% of its explainable variance. These results agree with theoretical reasoning and confirm the construct and predictive validity of the child OIDP as applied in the context of Tanzanian school students [97]. Dental pain was most strongly related to problems sleeping and difficulty in performing schoolwork and least strongly to problems speaking and smiling and emotional stability. Thus, in Kilwa schools, students' toothaches seem to have more serious social and psychological consequences than consequences for functional performances. In Brazilian adolescents, concentration in school and interference with sports and home activities were the main impacts caused by dental pain [142]. In Sri Lankan children, difficulty eating (58%) and being prevented from playing (40%) and from attending school (22%) were the most common impacts related to dental pain [136]. Reported oral problems were most strongly related to problems eating and cleaning teeth and more weakly associated with other impairments. Similar trends were reported by other studies using the Child-OIDP inventory in Tanzanian primary- and secondary-school students [91, 111].

5.2. 3. Contribution of oral-health behaviors to the explanation of social inequalities in adolescents' oral-health outcomes

Social inequalities have been confirmed across clinical- and self-reported indicators of oral health in adults [90, 92, 207] but less consistently so in adolescents [208]. Relatively few

studies have reported on the socio-economic differences in adolescents' self-reported oral health and perceived treatment need [209]. Paper II provides evidence that a social gradient is present with respect to three different oral-health indicators, dental caries, treatment need, and reported oral health status, being in accordance with literature emanating from both developed and developing countries [67, 91, 210, 211]. Socio-economic differences were also present with respect to Kilwa adolescents' sugar intake, tooth brushing, use of fluoridated toothpaste and dental attendance patterns. The gradient in sugar consumption was the opposite of that observed in Korean adolescents [208]. In the present study, adolescents in the least poor quartile (the most affluent) had a higher rate of sugar intake than those in the poorest 1st, 2nd and 3rd quartiles. This finding agrees with those of other studies in Africa [55, 91] and supports evidence that commercialized sugar products are highly preferred by higher SES groups in low-income countries [212]. Thus, differences across educational level, household wealth and place of residence groups were statistically significant for most oral-health outcomes and oral-health-related behaviors investigated in Paper II, both in unadjusted and adjusted analyses.

Conceptually, influences of social stratification on health might be mediated through material and behavioral pathways [92]. In Paper II, the behavioral pathways that could mediate the socio-economic disparities in adolescents' oral health were explored by multiple variable logistic regression analyses. Although dental attendance, oral hygiene behavior and sugar intake varied systematically with oral-health outcomes, social disparities in caries experience and self-reported oral health were not attenuated while adjusting for those lifestyle patterns in the models. This result agrees with findings in industrialized countries [67] but is at odds with results of secondary-school students in Tanzania [91]. Despite some attenuation of the relationship between household wealth and (moderate to high) perceived treatment need after

controlling for dental attendance, a direct relationship persisted that was unexplained by the subjects' dental-attendance profiles. This result partly agrees with findings obtained elsewhere, suggesting that unequal access to dental care explains socio-economic disparities in adolescents' oral health [208, 210]. Most behavioral patterns that are detrimental to oral health are established during childhood and adolescence and tend to continue into adulthood, being important determinants for future adult oral health [211]. Information on how possible inequalities in oral health develop could facilitate the planning of effective interventions to tackle an unwanted development at an early stage. It should be noted that socio-economic differences in oral-health behaviors provide only one possible mechanism for explaining oral-health inequalities. Studies have shown that material and psychosocial factors play a larger role in explaining health inequalities [208, 210, 213]. Further research using longitudinal designs and a plethora of behavioral, psychosocial and material variables is required to address the pathways that might explain social disparities in oral-health outcomes among adolescents in non-occidental cultures.

5.2. 4. Responsiveness to change of Child-OIDP and short-term evaluation of an ART/OHE intervention

The results presented in Paper III suggest that the ART/OHE intervention provided was associated with moderate but statistically significant improvement in Child-OIDP scores, a reduction in reported oral problems and improved satisfaction with oral health. While it is important to demonstrate improvement in OHRQoL after treatment, it is difficult to give meaning to this improvement unless it is associated with a minimally important difference (MID) [214]. Because the assessment of change is central to planning health care from both a clinical and a public-health perspective, determining the MID of any OHRQoL measure is a crucial feature, particularly if the measure is to be used for evaluating interventions [215]. The

present study did not determine MID due to very few subjects reporting "little improvement" by the global rating. Thus, it may be somehow difficult to interpret the OHRQoL change scores in terms of clinically significant change. Moreover, the use of a before-and-after-treatment study design to some extent limited valid comparison of changes in scores between intervention groups as compared with a design with random allocation of subjects to intervention and control groups. The lack of control group leaves unanswered the question as to what would have happened without any intervention.

5.2. 5. Implication for oral-health service

Preventive methods such as affordable fluoride toothpaste, use of dental services and restricted sugar consumption continue to restrict the development of dental caries [13-15]. In the absence of restorative treatment, caries lesions will lead to pain, which in turn impact oral quality of life. Knowing that caries, dental pain and oral problems impact negatively on OHRQoL and that reduced oral quality of life influences perceived treatment need, Paper I highlighted that perceived treatment need and impact caused by caries, dental pain and oral problems need to be taken into consideration in the process of planning oral-health services in Tanzania.

Paper II gives a detailed analysis of socio-demographic disparity in oral health among the adolescents in Kilwa district. Substantial proportions of adolescents reported detrimental oral-health behaviors, suggesting that OHE should be a priority means of coping with their oral-health situation [172]. However, sugar intake, oral hygiene and dental attendance patterns did not explain the socio-economic gradient in oral-health status. Thus, developing policies and programs targeting both social structural and individual behavioral determinants of oral health should be an urgent public oral-health strategy in Tanzania. The provision of outreach oral-

health care may also help reduce inequalities in oral health among primary-school students in Kilwa district.

In a situation in which a large segment of the population has no or limited access to dental services, it is important to establish and implement oral health care that is affordable within the prevailing health infrastructure of deprived communities [161]. The basic oral health care for school-going adolescents that was implemented in Kilwa provided evidence that basic oral health care (ART, extraction and OHE) improves OHRQoL and oral-health satisfaction and reduces self-reported oral problems. (Paper III). This finding implies that BPOC should be considered for implementation of oral-health-care services in deprived communities of Tanzania.

6. SUMMARY AND CONCLUSION

Substantial proportions of adolescents reported detrimental oral-health behaviors, indicating that there is room for improving oral self-care, diet and access to and use of dental services among school-going adolescents in Tanzania. Despite demonstrating strong social disparities across oral health and oral-health behaviors, sugar intake, oral hygiene and dental visits did not explain the socio-economic gradient in oral-health status. This finding suggests that, in addition to individual factors, those associated with the environment are important. The Child OIDP inventory was able to detect oral impacts in schoolchildren with pain-associated dental caries and was responsive to change following treatment, most substantially so following tooth extraction and ART. The sensitivity of this instrument to more subtle changes in OHRQoL should be a topic for further studies using the design of a controlled clinical trial.

In short, the findings of this thesis are of importance for Tanzanian policy makers in their work with planning and implementing public oral-health strategies for school-going adolescents in Tanzania.

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8.Original Papers I - III