DIETARY FLUORIDES, DENTAL FLUOROSIS AND DENTAL CARIES IN TANZANIAN POPULATIONS

LAMECK MABELYA, MD (Stomat), MSc, DDPH.

A THESIS SUBMITTED FOR THE AWARD OF THE DEGREE OF DOCTOR OF PHILOSOPHY OF THE UNIVERSITY OF DAR-ES-SALAAM

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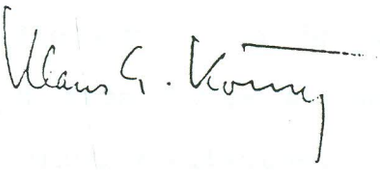
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SUPERVISORS

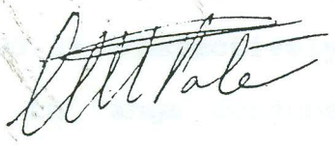
December 6, 1994

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ABSTRACT

High levels of dental fluorosis have been reported from several African countries which can not be explained by F^- in the drinking water. Climate, altitude, diet and malnutrition have been suggested as possible factors.

This study aimed to investigate the effect of climate, altitude, F^- in drinking water and dietary F- on dental fluorosis in 3 Tanzanian populations from Tanga at sea level, and Singida and Iramba both at 1500 m altitude.

The severity of dental fluorosis was assessed with the aid of 2 scoring systems. The TFI proved to be superior in determining mild and severe forms of fluorosis and was used in this study.

Despite similar and low F^- concentrations in the drinking water in the 3 populations, remarkable differences were noted in the prevalence and severity of dental fluorosis. The prevalence of dental fluorosis in Tanga was 22.8%, in Singida and Iramba was 72.0% and 99.3% respectively. People in Singida and Iramba but not in Tanga consumed "magadi", a volcanic salt Na2(CO3)2H2O), which appeared to contain F^- in the range of 28-9000 ppm F^-. The severity of dental fluorosis in the three areas appeared to be strongly associated with the consumption of magadi.

Children with severe dental fluorosis i.e. with TFI> 5 were 2% in Tanga, 28% in Singida and 92% in Iramba. Samples of magadi collected from Sepuka in Singida contained F^- in the range of 36 - 180 ppm F^- with a median of 112 ppm F^-, likewise samples collected from Kinyeto another location in Singida contained F^- in the range of 28 - 900 with a median of 174 ppm F^-. In Iramba the F^- content in magadi samples ranged from 690 - 6800 ppm F^- and the median was 1750. This association was further substantited by the finding that urine samples from infants in Singida and Iramba contained significantly higher F^- levels than in Tanga. Urine samples from Iramba revealed twice as high F^- levels than urine samples from Singida. It was therefore established that Iramba with the highest fluorosis scores was the area with the highest F^- content in magadi and in urine samples.

The differences in prevalence and severity of fluorosis could therefore be attributed to the consumption of magadi. The prevalence of dental caries in Tanga was 21.1% with a mean DMFT of 0.4. This was in agreement with data from Dar es Salaam and Morogoro, areas which are similar to Tanga with respect to low F^- content in drinking water and the absence of magadi. The prevalence of caries was 6% with mean DMFT 0.1 in Singida, and in Iramba the prevalence was 12.0% with mean DMFT 0.2. The lower caries levels in Singida and Iramba could be attributed to a higher F^- exposure in these areas, but the effect of other factors like ethnic and socioeconomic variables, nutrition and dietary habits cannot be ruled out.

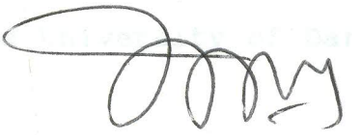
An analysis on the relationship between increasing dental fluorosis and the prevalence of caries on tooth level in Singida and Iramba indicates that severe fluorosis does not render teeth more susceptible to caries.

This finding urges further and more extensive investigation on water analysis, on dietary habits and local customs regarding food preparation in endemic fluorosis areas in order to identify the main F^- source as a first step in the control of fluorosis.

In conclusion, the findings strongly suggest magadi as an important source of F^- in endemic fluorosis areas.

DECLARATION

I declare that this thesis has not been submitted for a diploma or degree in any other University



February 12, 1995. L. Mabelya

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I appreciate with great respect how my sons Mabelya and Ilago have been able to endure my absence in the family for the two years and in this respect I like to thank Mrs. Mathilda Kitwanga for taking up the responsibility of the children.

DEDICATION.

This work is dedicated to my dear wife **"The Late Clare G. S.Kaphipa-Mabelya".** She was my best friend and the source of inspiration and love in our family.

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CHAPTER 1.

INTRODUCTION.

1.1. GENERAL INTRODUCTION.

1.1.1. Fluoride in Nature.

Fluorine is a natural component of the biosphere and the 13th most abundant element in the earth's crust. It is the most electronegative of the elements of the periodic table. In nature, fluorine does not exist in a free state, since it reacts with almost all elements to form fluoride compounds. Therefore it is found in all non-living and living things in a wide range of concentrations. Fluoride in the form of mineral compounds constitutes about 0.032% of the earth's crust. High amounts of fluoride are found in water; moreover there are mineral deposits of fluorspar, cryolite and fluorapatite and surface deposits.

The major compounds constituting the flubride reserves in the earth's crust are:

(a) Rock forming minerals like: fluorite, apatite, the mica, horn-blend and pegmatite like topaz and tourmaline. From these rocks fluoride occurs commonly as fluorite or fluorspar (CaF_2) which may contain up to 49% fluoride. The apatite is widely distributed in all igneous rocks (the most important F^- carrier).

Samples of apatite from igneous rocks have shown levels of fluoride between 13,500 -26,000 ppm. Mica has fluoride values up to 68,000 ppm, Topaz $Al_2F_2SiO_4$ has up to about 21% fluoride.

(b) Plutonic rocks contain fluoride with a concentration ranging from 20 to 4,000 ppm. Volcanic and hypabyssal rocks may contain fluoride with concentrations ranging from 80 to 2,500 ppm. Sedimentary rocks have been found to contain fluoride values of 80 - 450 ppm for a variety of sand stones, 40 - 80 ppm for greywacke and 360 ppm for loess. Lime stones are generally considered as being poor in fluoride although averages of up to 270 ppm of fluoride have been reported.

(c) Fluoride content of soil varies from area to area. High levels have been found in areas where the use of fluoride containing phosphate fertilizers is common.

1.1.2. Fluoride in water.

Much of the fluoride in water is derived from the earth's crust. The fluoride content of surface and ground waters depends on a range of factors, mainly the availability of the fluoride minerals with which these waters are in contact. The fluoride concentration found in particular surface or ground waters is determined by the porosity of the rocks or soils through which the water passes and the speed with which the water flows through, the temperature

of interaction between the rock and the water, the acidity of the water, and the calcium content in the water. When fluoride compounds interact with water, F^- ions are liberated by dissolution. However, since all surface waters contain a surplus of Ca^{2+} ions, the solubility product of calcium fluoride will control the fluoride concentration and keep it below 10 ppm. However, there are exceptions: shallow lakes in volcanic areas (e.g. Ngorongoro crater in Tanzania) dissolve a of lot of soil minerals and when water evaporates in the dry season salt crystals are formed which are heavily contaminated with soluble fluorides. Inhabitants of areas around such lakes mine this salt and use it for domestic purpose.

1.2. MAIN SOURCE OF FLUORIDE TO MAN.

Human beings ingest fluoride compounds mainly from water, from foods e.g. .marine animals and certain vegetables, and from drugs for example fluoridated toothpastes and other preparations used in the prevention of dental caries.

1.2.1. Intake of fluoride from water.

The principal sources of F^- uptake for human beings are water, beverages and food. F^- is found in most, if not all, potable waters consequently it becomes universally available for ingestion by man and animals from this source.

The amount of F^- which is ingested by man is considered to be dependent on the fluoride content of the water and the amount of water consumed daily. Climatic conditions can affect F^- intake from water intrinsically the amount of water required by the body is influenced by body weight and size, kind of foods eaten, eating pattern and physical activity. At the same moment extrinsic factors also play a leading role in influencing the amount of water intake as well as F^- metabolism. Among these factors are: average annual temperatures, excessive day time temperatures, radiant heat gain, relative humidity and wind movement.

1.2.2. Intake of fluoride from foods.

As is the case with water, F^- content of most food types is very low (about 0.1 ppm). Certain foods have relatively high F^- levels and among these are various sea foods, food supplements, tea and wines. Knowledge of F^- content in foods and drinks is important in estimating total F^- intake.

1.2.3. Intake of fluorides from drugs.

Owing to its caries preventing action and treatment of osteoporosis, F^- ingestion in the form of drugs has become another source to people. This is more evident developed countries and in urban areas of developing countries where the use of fluoridated dentifrices has become popular.

Systemic F^- application e.g. tablets, has become a routine caries preventive method in industrialised populations who use drinking water containing less than 0.7 ppm fluoride.

1.2.4. Intake of fluoride from dusts and vapours.

Although considerable amounts of inorganic fluoride enter the environment as dusts, intake from such sources does not play an important role for the total amount of F^- ingested.

1.3. FLUORIDE METABOLISM.

1.3.1. Fluoride absorption.

The fate of ingested fluorides is dependent on the solubility of the compound, the amount and the kind of the contents of the stomach of an individual. Absorption of soluble fluoride salts is rapid and nearly complete from the stomach, whereas the absorption of fluoride from less soluble fluoride compounds is incomplete and depends on the degree of the compound's solubility, physical properties of the crystals, particle size and mode of intake. Ingested soluble F^- is rapidly absorbed from the gastrointestinal tract and is rapidly distributed and subsequently partly excreted from the body. A number of animal studies provide evidence to the rapidity of fluoride absorption. Wallace-Durbin (1954) observed that within one hour 72% to

75% of the ingested fluoride dose was absorbed and present in the plasma of rats. Measurable increases in plasma fluoride levels take place almost immediately after ingestion. This phenomenon is in agreement with the fact that fluoride is rapidly absorbed from the stomach. The peak plasma concentration in humans which follows ingestion is usually observed within 30 minutes after ingestion, the plasma F^- concentration is determined by the amount of ingested F^- (Ekstrand et al. 1977) and the solubility of the ingested compounds (Ekstrand et al. 1978, Spak et al. 1982). Based on the rapidity with which F^- ions are absorbed, its appearance in the blood and distribution in the body indicates that no active transport system is involved in the absorption of fluoride from the gastro-intestinal tract into the blood.

Most of the ingested F^- is absorbed from the stomach already, where under the high acidity the surplus of H+ ions causes formation of hydrofluoric acid in an ionized but not completely dissociated form. This means that the ion pair behaves as if it were uncharged and so, unlike charged ions, passes through the membranes fast and leaves the stomach for the blood. The bio-availability of ingested F^- has been estimated to be almost 100% in humans (Ekstrand, et al. 1990). The plasma F^- levels have been found to rise proportionally to ingested F^- , thus making plasma F^- concentration the best and most reliable indicator for establishing F^- exposure levels (Ekstrand et al. 1978).

However, urinary excretion of fluoride can also be used to estimate F^- intake Mc Clure and Kinser 1994, Marthaler 1992.

1.3.2. Fluoride clearance from plasma.

The body maintains a steady state of the plasma fluoride concentration by two major processes, renal excretion of fluoride and clearance of fluoride by calcified tissues. Ekstrand (1978) found that the plasma fluoride steady state is almost the same for subjects using drinking water with about 0.25 ppm F^- and 1.2 ppm F^-. He observed only a slightly higher plasma F^- level in individuals who drink water with about 1.2 ppm F^-. Individuals drinking water with 9.4 ppm F^- had a much higher plasma F^- steady state and it was age dependent. Ekstrand (1978) observed that the steady state was reached within 24 - 30 hours following multiple F^- ingestion.

1.3.2.1. Renal fluoride excretion.

The kidney represents the major route of fluoride elimination from the blood (Hodge el al 1970). It has been established that renal excretion of fluoride is rapid and several studies have shown that up to 30% of ingested fluoride is excreted through urine within the first six hours and up to 60% is excreted within 24 hours (Ekstrand and Whitford 1988). The amount of fluoride excreted through

urine is chiefly determined by the glomerular filtration rate and the kidney clearance rate (Waterhouse et al. 1980, Schiffel and Binswanger 1980). Fluoride excretion by perspiration is normally low but may be considerable in a hot environment (Ekstrand and Whitford 1988). About 50% of fluoride absorbed from the gastro-intestinal tract is excreted through the kidneys (Machle and Largent 1943, Ekstrand and Whitford 1988).

1.3.2.2. Clearance of fluoride by calcified tissues.

The second route of clearing fluoride from the blood is by fluoride sequestration to calcified tissues. Due to high affinity to calcifying tissues almost 99% of all fluoride in the human body is deposited in these tissues. During an intake of a single dose of fluoride, the amount of F^- deposited in the calcifying tissues ranges between 40% and 60% (Parkins et al. 1974).The rate of F^- uptake is chiefly determined by the age or stage of skeletal development. Several studies have shown that the amount F^- retained in young and fast growing bones is higher compared to that retained by old skeleton with slow remodelling process (Parkins et al. 1974, Whitford 1990). The amount of F^- deposited in the calcifying tissues depends on the dose, duration of exposure and age of the calcified tissues (Parkins et al. 1974). It has been shown that higher proportion of F^- is deposited in calcifying tissues in the

first days of exposure, which later declines and levels to a constant (Ekstrand and Whitford 1984, Ekstrand et al. 1990, Whitford 1990). This is supported by the rising percentage of excreted F^- through urine with increasing duration of exposure to fluoride (Ekstrand et al. 1977).

1.4. THE EFFECT OF FLUORIDE ON SKELETAL AND BONE TISSUES.

Chronic ingestion of high amounts of F^- can lead to occurrence of skeletal fluorosis. Siddique (1955) demonstrated that the length of exposure to fluoride is important in developing skeletal fluorosis. The causative factor being the high plasma level which is dependent on the amount, frequency and length of fluoride ingestion. (Zipkin et al 1958, Zipkin 1970).

Two levels or stages of skeletal fluorosis can be differentiated:

Asymptomatic osteo-sclerosis and crippling skeletal fluorosis. The early signs of asymptomatic osteo-sclerosis can only be diagnosed on radiographs. The less advanced skeletal fluorosis show accentuation of the trabeculae structure of the cancellous bones. These signs are best observed on radiographs of the pelvis and spine (Siddique 1955), currently radiographic analysis of the metacarpal bones are used to diagnose the condition(Tanner et al. 1975, Wenzel and Melsen, 1882b.

Advanced cases often called crippling skeletal fluorosis occur mostly in combination with mineral deficiency and malnutrition. These cases show signs of stiffness of the spine even limiting free movement with possibilities of advancing to kyphosis and flexion deformities of the knees. In these cases there is difficulty in walking, partly due to stiffness resulting from secondary neurologic disorders (Jolly et al. 1969). Radiographic examination of the bones reveals several pathological signs among which are:

(a) increased density of the bone, especially the pelvis and the vertebrae,

(b) uneven bone contour,

(c) irregular periosteal growth (exostoses and osteophytes are seen),

(d) calcified ligaments,

(e) fused bones of the vertebrae column (Poker back).

Fluoride is not irreversibly bound to calcifying tissues. It has been shown that subjects who moved from high to low fluoride areas, maintained high urinary fluoride excretion. Similar results have been reported in subjects who were chronically exposed to high fluoride and later moved to a low fluoride area (Weatherell and Robinson 1988).

These findings indicate that F^- is slowly but continuously mobilized from the calcified tissues. F^- mobilization from the calcified tissues is achieved through remodelling of these tissues. A typical example has been reported by Backer Dirks (1992), who observed a 13 year old girl who

lived in an endemic fluoride area in Ethiopia (10 - 15 ppm F^- in drinking water) from the age of 2 years and 7 months. On emigrating to the Netherlands (0.08 ppm F^-) she slowly lost through urinary excretion more than 6000 mg F^- over a period of 20 months, that is about 10mg F^- per day.

1.5. FLUORIDES AND DENTAL HEALTH.

Unlike fluoride bound to the skeletal calcified tissues, fluoride is irreversibly bound to dental hard tissues because of the lack of remodelling process in the these tissues. Two major dental health effects of fluorides are well established, depending on dose and duration to F^- exposure. Dosed moderately, F^- is a caries preventive agent but in excess it may cause dental fluorosis (Dean et al.1942, Arnold et al. 1962, Aasenden and Peebles 1974). Tooth mottling now commonly known as dental fluorosis is a hypoplasia of dental enamel and dentine (Thylstrup and Fejerskov 1978). This phenomena is caused by chronic ingestion of excessive F^- during the formative stages of dental hard tissues (Dean 1938, Hodge 1950). Severity of dental fluorosis may range from only narrow white lines along the perikymata or small surface areas of the enamel with diffuse borders to pitting and loss of the enamel which may include changes in the anatomic appearance of the affected tooth. The slight forms of dental fluorosis, either lines or diffuse chalky areas, are due to higher

than normal pore volume of the sub-surface enamel (Thylstrup and Fejerskov, 1978; Fejerskov, Kragstrup and Richards 1988). This results in a change of refraction of light, and the appearance of the chalky areas is dependent on the water content. When the enamel pore volume (which normally is about 10%) is only slightly increased, drying and thus removing water from the pores is necessary to make the enamel appear chalky. If the pore volume is increased to about 20%, (which still is not high) the enamel may look chalky without being dried thoroughly. In situations of slight mottling, the enamel surface is hard and smooth. If the pore volume is even higher, due to much higher uptake of fluoride during enamel formation, and especially when very high fluoride uptake prevails during all phases of enamel development so that pitting and other forms of gross hypoplasia are caused, secondary staining by incorporation of organic salivary compounds, bacterial material, and food substance occurs. This stain, can get quite dark within a few years after eruption, usually is aesthetically objectionable, while slightly whitish teeth may be cosmetically acceptable. The first report of endemic hypoplasia was made by Eager in 1901 after observing frequent and common dental peculiarities among Italian immigrants. According to Eager similar enamel defects were also seen in the U.S.A. and in other countries. From about 1950 these conditions were called dental fluorosis.

Black and McKay (1916) associated dental fluorosis and domestic water supply. Dean (1933) using epidemiological techniques proved beyond doubt that fluoride in the drinking water produced recognizable dental changes under certain conditions. Dean et al (1942) established that the severity of dental fluorosis is positively correlated with fluoride content of water ingested during childhood. It has become evident that more places world-wide are faced with the problem of endemic dental fluorosis and the early investigators at the National Institute of Health in the U.S.A. associated places with volcanic soils to water with high F^- concentrations (Möller 1982).

1.5.1. Factors which influence the level of fluorosis.

Several factors determine the prevalence and severity of both skeletal and dental fluorosis. Among them the most important is the amount of fluoride in the drinking water. A positive relationship between the prevalence of dental fluorosis and the amount of fluoride in the drinking water was first reported by Dean 1942 et al. Recently it was computed that the association between F^- dose and dental fluorosis in the early studies of Dean et al. (1942) and in later reports (Richards et al. 1967, Butler et al. 1985, Fejerskov et al. 1990) was linear. While Zipkin et al. (1958) demonstrated a linear relationship between drinking water F^- level and F^- concentration of the human bone.

The effect of temperature was first reported by Galagan 1953; Galagan and Vermillion (1957) and later similar observations were made by Richards et al. (1967). These authors established that the mean annual temperature influenced the prevalence and severity of dental fluorosis. Increasing temperature increases body demand for fluids leading to higher fluoride ingestion and higher probability of dental fluorosis (Galagan and Vermillion 1953,1957). Climatic conditions (mean annual temperature, excessive day heat, high humidity and wind movement) influence individual water drinking habits leading to high amount of water intake. Galagan and Vermillion (1957) established that, in normal life conditions the amount of water drunk corresponded with temperature increase. Individual intrinsic factors also influence the water intake habits and therefore the amount of fluoride absorbed into the blood. Among them are: the body weight and size, physical exercise and the dietary constituents of the food eaten. Food rich in calcium and magnesium reduces the absorption of fluoride from the gastro-intestinal tract, since the elements combine with fluoride and form insoluble fluorides which can not easily be absorbed (Ericsson 1958).

Recently it was reported that subjects from high altitude exhibited higher prevalence and severe dental fluorosis than subjects from low altitude (Manji et al. 1986b). The effect of altitude on dental fluorosis has not been reported elsewhere, but has been demonstrated through

animal experiments that chronic hypobaric hypoxia even in substantial absence of F^- intake is capable of producing changes in enamel mineralization which resemble dental fluorosis (Angmar-Mansson et al. 1986). Acute exposure to reduced atmospheric pressure has been shown to affect the body weight, length, food intake and body composition of growing rats (Elia et al. 1985). Similar findings have been reported (Giglio et al. 1987) who demonstrated that simulated high altitude affected the body haematocrit, body weight and length and impeded tooth eruption of the rats. These animal studies provide support to the reported epidemiological findings by Manji et al. (1986b).

1.5.2. Dental Fluorosis in Tanzania.

The earliest reports on mottled enamel in East Africa were those of MacQuilan 1944 and the resolution of East African Dental Association Council 1949 (Manji and Kapila 1984). Other reports are by Schwartz (1952), Ockerse (1953), Grech and Latham (1964), Akpabio (1966) and Akinosi and Bulusi (1972). Recent reports are of Thylstrup and Fejerskov (1978), Thylstrup (1978) and Wenzel et al. (1982a).
In Tanzania reports on dental fluorosis have mainly been from the northern areas of Tanzania (Akpabio 1966, Grech 1966, Thylstrup 1978, Thylstrup and Fajerskov 1978 and Wenzel et al 1982,van Palenstein and Mkasabuni 1993).

It is undisputed that many people in the north of Tanzania experience dental fluorosis, but whether the observed levels are due to a single factor like the amount of fluoride in drinking water, which is cardinally considered to be the major cause of dental fluorosis in most populations or are a result of other factors acting alone or cumulatively has yet to be clarified.

An increasing number of reports have appeared from African countries indicating a higher prevalence and severity of dental fluorosis than would be expected from the levels of fluoride in the drinking water (Möller et al. 1970, Olsson 1978, Manji et al. 1986a, Brouwer et al. 1988, Grobler et al. 1988, Lewis et al. 1992, Ng'ang'a et al. 1993).

McClure 1947 demonstrated that certain foods and drinks contain relatively high F^- levels, among these are fish, ea, and wines. Besides foods and drinks application of F^- in its different forms has increased the risk increased F^- ingestion. In addition to F^- exposure via intentionally administered preventive preparations, the possible impact of a new, not yet identified F^- carrier can not be excluded.

The author in the course of the field work preceding data collection, found out that some populations in the study areas used a kind of a salt locally called "MAGADI'. A similar salt with high F^- content had been suggested by Mungure (1985), to be a possible cause of dental fluorosis. This salt is locally available in waters of the salt lakes in these areas and is used to speed the cooking time and as

a tenderizer for certain vegetables like beans and bananas. Magadi samples submitted for analysis showed that they consisted of trona, sodium carbonate, and sodium bicarbonate. In nature this salt can be heavily contaminated with F^- ions, mainly in volcanic areas.
For better understanding of the relationship between exposure and dental fluorosis, other F^- sources besides drinking water should be recorded in order to determine a more exact F^- intake. Furthermore plasma F^- levels are used as the most reliable fluoride bio-markers could be used to determine the levels or amount of F^- ingested. The disadvantage of this method is the difficulty to get cooperation in collecting blood samples from rural African populations. Since a linear relationship exists between the amount of F^- ingested to that excreted through urine (McClure and Kinser 1944), it was decided to collect urine samples and determine the F^- intake of individuals.

1.5.3. Fluorides and dental caries.

Fluoride compounds are widely applied in prevention of dental caries. The common vehicles of these compounds to man are naturally and artificially fluoridated drinking water, fluoridated table salt, fluoride tablets, mouth rinses and dentifrices. Following reports of scientists from the National Institute of Health in the U.S.A., F^- compounds received wide interest, starting with the work of

Dean who conclusively studied the relationship between F^- and dental caries (Dean 1938). In a very large study Dean et al. (1942) studied the caries experience in 12-14-year old children in twenty one cities of four states in the U.S.A. The fluoride levels in the drinking water ranged from 0.1 to 2.5 ppm in those cities. In this study it was found that children who lived in cities which had drinking water containing F^- at the level of 0.6 ppm F^- had 50% less caries compared to the children who lived in cities whose drinking water contained about 0.2 ppm F^-. In children whose drinking water had 1.2 ppm F^- they observed 60% less caries. When the amount of F^- was analyzed in relation to enamel mottling and caries reduction, a range of F^- concentration was found to exist through which no danger of socially unacceptable dental fluorosis was observed but the protection of teeth against dental caries was maximum. This cut-off point has since then been called "the optimal F^- concentration". At this level dental fluorosis is minimal and is not socially objectionable yet it provides maximum caries protection (Dean 1938). Following these reports, fluoridation of water with low natural fluoride to the optimum concentration was introduced first in the U.S.A (Arnold et al. 1962) and later in many European countries and New Zealand (Ludwig 1965). Studies conducted in 7-16-year-old children who used the artificially fluoridated drinking water from birth provided more evidence about caries reduction.

1.6. SKELETAL AND DENTAL FLUOROSIS IN TANZANIA.

This section attempts to review reported findings on skeletal and dental fluorosis in East Africa. East African countries have similar climatic and geographic features, especially Ethiopia, Kenya and Tanzania through which the Great Rift Valley caused by volcanic activity passes. Severe cases of dental fluorosis were reported by Akpabio (1966) in northern Tanzania. Water analysis in Arusha showed high fluoride levels up to 40 ppm. Thylstrup and Fejerskov (1978) reported severe cases of dental fluorosis in three communities of Arusha whose drinking water fluoride levels were 3.5, 6.0 and 21.0 ppm. Even cases of mottled primary teeth were found in these communities (Thylstrup 1978).In northern Tanganyika high prevalence of skeletal fluorosis was reported by Grech and Latham in 1964. In a study involving one hundred and nineteen 9-13-year old children in Arusha, Grech (1966) observed skeletal changes in the pelvis and lumbar vertebrae following radiological examination in two of the children. Similarly in another study conducted by Christie (1980) on 251 children and adolescents, he reported 23% knock knee, 17% bow legs and 12% saber shins in the children he investigated in northern Tanzania. Fluoride concentration in drinking water above 3 ppm fluoride has been found to affect all mineralizing tissues under formation (Wenzel et al. 1982 a). Since all the studies were carried out in an

area with extremely high fluoride in the drinking water, it is not surprising that dental and skeletal fluorosis was highly prevalent and severe. The effect of diet and climate have received little attention (Manji et al. 1986b, Brouwer et al. 1988).

1.7. STATEMENT OF THE PROBLEM, AIM AND OBJECTIVES OF THIS STUDY.

1.7.1. Statement of the problem.

The available information on skeletal and dental fluorosis in Tanzania is from studies conducted in northern Tanzania, mainly Arusha. While Arusha region is known for its high F^- levels in water, therefore the reported prevalence and severe fluorosis were to be expected. As mentioned before, most of the observed severe cases of dental fluorosis in East Africa are attributed to F^- levels in drinking water, and the other factor which was identified was the effect of altitude without questioning the possibility that other factors may exist. However it is questionable whether all dental fluorosis in Tanzania is due to water borne F^- since several studies elsewhere have shown a high prevalence and severity of dental fluorosis which can not be explained by the F^- in water sources (Möller et al. 1970, Olsson 1978, Manji et al. 1986a, Brouwer et al. 1988 Gobler et al. 1988, Lewis et al 1992, Ng'ang'a et al. 1993).

The role of dietary fluoride in the reported fluorosis levels has not adequately been investigated, although it still may be that the observed severe fluorosis is a result of cumulative effect of amount of fluoride in drinking water, dietary fluoride and the effect of altitude. In any case the assumption that, " the observed dental fluorosis in East Africa is caused mainly by drinking water" may be premature. To be able to understand the present status of dental fluorosis in Tanzania a more detailed study had to be conducted.

1.7.2. Aim of this study.

It is assumed that there are populations in Tanzania affected by dental fluorosis of which the cause is not or not fully understood. This study aims to investigate the relationship between water fluoride and dental fluorosis and to find out which factors influence the prevalence and severity of dental fluorosis in Tanzania.

1.7.3. Objectives of the study.

The following are the objectives of this study:

(a) to study the adequateness of the classification systems for the assessment of dental fluorosis.

(b) to investigate how increase in altitude influences the prevalence and severity of dental fluorosis.

(c) to study the distribution of dental fluorosis by tooth-type and the distribution of dental caries by tooth-type and surface pattern.

(d) to compare urinary fluoride excretion levels between populations with different prevalence and severity of fluorosis.

(e) to investigate the presence and effect of dietary fluoride.

(f) to establish the prevalence and severity of dental fluorosis for populations living in different climatic conditions in Tanzania.

(g) to study the prevalence of dental caries in relation to fluoride levels and prevalence and severity of dental fluorosis.

CHAPTER 2.

STUDY DESIGN, MATERIALS AND METHODS.

This chapter describes the general methodological approaches and materials which were used in this study.

2.1. IDENTIFICATION OF STUDY AREAS AND SELECTION CRITERIA.

The main objective was to study the prevalence of dental fluorosis in Tanzanian populations and to investigate its relationship to water fluoride and find out possible factors which may be playing a role in the occurrence of dental fluorosis.

The first step in implementing this study was to obtain the fluoride map of Tanzania from the Ministry of Energy, Mineral resources and Water. It was found out that there is no detailed fluoride map of Tanzania. Only scanty information was available for some areas whose fluoride concentration in few drinking water sources was roughly known. On the basis of this information, areas which had reasonable numbers of water sources with F concentrations ranging between 0.3 to about 1.1 ppm were noted.

Areas with higher than 1.1 ppm fluoride were not considered because the aim of this study was to investigate the relationship between low fluoride content in drinking water and associated factors such as altitude. Two regions, Tanga at sea level altitude and Singida region at 1500m altitude

were identified to be ideal for this study. Visits were then made to these regions to collect on-spot information regarding the available water sources and to collect water samples from them for fluoride analysis. Only permanent water sources with a history of continued use for at least 15 years were identified as acceptable for the study program. Several water samples were taken from these sources at various seasonal times of the year to determine the annual average.

Demographic data were collected from the Regional and District authorities regarding population settlement and migration. The selection criteria for the villages were that they should have stable populations with most of the people being born there, and the villages should be accessible throughout the year, have permanent water sources which have been in constant use for a period of at least 15 years and which are used throughout the year, the fluoride concentration of the water sources should range between 0.3 and 1.1 ppm.

In Tanga, 9 villages were identified for this study. These were Bawa, Boma Ndani, Moa and Zingibari in Muheza District and Kibinda, Mkwaja, Mwera, Pangani and Ushongo in Pangani District. In Singida Region, 10 villages were identified. These were five villages from Singida District which were Kinyeto, Kintuntu, Ntunduu, Sepuka and Puma and 5 villages from Iramba District which were Kyengenge, Lulumba, Kiomboi Bomani, Old Kiomboi and Salala.

2.2. SELECTION OF SUBJECTS.

This section explains the different groups of subjects which were used to collect relevant data related to the different planned studies that is :

(a) Dental fluorosis and dental caries

(b) Dietary habits in the study areas related to F^- intake

(c) Estimation of fluoride intake and fluoride excretion.

To study the prevalence and severity of dental fluorosis and dental caries, the primary school in each study village formed the sampling unit. The study population consisted of all children in classes 3 to 7 in the primary schools of the villages. 10 - 20% of all children who in their history had lived outside the village for a period of 6 months or more were excluded from this study.

A total of 1559 whose age ranged from 11 to 18 years who were born, grown and had lived almost entirely in the selected villages formed the target population.

All children who participated in the study were examined for dental fluorosis, and dental caries. All selected children present at school at the day of examination were prepared to participate in the study. Age and sex distribution of the children is shown in Table 2.1.

Table 2.1 Age and sex distribution of children according to altitude and study areas.

Age	Sea level				1500 M. altitude				Total
	Tanga		Muheza		Singida		Iramba		
	♂	♀	♂	♀	♂	♀	♂	♀	
11 and 12	18	52	24	42	17	54	26	40	273
13 and 14	45	83	79	68	96	141	68	97	677
15 and 16	16	16	36	26	107	109	83	93	486
17 and 18	3	0	9	5	38	25	25	18	123
Total	82	151	148	141	258	329	202	248	1559

2.3. ASSESSMENT AND SCORING OF DENTAL FLUOROSIS.

Dental fluorosis was examined and scored according to both Dean's Index (DI), (Dean 1942) and the Thylstrup and Fejerskov Index (TFI), (Thylstrup and Fejerskov 1978). Two examiners performed the clinical examinations, each using only one of the two diagnostic criteria throughout the study. Dental fluorosis was first assessed with DI.
As it is customary with the DI no attempt was made to dry the teeth. Then dental fluorosis was assessed by using the TFI. Before the oral examination was started using the TFI, all teeth in the mouth were cleaned, wiped with cotton wool and left to dry for about two minutes before dental fluorosis was scored. All examinations were conducted using a plane mouth mirror and a probe in natural daylight in the shadow of a tree. The fluoride concentrations of water sources used by the examined persons were not known at the time of clinical examination. Table 2.2 shows the diagnostic criteria according to Dean's classification of dental fluorosis and Table 2.3 shows the diagnostic scores according to TFI.

Table 2.2. Dean's index of dental fluorosis.

Score.	Category	Descriptive explanation
0	"Normal"	Enamel presents the usual translucent semivitriform type of structure. The surface is smooth, glossy, and usually of creamy white colour.
0.5	"Questionable"	The enamel discloses slight abberations from the translucency of normal enamel, ranging from a few flecks to occasional white spots. This classification is utilized in those instances where a definite diagnosis of the mildest form of fluorosis is not warranted and a classification of "normal" not justified.
1	"Very mild"	Small, opaque, paper white areas scattered irregularly over the tooth but not involving as much as approximately 25% of the tooth surface. Frequently included in this classification are teeth showing no more than about 1 - 2 mm of white opacity at the tip of the summit of the cusps of the bicuspids or second molars.
2	"Mild'	The white opaque area in the enamel of the teeth are more extensive but do not involve as much as 50% of the tooth.
3	"Moderate"	All enamel surfaces of the teeth are affected, and surfaces subject to attrition show marked wear. Brown stain is frequently a disfiguring feature.
4	"Severe"	All enamel surfaces are affected and hypoplasia is so marked that the general form of the tooth may be affected. The major diagnosis is the discrete or confluent pitting. Brown stains are widespread and the teeth often present a corroded-like appearance.

Table 2.3. The TF-index of dental fluorosis.

Score	Descriptive explanation
0	Normal translucency of the glossy creamy-white enamel remains after wiping and drying.
1	Thin white opaque lines are seen running across the tooth surface. Such lines are found on all parts of the surface. The lines correspond to the position of the perikymata. In some cases, a slight "snow capping" of cusps /incisal edges and cusp tips is common.
2	The opaque white lines are more pronounced and frequently merge to form small cloudy areas scattered over the whole surface. "Snow capping" of incisal edges and cusp is common.
3	Merging of white lines occurs, and cloudy areas of opacity occur spread over many parts of the surface. In between the cloudy areas white lines can be seen.
4	The entire surface exhibits marked opacity, or appears chalky white. Parts of the surface exposed to attrition or wear may appear to be less affected.
5	The entire surface is opaque, and there are round pits (focal loss of outer-most enamel) that are less than 2 mm in diameter.
6	The small pits may frequently be seen merging in the opaque enamel to form to form bands that are less than 2 mm in vertical height. In this class are included also surfaces where the cuspal rim of facial enamel has been chipped off, and the vertical dimension of the resulting damage is less than 2 mm.
7	There is a loss of outermost enamel in irregular areas, and less that half of the surface is so involved. The remaining intact enamel is opaque.
8	The loss of the outermost enamel involves more than half the enamel. The remaining intact enamel is opaque.
9	The loss of the major part of the outer enamel results in a change of the anatomical shape of the surface/tooth. A cervical rim of opaque enamel is often noted.

2.4. ASSESSMENT OF DENTAL CARIES.

All the children who were examined for dental fluorosis were also examined for dental caries conditions. The Marthaler (1966) criteria were used to diagnose and score dental caries as presented in Table 2.4 Caries conditions which could reverse through re-mineralization (scores 1 and 2 for white and brown enamel lesions) were not recorded.

Table 2.4. Scoring criteria for dental caries (Marthaler 1966).

Score	Descriptive explanation
0	Sound enamel
1	Enamel lesion (white in colour)
2	Enamel lesion (brown in colour)
3	Dentinal lesion
4	Pulpal lesion
5	Tooth with a permanent filling
6	Tooth missing due to caries
7	Tooth missing due to other reasons than dental caries
8	Unerupted tooth
9	Tooth extracted for other reasons than dental caries e.g. orthodontic treatment.

2.5. ESTIMATION OF FLUORIDE INTAKE

The frequency of ingestion and amount consumed of fluoride containing foods (mainly tea, fish and magadi) was assessed. In the same way the frequency of drinking milk was investigated. Three types of sample groups were used to provide this information with the aid of recall questionnaires. These groups were (a) school children, (b) mothers of 2-to 5-year-old children who attended the village Mother and Child Health Clinic at the Village dispensary and (c) mothers of the 2-to 5-year-old children who participated in the urinary fluoride excretion study.

2.5.1. One week dietary history by school children.

The school children in the fluorosis study were asked to respond to a seven-day recall questionnaire. The purpose of the questionnaire was to obtain general information on the availability and frequency of intake of foods and drinks which could contribute to increased fluoride ingestion especially tea, fish and magadi.

The children were requested to recall types of foods and drinks which were common in the daily lives of the households they came from. Whenever the child said that any or all types of foods/drinks were common in the family, then he or she was asked to remember how many times during the one-week study period he/she had eaten or drank them.

2.5.2. 24-hour interview for mothers.

Mothers of children who were born in these villages and had not moved away or stayed outside these villages for more than six months and over were asked to come to the village health post. Over 90% of the mothers were prepared to cooperate. The questionnaire was designed to provide information on the different foods and drinks which the children consume that could contain high amounts of fluoride and therefore become sources of fluoride to the study populations.

The mothers who attended the M.C.H.-Clinic were requested to respond to a 24-hour recall dietary questionnaire. They were asked to recall all the different types of food and drinks they had prepared for the family the previous day starting from the first meal in the morning to last meal in the evening. The purpose of this questionnaire was to obtain a better understanding regarding the types of foods and drinks used by each of the study population and to compare the reliability of information collected from both the school children and these mothers. Comparison of information from school children and mothers was possible since girls in Tanzania start participating in food preparation from the age of about 11 to 13 years.

2.5.3. 24-hour dietary record.

Village health posts were used as the sampling unit for families with children aged between 2 to 5 years in the study villages. A list of families which had children with age ranging from about 2 and 5 years was therefore obtained from the village health post. In order to assess the F-excretion of the 2- to 5- year- old children as a reflection of the amount of fluoride ingested through foods and drinks, the mothers were requested to keep a strict record concerning all the food and drinks their children consumed on the day when the urine was being collected. This information was collected with the aid of a similar questionnaire as the one used in section 2.5.2

2.6. COLLECTION OF WATER SAMPLES.

From each of the identified and selected water sources serving the study populations, samples of water were collected at regular intervals. From Tanga samples were collected from February 1988 until October 1989.
From Singida and Iramba samples were collected from August 1988 until July 1990. In certain instances, water samples could not be collected from some sources either due to inaccessibility during the heavy rains or wells had no water in the dry season. An annual average of the fluoride concentration from the sources was calculated.

2.7. COLLECTION OF URINE SAMPLES.

Urine samples were collected from children aged from about 2 years to 5 years old in each of the study villages. Mothers were asked for their consent and also cooperation in supervising the collection of urine. From each family only one child participated in this study. For practical reasons only families close to the dispensary were asked to cooperate in the urinary study. Because of either children wetting in bed and/or doubtful cooperation from the mothers it was difficult to collect 24 hours urine.

The urine which was excreted before breakfast, was not colected, only after breakfast urine was collected for the whole day until the child went to bed. Urine before breakfast was not considered to reflect previous day's fluoride ingestion. Later amounts of fluoride excreted were estimated from the urine samples which were collected from the 2-to 5-years old children. Table 2.5 shows the distribution of children according to area and age in months.

Table 2.5. Area and age distribution of children in the urine study.

District	Location	Age					Total
		< 2 years	2- < 3 years	3 - < 4 years	4 - < 5 years	5 years	
Tanga	Mkwaja	-	1	8	14	3	26
	Ushongo	-	4	10	4	-	18
Muheza	Boma ndani	5	3	10	4	4	26
Singida	Sepuka	1	1	7	9	2	20
	Kinyeto	-	-	7	11	2	20
Iramba	Kiomboi	-	3	10	16	4	33

2.8. COLLECTION OF MAGADI SAMPLES.

Samples of magadi were collected from households in the study areas. In Tanga no samples of magadi were collected since magadi are not used there. In Singida magadi samples were collected from two locations from the five locations from where the study samples were drawn. From Iramba, magadi samples were collected from Kiomboi (an agglomeration of 4 locations i.e. New Kiomboi, Old Kiomboi, Lulumba and Salala). Because of local taboos it was not possible to get samples from all the mothers as initially planned. In this respect additional samples were collected from market places of the villages.

2.9. F^- ANALYSIS IN WATER, URINE AND MAGADI SAMPLES.

The specific ion electrode was used to determine the fluoride ion concentration in water, urine and magadi according to the method designed by Frant and Ross (1966). Reagents which were used are; a stock solution of 100mg/l NaCl from which standards were made with appropriate dilutions and Total Ionic Strength Adjusting Buffer (TISAB). All these chemicals were kept in plastic bottles. The laboratory procedure for water and urine F^- ion measurements was done as follows: 25 ml of the water/urine sample was transferred into a 100 ml plastic beaker using a 25 ml capacity measuring cylinder and then a magnetic rod was put into the beaker. After rinsing the cylinder, 25ml of TISAB solution were measured and also transferred into the beaker containing the water/urine sample. Then the beaker was put on a magnetic stirrer. The electrode was lowered very slowly so that the tip was not touching the magnetic rod. The sample and the TISAB solutions in the beaker were stirred and finally the concentration of fluoride in the sample was read when the meter reading was steady. The actual figure in mg/l was obtained with the help of a standard curve. In the case of magadi 5 grams were dissolved in 100 ml of distilled water. The resulting solution was then analyzed for fluoride ion concentration following the same procedure as was done for water and urine samples as described.

CHAPTER 3.

RESULTS.

3.1 CLINICAL METHODOLOGICAL DIAGNOSTIC CONSIDERATIONS.

3.1.1. Reproducibility.

Figures 3.1 to 3.4 present the observed dental fluorosis scores in the three different sub-populations.

For assessment of reproducibility, no differentiation regarding F^- exposure and degree of fluorosis was made. Later it was considered feasible to separate the three sub-samples with respect to area in order to show the distribution and the severity of fluorosis according to area and thus to judge the suitability of the two indices according to F^- exposure.

Reproducibility of the indices was studied in two ways: the scale points are considered as ordinal measurement and Kappas values were calculated, secondly the scales are considered as metric measurements and the duplicate measurement errors were calculated. Since the indices, particularly the DI are supposed to have an ordinal scale the weighted Kappa are much better than the unweighted Kappa. The reproducibility for anterior and posterior teeth are well comparable and are characterized as the same (Landis and Koch 1977) (Table 3.1). The duplicate

measurement error was calculated separately for jaw type (maxilla or mandible) and region (anterior or posterior) and was analyzed using ANOVA. No significant differences were detected between jaws or regions for both DI and TFI (all $P > 0.50$). This implied that for both indices one overall error could be calculated, which resulted in duplicate errors of 0.53 for the DI (6 scale points) and 0.50 for the TFI (10 scale points).

Table 3.1. Kappa values as measure of agreement between duplicate examinations using the DI in 75 children and the TFI in 111 children and the duplicate error.

Kappa coefficient	DI	TFI
Overall Kappa	0.69	0.70
Weighted Kappa	0.83	0.87
Weighted Kappa (anterior)	0.84	0.87
Weighted Kappa (posterior)	0.82	0.86

Since there are situations where the subject instead of the tooth is used as the unit of analysis, the reproducibility of both indices was also computed on mouth level.

A mouth score would be the proportion of teeth having a defined severity of dental fluorosis, for example teeth having DI ≥ 0.5, score ≥ 1, etc. Tables 3.2 and 3.3 present the proportion of teeth per subject with a difference in score between duplicate measurements and the measurement - remeasurement correlation for DI and the TFI respectively. When the DI was applied on teeth with fluorosis, the percentage of errors was 8.4% (Table 3.2) whereas the TFI resulted in 4.5% errors (Table 3.3). Generally the occurrence of errors in TFI was somewhat lower than in DI, which was also reflected in the measurement remeasurement correlation.

Table 3.2. Percentage of affected teeth per subject (N = 75) with a difference in DI score between duplicate measurements and the correlation coefficient of the duplicate measurements.

DI criterion for affected teeth	% affected teeth with different scores	Measurement- remeasurement correlation
≥ 0.5	8.4	0.89
≥ 1	7.5	0.91
≥ 2	7.5	0.95
≥ 3	8.2	0.95
4	4.2	0.98

Table 3.3. Percentage of affected teeth per subject (N = 111) with a difference in TFI score between duplicate measurements and the correlation coefficient of the duplicate measurements.

TFI criterion for affected teeth	% affected teeth with different scores.	Measurement-remeasurement correlation
≥ 1	4.5	0.97
≥ 2	7.3	0.96
≥ 3	6.7	0.97
≥ 4	8.3	0.96
≥ 5	3.9	0.99
≥ 6	5.4	0.96
≥ 7	3.6	0.94
≥ 8	1.5	0.98
9	0.7	0.99

3.1.2. Correspondence between DI and TFI.

Comparison of the DI and the TFI was made on the basis of 1155 children and 30627 tooth-surfaces. The corresponding relationship between the DI and TFI is depicted in Table 3.4 which shows the prevalence of teeth with a DI score in cross tabulation with the TFI score. The large majority of teeth with DI scores of > 0 resulted in higher TFI scores. In contrast no teeth with a TFI score > 0 gave higher DI scores. The proportional distribution of each DI score into the TFI and the conversion values are shown in Table 3.5. The large majority of DI score 0 corresponded with TFI score 0. Dean's questionable score corresponded mainly with TFI scores 1 and 2, whereas the large majority of Dean's very mild score 1 and mild score 2 corresponded with one or two higher scores of TFI. Dean's moderate score 3 corresponded mainly with TFI score 4 whereas Dean's score 4 corresponded with TFI scores 5 - 9. Table 3.6 shows the inverse relationship where each TFI score is distributed into DI with accompanying conversion values. TFI score 0 corresponded to the DI score 0. The majority of TFI score 1 fitted in DI score 0 and the remaining into questionable and very mild scores. Majority of TFI score 2 fitted in DI's very mild and the rest into questionable and no fluorosis scores. TFI score 3 and 4 corresponded to one or two lower DI scores. TFI 5 - 9 corresponded to DI score 4.

Table 3.4. Cross tabulation between DI and TFI scores.

	Dean Index scores						
TFI scores	0	0.5	1	2	3	4	Total teeth
0	46.4	0.2	0.1				14347
1	3.2	1.4	1.0				1730
2	1.6	1.0	4.9	0.3			2416
3	0.3	0.2	5.1	3.8	0.2		2945
4			0.8	3.4	3.8		2459
5						12.2	3748
6						5.7	1763
7						2.3	696
8						1.1	350
9						0.6	173
N° of teeth	15787	895	3696	2293	1226	6730	30627

Table 3.5. Percentage distribution of DI scores into TFI and conversion value of each DI scores into a TFI score.

	Dean Index scores					
TFI scores	0	0.5	1	2	3	4
0	90.2	7.1				
1	6.1	50.1	8.8			
2	3.7	35.7	41.0	4.0		
3		7.1	42.2	50.7	6.1	
4			7.0	45.3	93.9	
5						55.7
6						26.0
7						10.5
8						5.0
9						2.7
Conversion values	0.1	1.4	2.5	3.4	4.0	*

*Conversion value depends on fluoride exposure.

Table 3.6 shows the inverse relationship where each TFI score is proportionally distributed into DI with accompanying conversion values. The TFI score 0 corresponded with the DI score 0. The majority of TFI score 1 fitted in DI score 0 and the remaining into questionable and very mild scores. The majority of TFI score 2 fitted in DI very mild score and the rest into DI questionable and no fluorosis scores. TFI score 3 and 4 corresponded with one or two lower scores of DI. TFI 5 - 9 corresponded with DI score 4.

Table 3.6. Percentage distribution of TFI scores in to DI and conversion value of each TFI score into a DI score.

	Thylstrup/Fejerskov Index Scores					
DI scores	0	1	2	3	4	5-9
0	99.2	56.0	20.8	2.7		
0.5	0.5	25.6	12.5	2.3	0.6	
1	0.3	18.4	62.8	53.0	10.5	
2			3.9	39.5	42.1	
3				2.5	46.8	
4						100
Conversion values	0	0.3	0.8	1.4	2.4	4

3.1.3. DI and TFI as instruments in dental fluorosis surveys.

To determine the suitability of the DI and TFI in assessing dental fluorosis in a population, both indices were applied on three communities with different F^- exposure. Tanga the low fluorosis area showed a skewed distribution of teeth according to severity of dental fluorosis for both the DI and the TFI (Fig.3.1). Iramba the high fluorosis area exhibited a normal distribution of teeth exclusively for the TFI while the DI showed a skewed distribution (Fig.3.3). Singida the moderate fluorosis area showed a skewed distribution of teeth for both the DI and the TFI (Fig. 3.2). The combined data from the three communities presented in Fig. 3.4 showed a bimodal distribution of teeth according to TFI and an irregular distribution pattern for DI. In the community with minor dental fluorosis, 3% and 11% of the teeth exhibited fluorosis according to the DI and TFI respectively. In the community with moderate dental fluorosis 36% and 46% of the teeth exhibited fluorosis according to the DI and the TFI. In the community with severe dental fluorosis 95% and 98% of the teeth showed fluorosis according to the DI and TFI respectively.

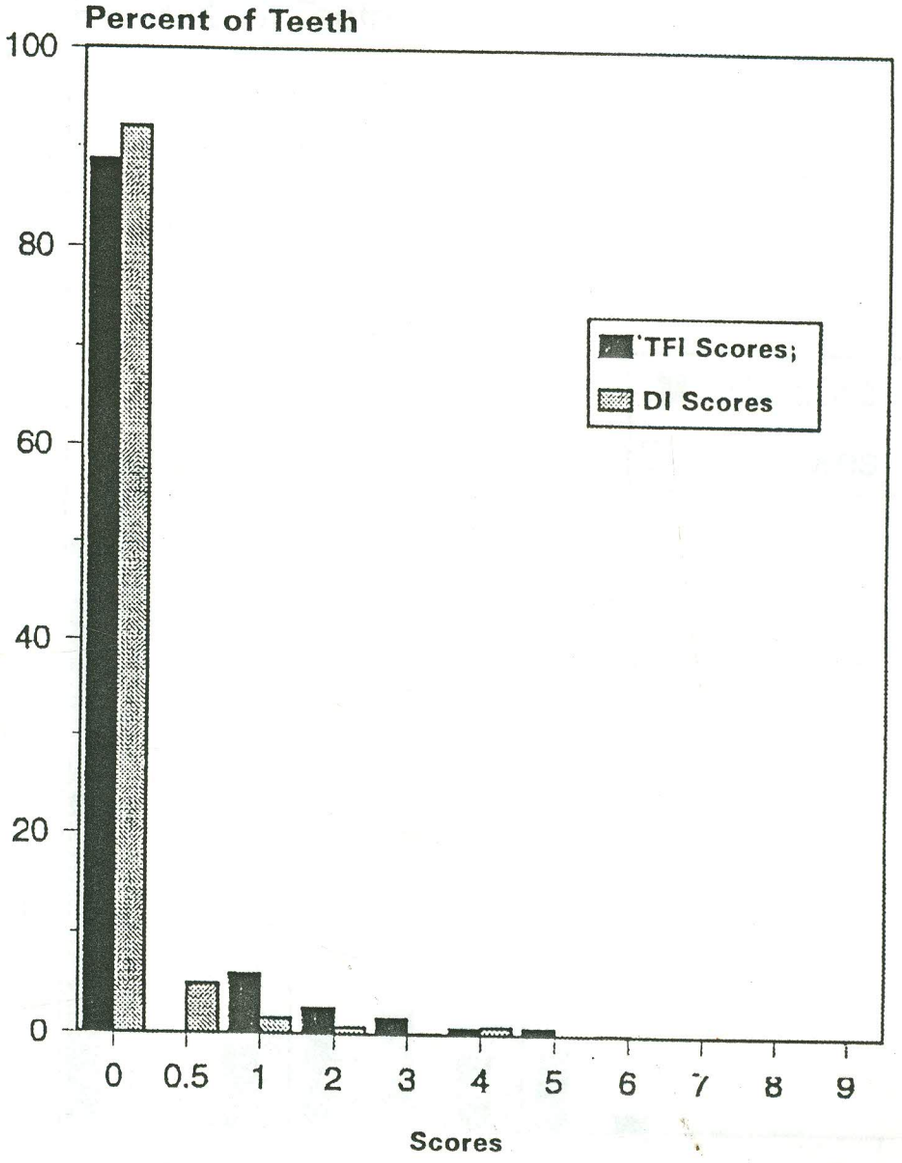


Figure 3.1. Distribution of teeth according to TFI and DI scores in Tanga.

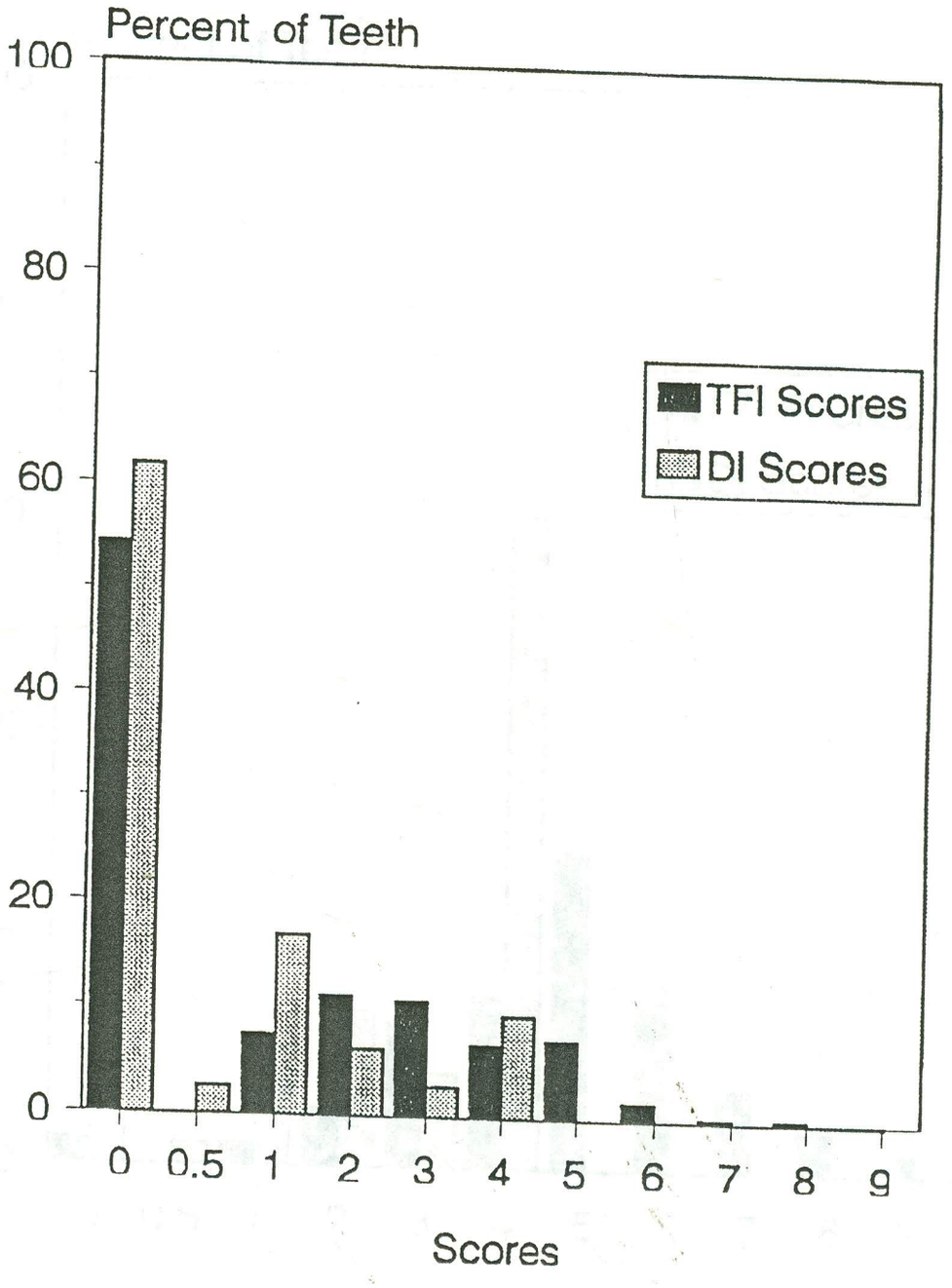


Figure 3.2. Distribution of teeth according to TFI and DI scores in Singida.

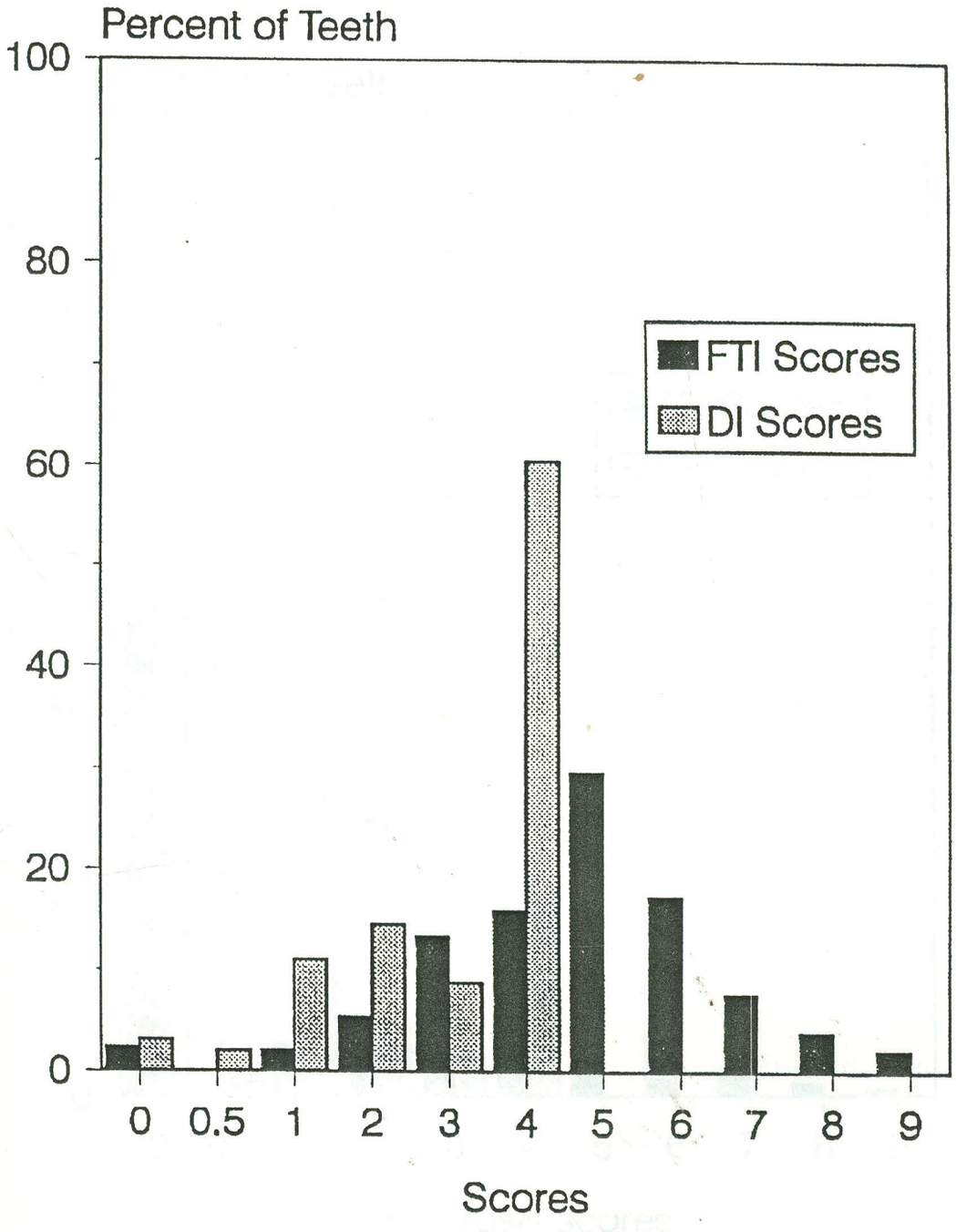


Figure 3.3. Distribution of teeth according to TFI and DI scores in Iramba.

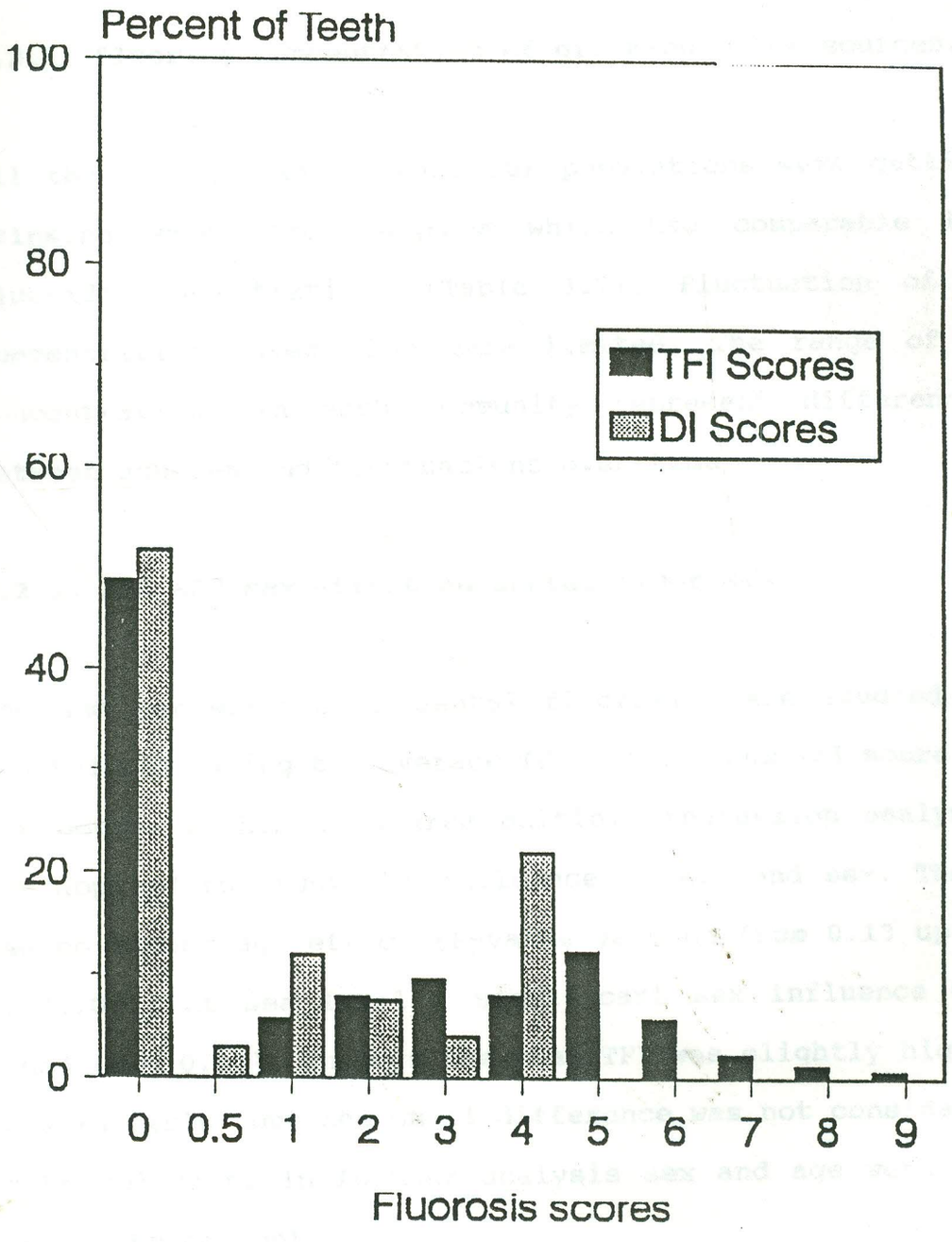


Figure 3.4. Distribution of teeth according to TFI and DI scores from all the three areas.

3.2. DENTAL FLUOROSIS RELATED TO WATER FLUORIDE, DIETARY FLUORIDE AND ALTITUDE.

3.2.1. Fluoride concentration of drinking water sources.

All the communities in the four populations were getting drinking water from sources which had comparable low fluoride concentrations (Table 3.7). Fluctuation of F^- concentrations over time were limited. The range of F^- concentrations in each community represent differences between sources and fluctuations over time

3.2.2. Age and sex effect on dental fluorosis.

Age and sex effects on dental fluorosis were studied at mouth-level using the average TFI and maximum TFI score of the mouth. Within each area multiple regression analysis was applied to study the influence of age and sex. There was no linear age effect (P-value varying from 0.13 up to 0.80).Only at sea level a significant sex influence was found ($P < 0.02$). In boys the mean TFI was slightly higher than in girls, but the small difference was not considered to be relevant. In further analysis sex and age were not taken into account.

Table 3.7. Fluoride concentration in drinking water sources (range, average and median) at different locations within the communities of the four study areas.

Area	Community	Number		Range	Average	Median
		Sources	Samples			
Pangani	Kibinda	2	8	0.1 - 0.4	0.2	0.1
	Mkwaja	8	36	0.1 - 0.9	0.4	0.3
	Ushongo	4	20	0.1 - 1.0	0.6	0.6
	Pangani(Boza)	2	5	0.2 - 0.7	0.3	0.2
	Mwera	1	3	0.1 - 0.2	0.2	0.2
Muheza	Bawa	3	7	0.1 - 0.6	0.3	0.3
	Boma	8	18	0.4 - 1.1	0.8	0.8
	Zingibari	3	6	0.1 - 0.5	0.3	0.3
	Moa	3	5	0.2 - 0.8	0.3	0.4
Singida	Kinyeto	11	44	0.2 - 1.3	0.6	0.4
	Ntunduu	9	35	0.2 - 1.3	0.5	0.3
	Sepuka	8	24	0.1 - 0.9	0.6	0.4
	Kintuntu	8	16	0.1 - 1.4	0.4	0.0
	Puma	5	12	0.5 - 1.2	0.7	0.8
Iramba	N.Kiomboi	4	7	0.3 - 1.3	0.6	0.5
	O.Kiomboi	5	8	0.2 - 1.9	0.8	0.6
	Lulumba	6	6	0.1 - 0.7	0.4	0.4
	Kyengege	4	4	0.5 - 0.6	0.6	0.6

3.2.3 Prevalence of dental fluorosis in the study areas.

Analysis of the prevalence and severity of dental fluorosis between the Muheza and Pangani populations revealed non significant differences and are therefore presented as one group under the name of Tanga.

The prevalence of dental fluorosis was found to be 22.8% in Tanga, 72.0% in Singida and 99.3% in Iramba (Figure 3.5). The proportion of teeth having TFI scores ≥1, ≥3, ≥4, ≥5, and ≥7 within each child was higher in Iramba and lowest in Tanga (Figures 3.5, 3.6, 3.7, 3.8, and 3.9). The prevalence of severe dental fluorosis (TFI ≥ 5) in Tanga was 2.0%, in Singida 28.9% and in Iramba 92.0% (Figure 3.8). The percentage of children with 50% or more of their teeth having TFI score ≥ 3 was about 2.0% in Tanga, 27.6% in Singida and 95% in Iramba (Figure 3.6). Children having TFI score ≥ 5 in 50% or more of their dentition were non-existent in Tanga, whereas 9.0% in Singida and 62.8% in Iramba were found (Figure 3.8). In Iramba 10.0% of the children had TFI score ≥ 7 in 50.0% or more of their dentition whereas none of the children in Tanga and Singida exhibited such a condition (Figure 3.9).

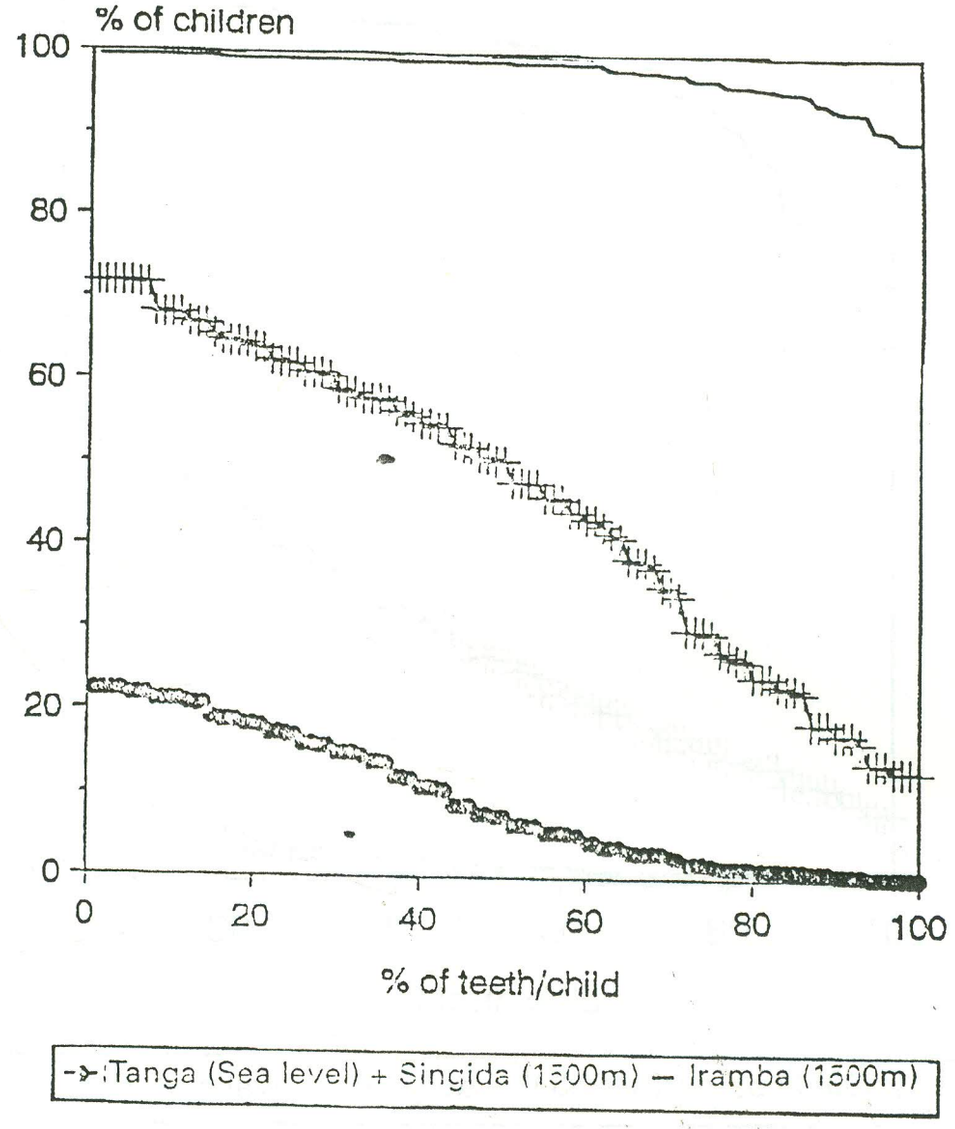


Figure 3. 5. Cumulative frequency distribution of children according to the proportion of teeth per child exhibiting TFI ≥1.

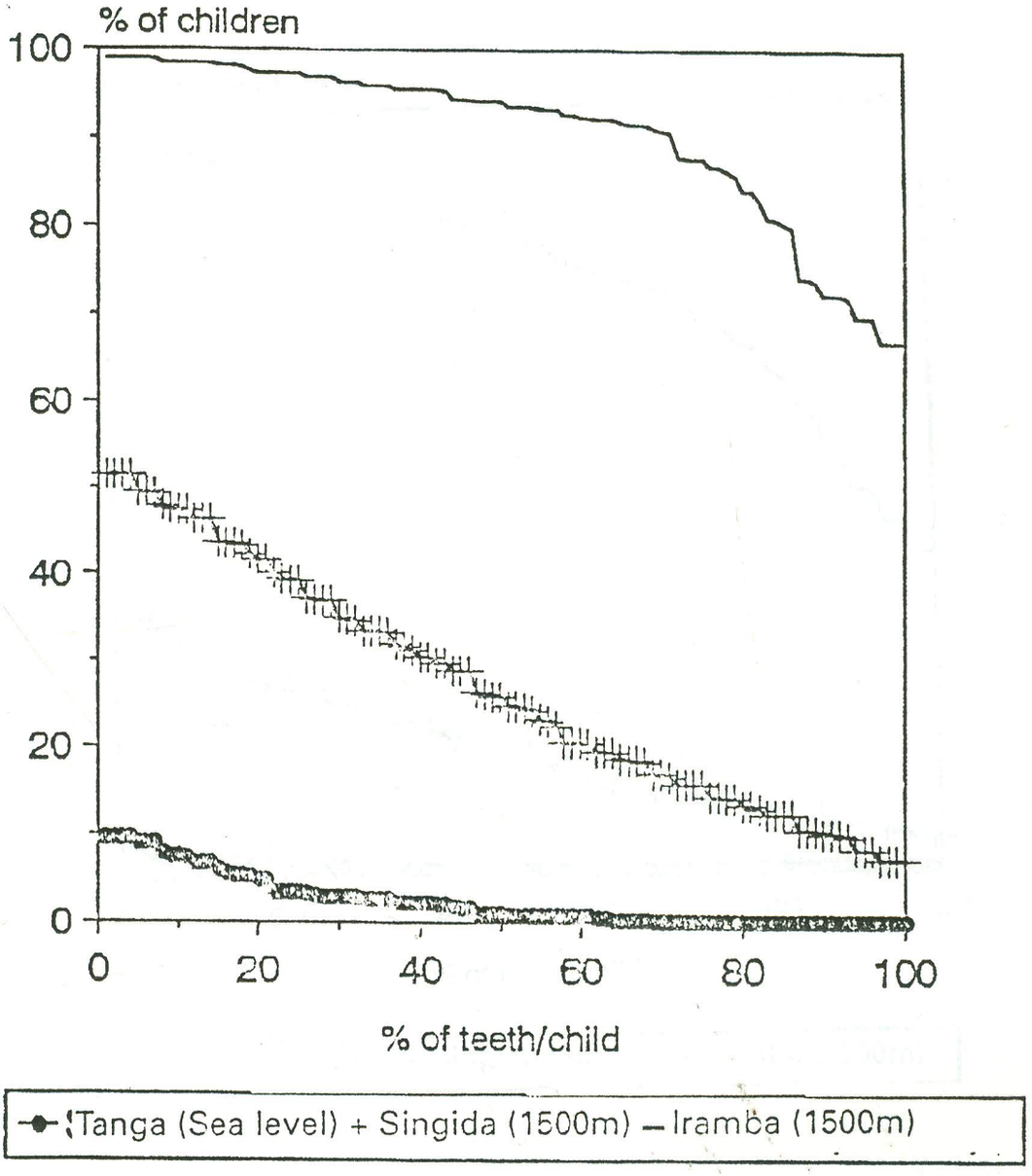


Figure 3.6. Cumulative frequency distribution of children according to the proportion of teeth per child exhibiting TFI ≥3.

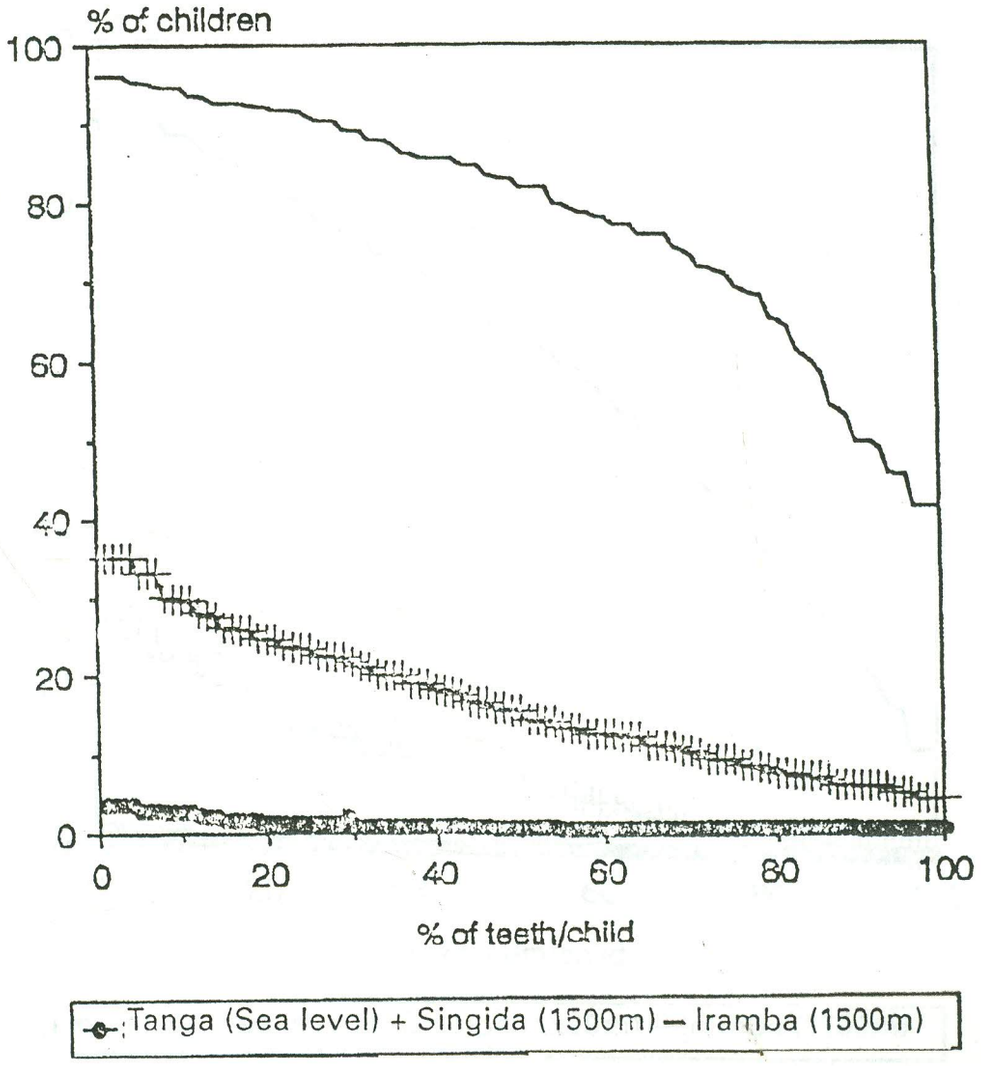


Figure 3.7. Cumulative frequency distribution of children according to the proportion of teeth per child exhibiting TFI ≥4.

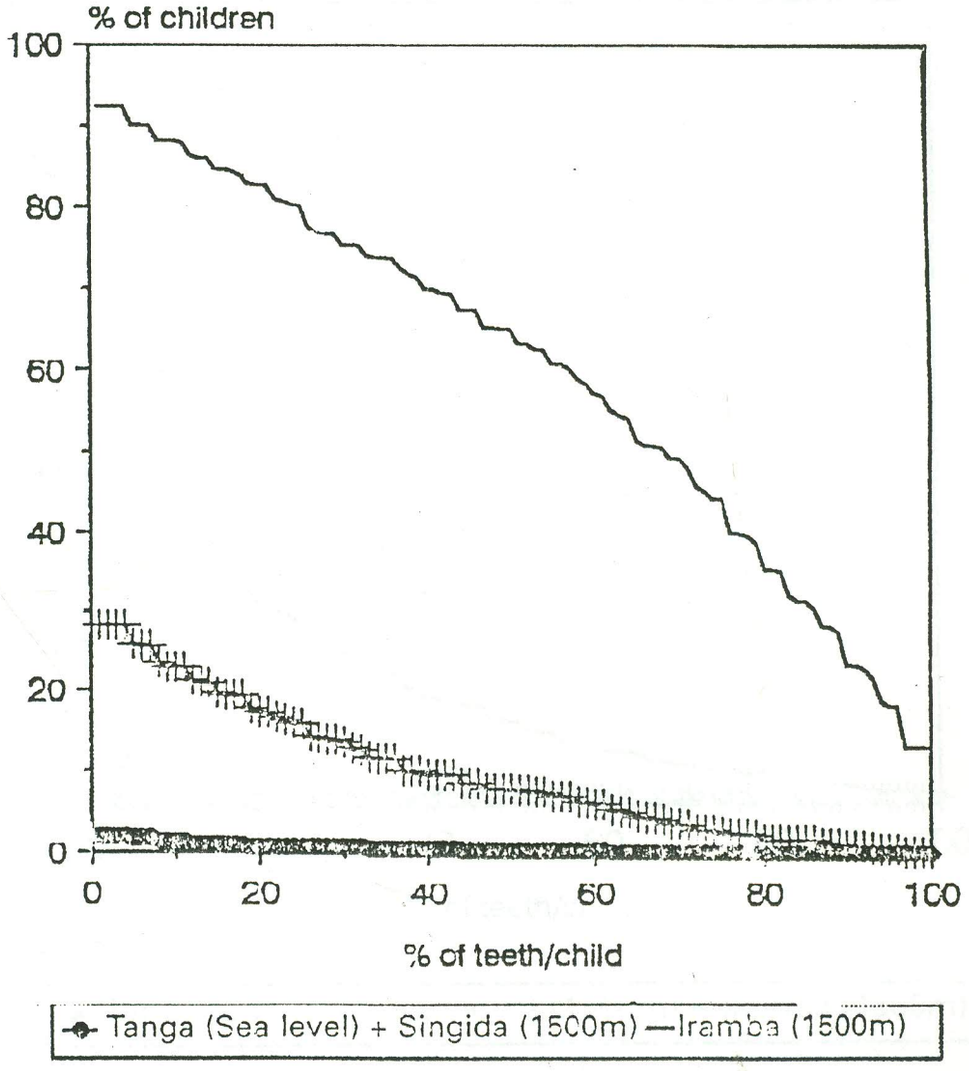


Figure 3.8. Cumulative frequency distribution of children according to the proportion of teeth per child exhibiting TFI ≥5.

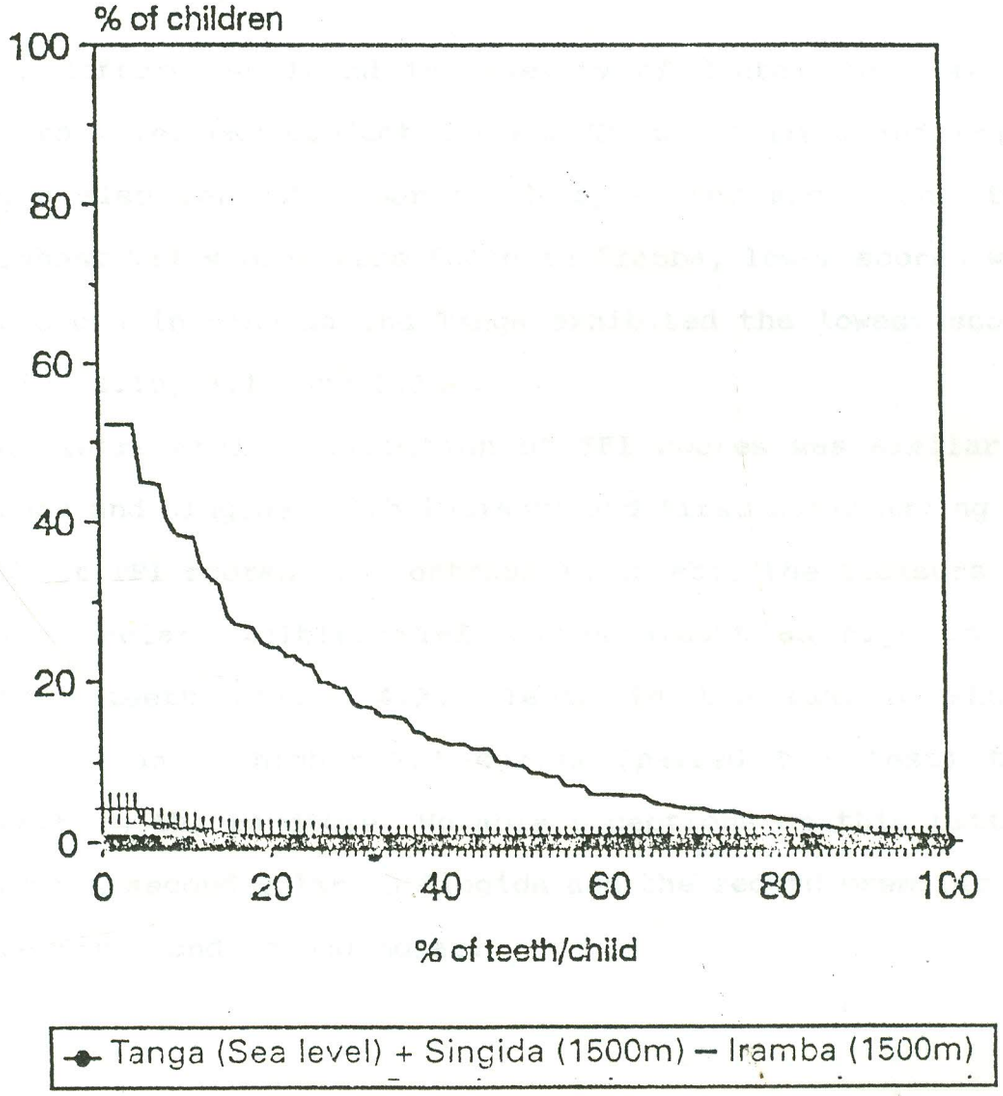


Figure 3 9 Cumulative frequency distribution of children according to the proportion of teeth per child exhibiting TFI ≥7.

3.2.4 Dental fluorosis and tooth-type distribution.

The differences found in severity of dental fluorosis on mouth level per subject between Tanga, Singida and Iramba were also reflected per tooth type. For each tooth type highest TFI scores were found in Iramba, lower scores were recorded in Singida and Tanga exhibited the lowest scores (Fig. 3.10, 3.11 and 3.12).

The intra oral distribution of TFI scores was similar in Tanga and Singida, with incisors and first molar having the lowest TFI scores. In contrast in Iramba, the incisors and first molar exhibited TFI scores almost as high as the other teeth (Table 4.2). Teeth in the maxilla showed significantly higher TFI scores (paired t - test) than teeth in the mandible. Notable exceptions on this pattern was the second molar in Singida and the second premolar and the first and second molar.

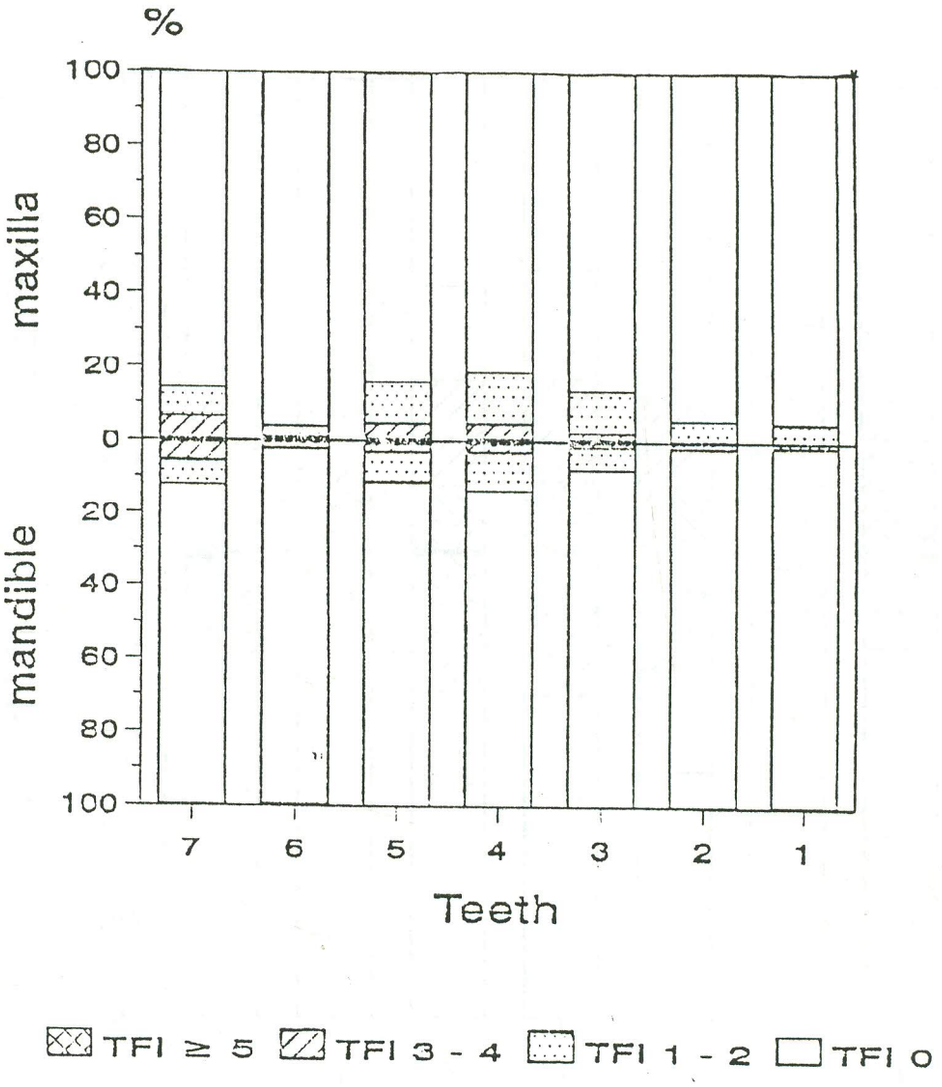


Figure 3 .10. Frequency distribution of TFI scores according to tooth type in children from Tanga.

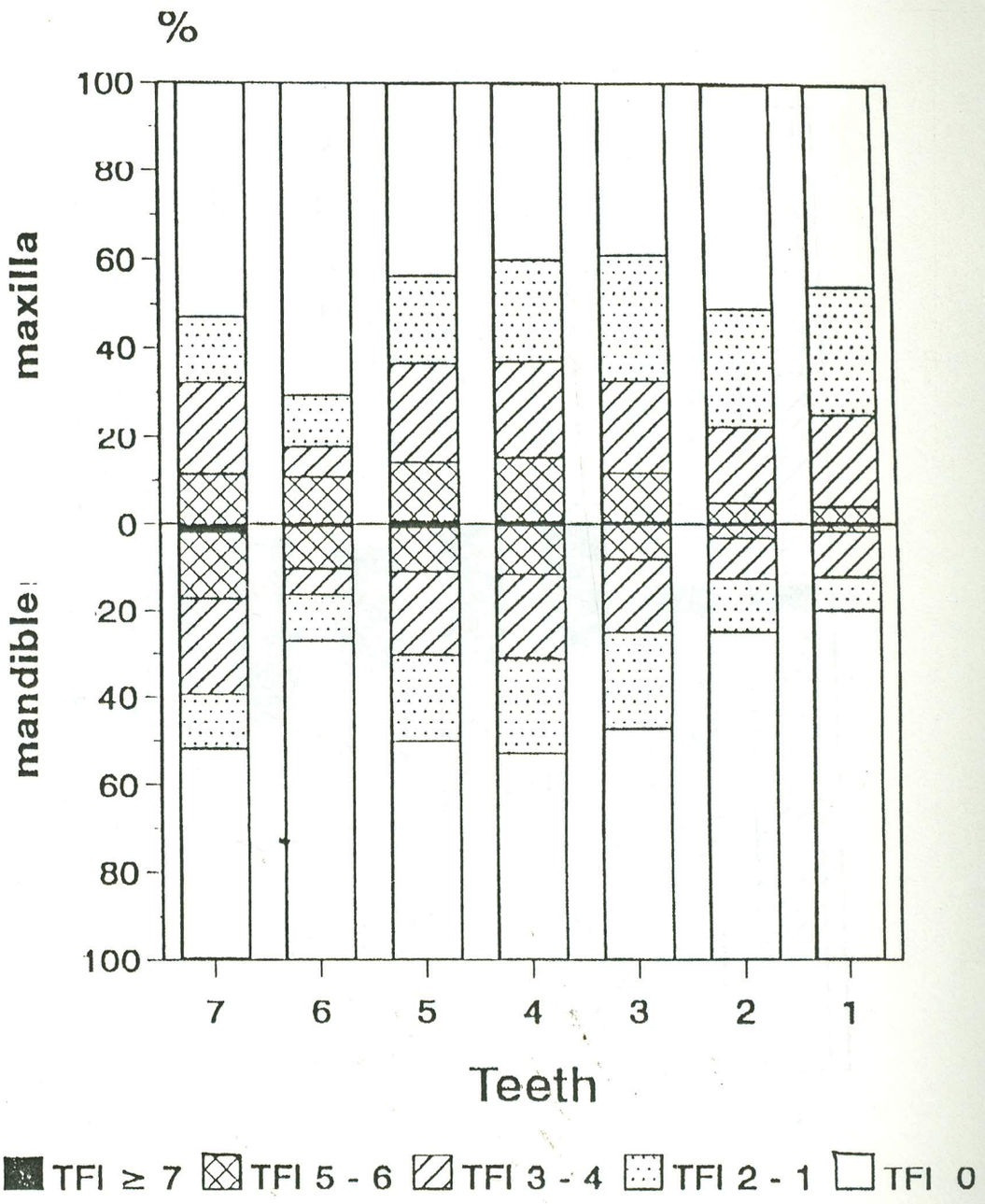


Figure 3.11. Frequency distribution of TFI scores according to tooth type in children from Singida.

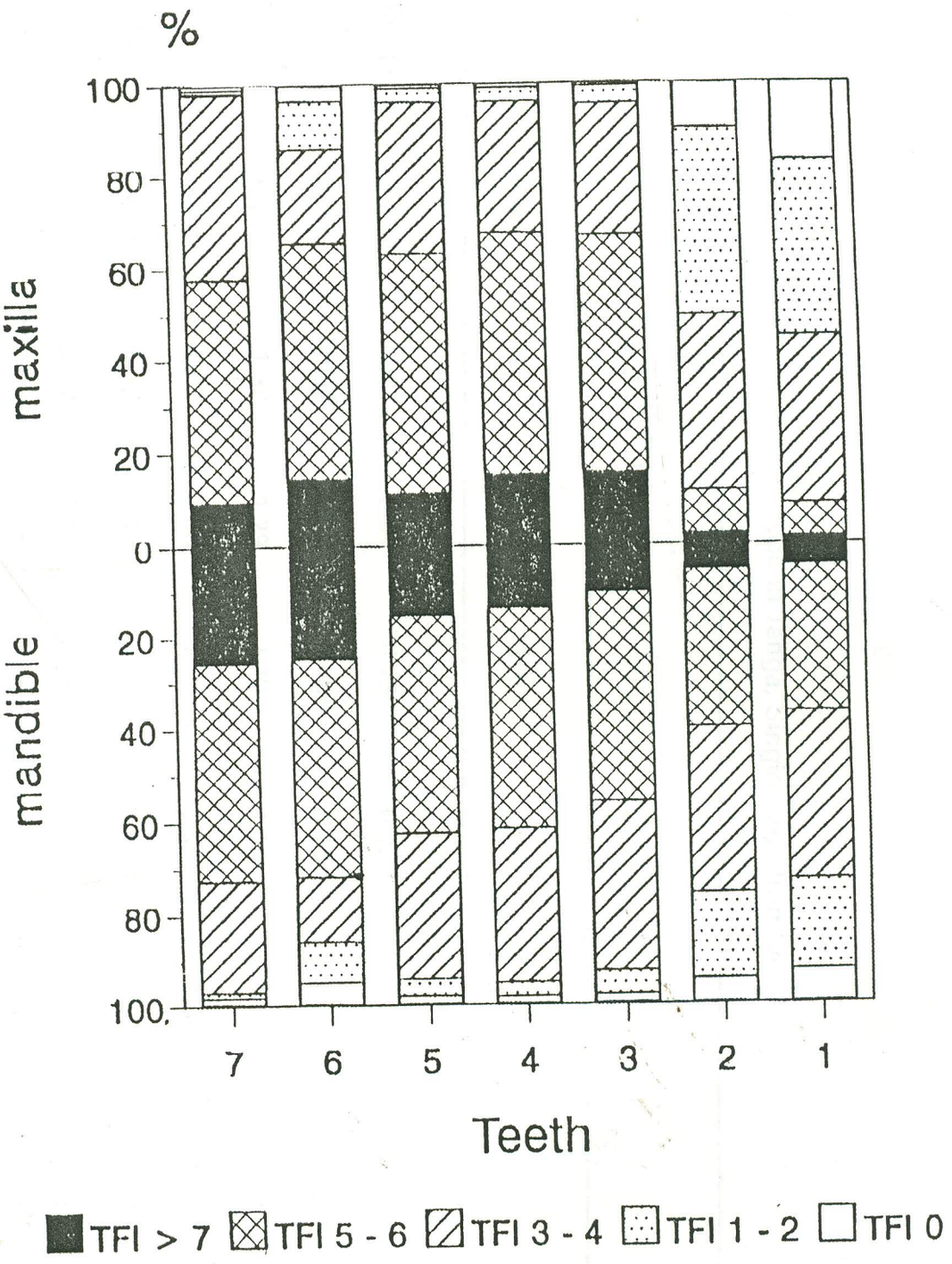


Figure 3.12. Frequency distribution of TFI scores according to tooth type in children from Iramba.

Table 3.8. Mean TFI scores per tooth-type in Tanga, Singida and Iramba.

		Tooth-type						
Area	Jaw	1	2	3	4	5	6	7
Tanga	upper	0.07	0.07	0.23	0.35	0.32	0.09	0.34
	lower	0.02	0.02	0.13	0.26	0.23	0.05	0.30
Singida	upper	1.38	1.29	1.72	1.90	1.82	0.99	1.93
	lower	0.57	0.68	1.33	1.60	1.56	0.96	1.96
Iramba	upper	4.72	4.47	5.05	5.02	4.92	4.70	4.84
	lower	3.67	3.78	4.65	4.87	4.93	5.05	5.53

3.2.5. Severity of dental fluorosis according to start and duration of enamel formation.

The mean TFI scores per tooth type were plotted for the three areas (Figure 3.13, 3.14, 3.15) and compared with a plot depicting the starting time and the duration of enamel formation for each tooth type (Figure 3.16). A corresponding pattern in the plot between the mean TFI scores per tooth type and the starting time of enamel formation for each tooth type was seen in Tanga and Singida but not in Iramba.

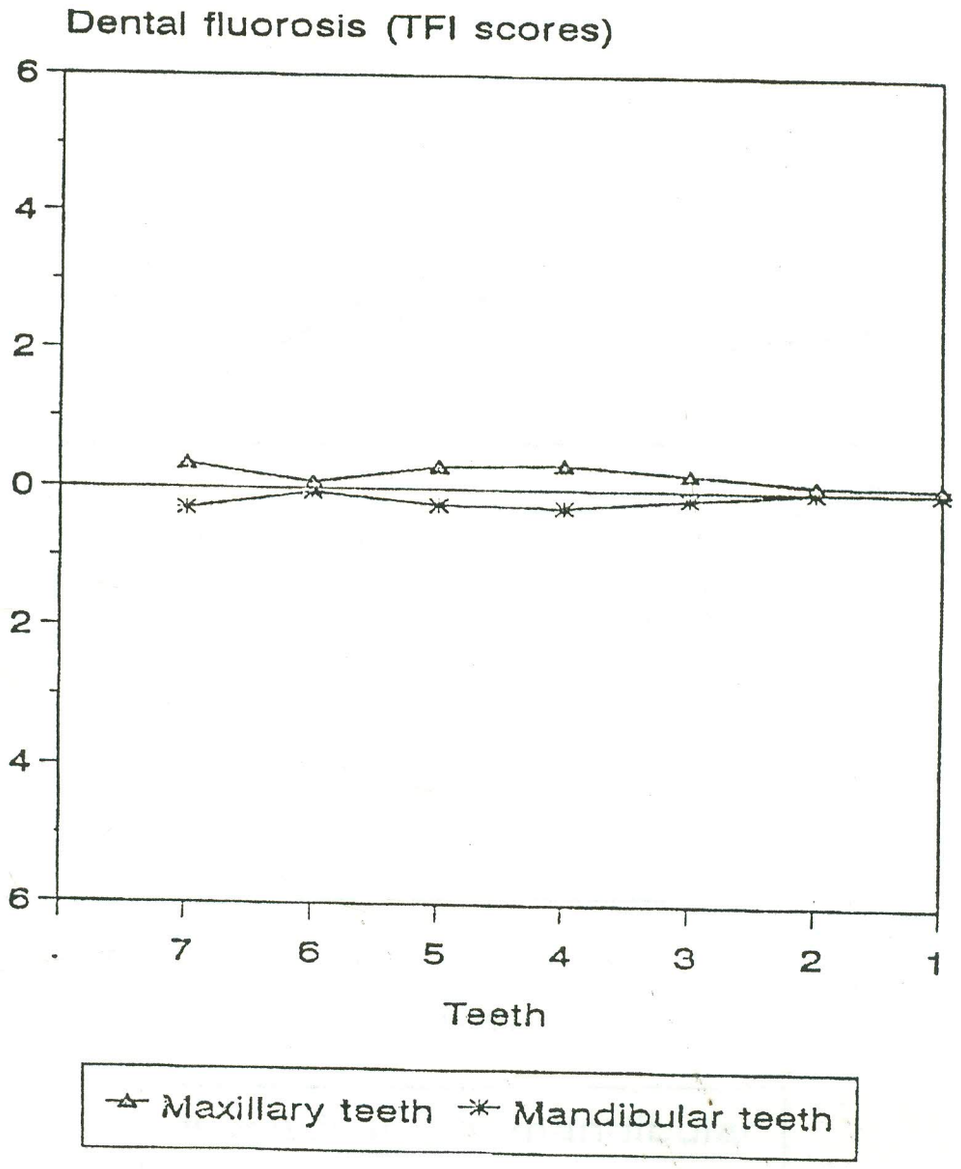


Figure 3.13. Mean TFI scores per tooth type in children from Tanga.

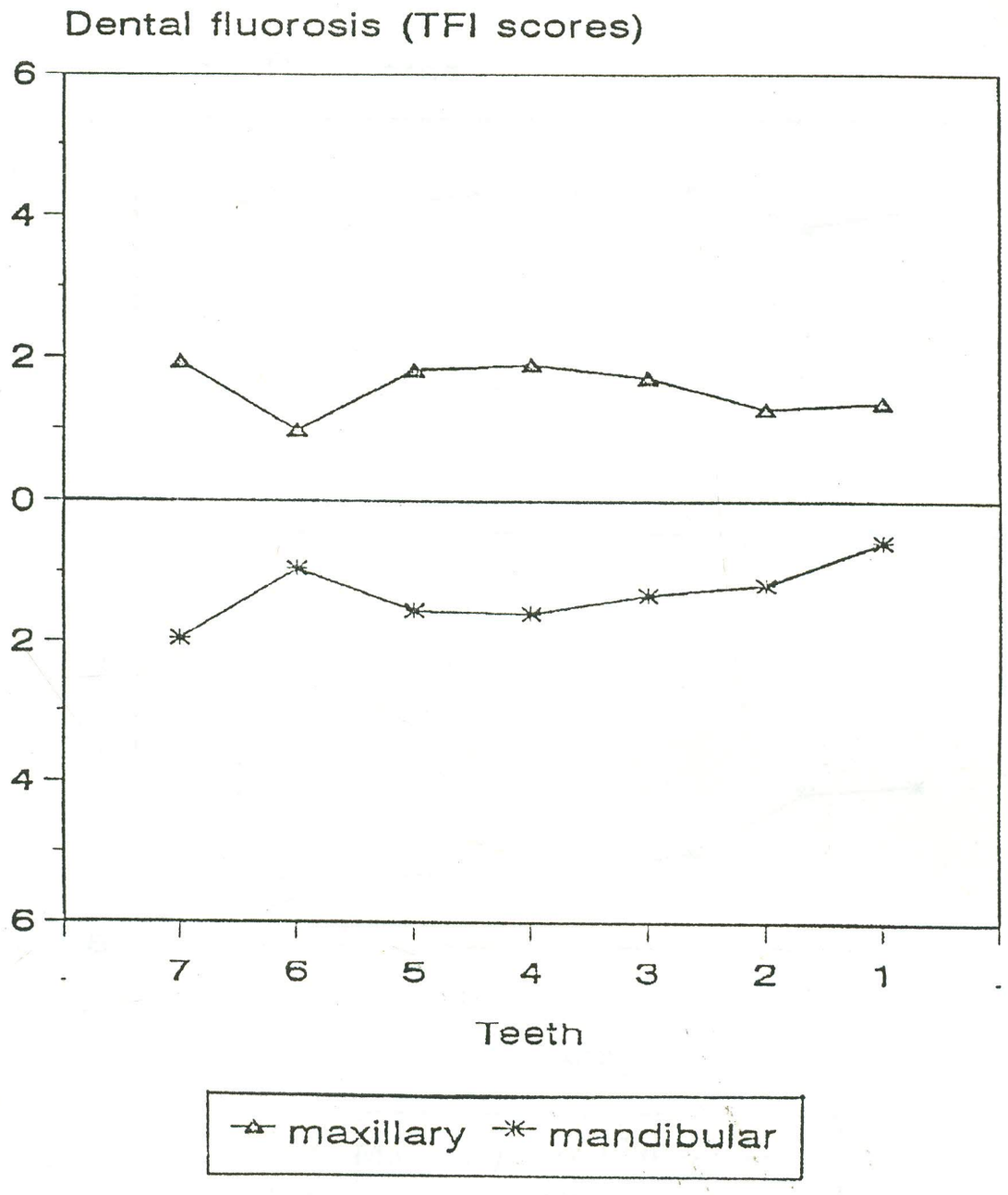


Figure 3.14. Mean TFI scores per tooth type in children from Singida.

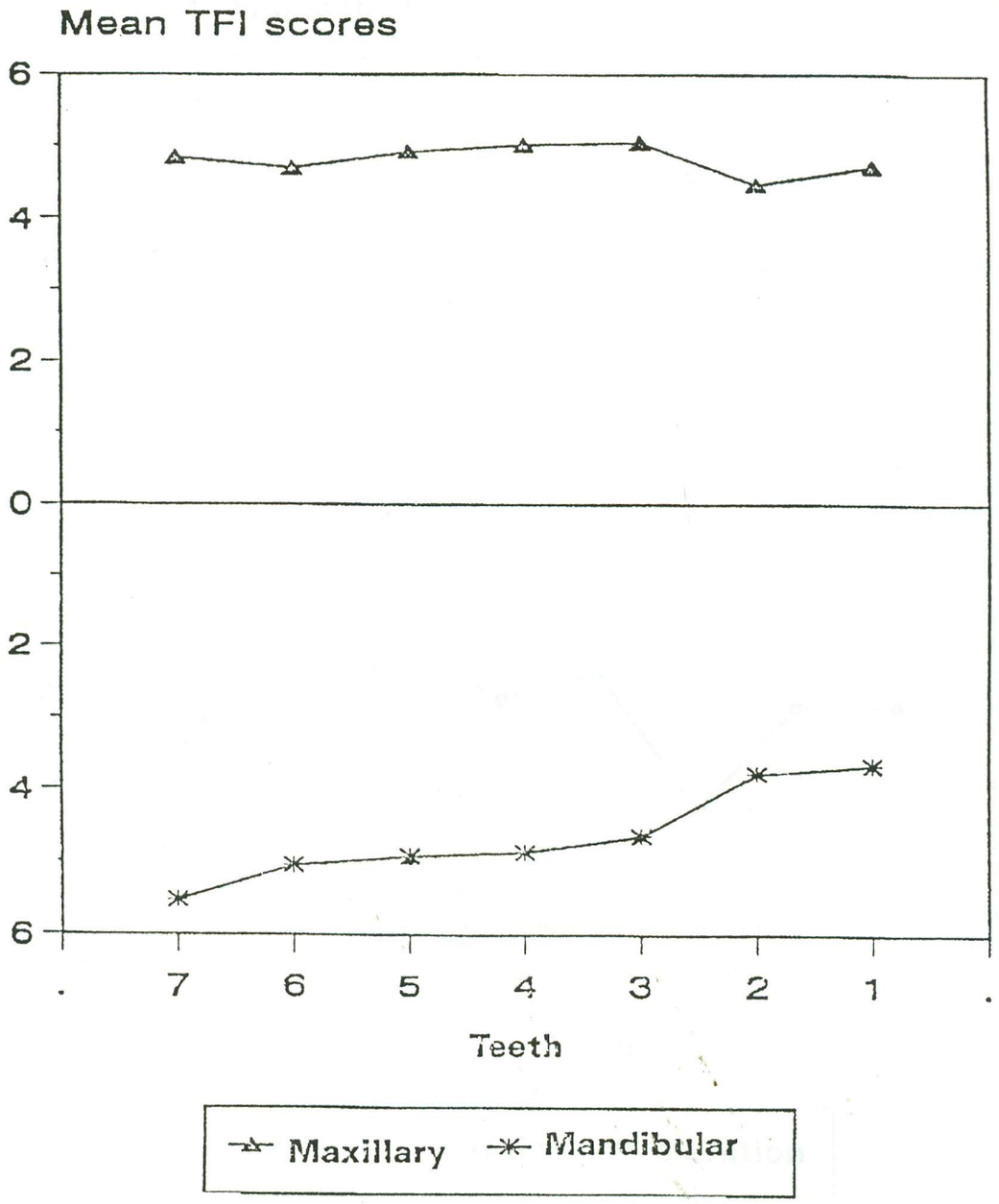


Figure 3.15 Mean TFI scores per tooth type in children from Iramba.

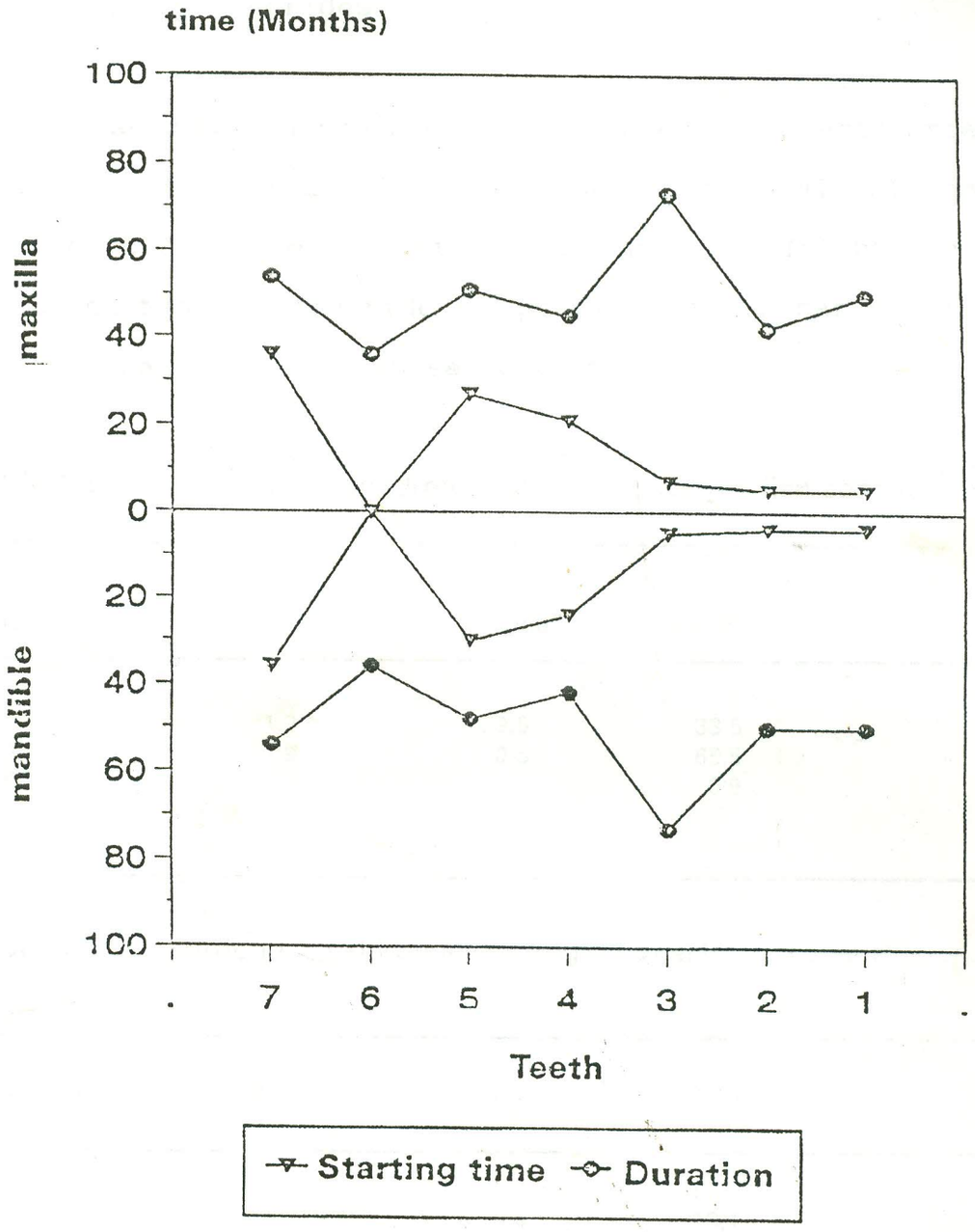


Figure 3.16. Starting time and duration of enamel formation of permanent teeth according to Watson and Lowrey (1962).

3.2.6 Dietary fluorides.

1.3% of the children reported to have used toothpaste once or twice a week. Fluoride tablets are not available in dental clinics or medical stores in Tanzania. Intentional supplementation of fluoride to prevent dental caries was therefore negligible in these populations.

Table 3.9. Proportion of children according to weekly fish consumption.

Frequency	Tanga	Singida	Iramba
0	1.2	99.5	33.6
1 - 3	27.9	0.5	65.5
4 - 5	25.0		0.9
Daily	46.0		

Table 3.10. Proportion of children according to weekly tea consumption.

Frequency	Tanga	Singida	Iramba
0	2.1	88.0	57.3
1 - 3	13.9	8.4	13.1
4 - 5	58.7	3.4	26.4
Daily	25.3	0.2	3.2

Table 3.11. Proportion of children according to weekly milk consumption.

Frequency	Tanga	Singida	Iramba
0	83.0	26.2	28.7
1 - 3	10.4	7.1	36.9
4 - 6	4.8	19.1	17.4
Daily	1.7	47.7	17.0

Table 3.12. Proportion of children according to weekly magadi consumption.

Frequency	Tanga	Singida	Iramba
0	100	4.1	1.4
1 - 3		16.1	60.0
4 - 6		73.3	20.6
Daily		6.4	18.1

Table 3.13. Mean frequency of fish, tea, magadi and milk consumption per week.

Food/Drink	Tanga	Singida	Iramba
	x (sd)	x (sd)	x (sd)
Fish	5.1(2.1)	<0.1 (0.2)	1.4 (1.1)
Tea	5.0(1.7)	0.3 (1.1)	1.8 (2.3)
milk	0.6(1.6)	5.4 (3.8)	3.1 (3.1)
magadi	0 (0.0)	4.5 (1.4)	3.5 (2.0)

The children from Tanga, at sea level, consumed fish and tea more often than children in Singida and Iramba, while milk consumption was low compared to the children in Singida and Iramba (Table 3.9, 3.10, and 3.11). Magadi was consumed frequently in Singida and Iramba but not at all in the study sample from Tanga (Table 3.12). Table 3.13 presents a summary of the dietary data. A distinctive difference in dietary habits can be seen between the communities in Tanga at sea level and those in Singida and Iramba both at 1500m altitude. The differences in dietary habits between Singida and Iramba were less pronounced.

3.2.7. F^- levels in magadi and dental fluorosis.

Twenty two samples of magadi were collected from Sepuka in Singida and 13 samples were collected from Kinyeto in Singida whereas 9 samples were collected from Kiomboi in Iramba. Use of magadi was not reported in Tanga and therefore no samples were obtained from there (Table 4.8).

Table 3.14. Number of samples, range, median and mean F^- concentration of magadi samples from Sepuka, Kinyeto and Kiomboi.

Location	n	range	Median	Mean
Sepuka (Singida)	22	36 - 180	112	111
Kinyeto (Singida)	13	28 - 9000	174	1160
Kiomboi (Iramba)	9	690 - 6800	1750	2638

The median F^- concentration differed slightly in magadi samples from Sepuka and Kinyeto, whereas the median F^- content in magadi samples from Kiomboi was very high being more than 10 times that of magadi from Sepuka and Kinyeto.

The mean F^- concentration in samples from the three areas varied greatly. The mean was 111 ppm F^- for magadi from Sepuka, 1160 ppm F^- for magadi from Kinyeto and 2638 ppm F^- for magadi from Kiomboi.

To further analyze the relationship between dental fluorosis and the exposure to F^- through magadi ingestion in the three communities, frequency distributions of TFI scores of the first molars in each community were constructed (Figure 3.17). Iramba with the highest F^- concentrations in magadi showed the highest prevalence and severity of dental fluorosis in the first molars, whereas Sepuka with the lowest F^- concentrations in magadi exhibited the lowest prevalence and severity of dental fluorosis.

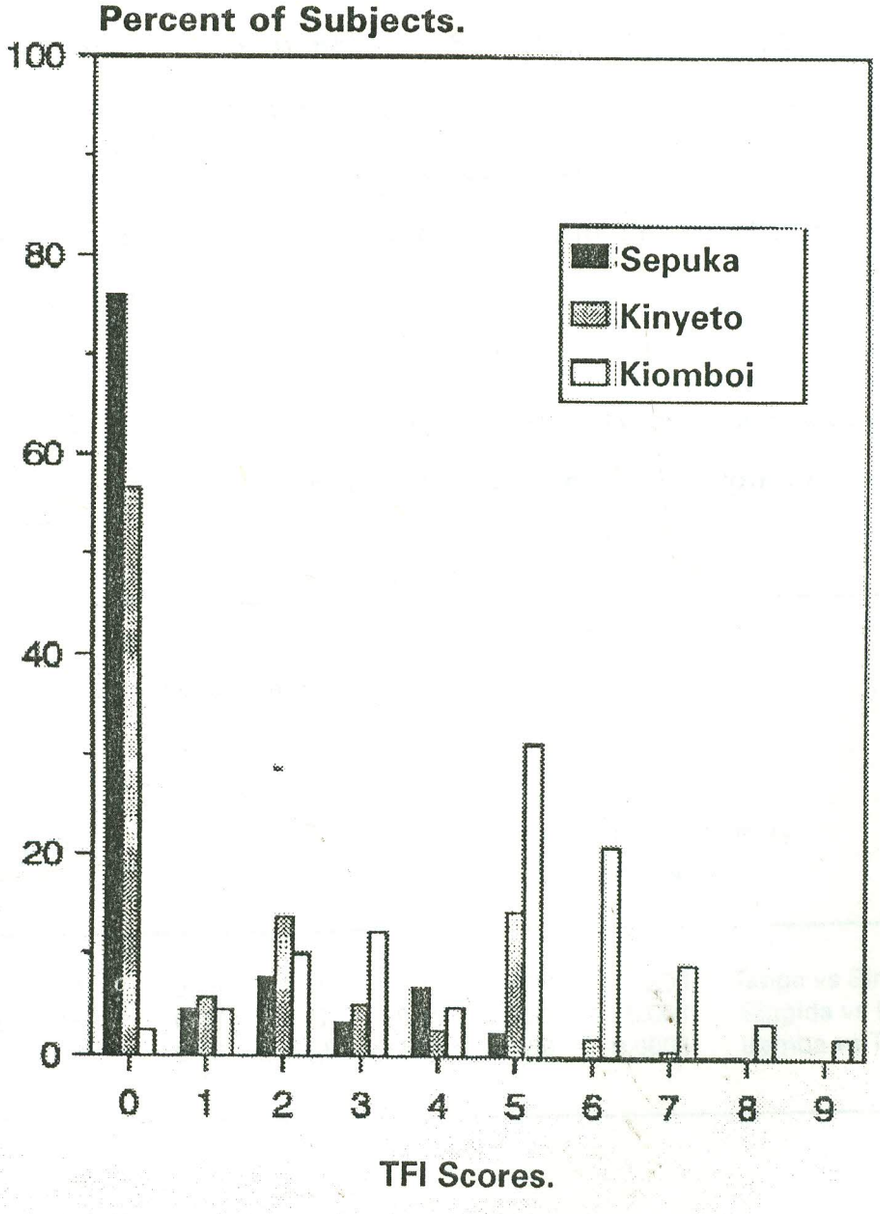


Figure 3.17. Frequency distribution of subjects from Sepuka, Kinyeto and Kiomboi according to TFI scores of the buccal surface of M1.

3.2.8. F^- levels in urine samples of children.

The age of the children ranged between 23 and 60 months. The mean age of children in Tanga was 46.2, in Singida 50.4 and in Iramba 47.7 months. The mean F^- concentration in urine differed significantly between the three areas, (Table 3.15). The urine F^- concentration in children from Iramba was approximately twice as high as in children from Tanga and Singida.

Table 3.15. **The percentiles of individuals according to amount F^- excreted through urine.**

Area	N	Percentiles 10	50	90	Mean urine F^-	Man - Whitney P - value	
Tanga	72	0.06	0.15	0.72	0.28	0.03	Tanga vs Singida.
Singida	40	0.08	0.27	0.58	0.32	0.001	Singida vs Iramba.
Iramba	33	0.15	0.54	1.07	0.56	0.0001	Iramba vs Tanga.

3.3 DENTAL CARIES IN RELATION TO DENTAL FLUOROSIS.

3.3.1. Caries prevalence and caries experience.

The three areas where the study on dental caries was conducted were Tanga with a mean TFI of 0.5 (sd 1.2), Singida with a mean TFI 2.7 (sd 2.7) and Iramba with mean TFI 6.6 (sd 1.7). Drinking water in these areas had comparable F^- concentrations ranging from 0.4 to 0.8 ppm with annual fluctuations of ± 0.2 ppm. Fluoride varied through the use of magadi which contained F^- in the range of 28 – 9000 ppm. The caries prevalence and caries experience among children in Tanga were the highest and in Singida the lowest (Table 3.16). ANOVA showed no age and sex effect on caries prevalence and experience, hence no attempts have been made to present the results according to age and sex.

Table 3.16. Caries prevalence and caries experience in Tanga, Singida and Iramba.

Area	TFI	Caries prevalence		DMFT	
		n		%	Mean (sd)
Tanga	0.5	522	**	21.1	0.4 (0.9) **
Singida	2.7	587	*	6.0	0.1 (0.5) *
Iramba	6.6	450		12.0	0.2 (0.6)

* $p < 0.001$, ** $p < 0.0001$, according to Man–Whitney U test.

No fillings were found. The M component constituted 14% of the DMT. Caries was predominantly present on the occlusal surfaces. Buccal surfaces were second most affected by dental caries but it was not recorded whether the decay on the buccal surfaces occurred in the pits or on the smooth surfaces (Table 3.17). 90% of all caries occurred in the molars (Table 3.18).

Table 3.17. Distribution of D component according to tooth surface and tooth type.

Tooth type	Tooth surfaces					
	Buccal	Distal	Lingual	Mesial	Occlusal	Total Surfaces
Anteriors	0	0	0	2	0	2
Premolars	3	3	2	5	23	36
Molars	110	50	41	38	220	459
Total	113	53	43	45	243	497

Table3.18. Distribution of dental caries according to jaw and tooth type.

	Tooth type						
	7	6	5	4	3	2	1
Maxilla							
Decayed	59	100	8	3	1	0	0
Missing	2	22	1	4	0	0	0
Mandible							
Decayed	58	70	7	7	0	0	1
Missing	1	18	0	3	2	0	0
Total	120	210	16	17	3	0	1

Comparison of the prevalence of caries in first and second molars according to area revealed differences between the areas according to ANOVA. In Tanga and Singida there were significantly more carious first molars than carious second molars, whereas in Iramba more carious second molars than carious first molars were found (Table 3.19).

Table 3.19. Number of decayed first and second molars in Tanga, Singida and Iramba

Area	Number of teeth		Number of carious teeth	
	M_1	M_2	M_1	M_2
Tanga	2006	1953	134	55
Singida	2319	2202	37	19
Iramba	1774	1684	39	46

3.3.2. Relationship between caries and fluorosis.

Since caries is predominantly present in molars the relationship between caries and fluorosis is only studied in the molars. Missing molars due to caries were excluded from the analysis because it was impossible to assign a TFI score. Another 21 carious molars were excluded since the remnants of the buccal surface did not allow adequate TFI scoring.

The relationship between the prevalence of caries in molars and their TFI scores is shown in Table 3.20 for first molars and in Table 3.21 for second molars. The analysis on the caries and fluorosis relationship was conducted separately for the first and second molar since they have different eruption times and hence they may have been exposed to a possible different cariogenic environment and further more their exposure time to the cariogenic challenge is different. Likewise the three areas were analyzed separately since the cariogenic conditions in these areas are likely to be different, firstly because the post-eruptive intraoral F^- exposure varies between the areas and secondly because nutrition and dietary habits may differ.

Table 3.20. Prevalence of caries in M_1 according to TFI score in Tanga, Singida and Iramba.

		TFI scores				
Area		0 - 1	2 - 3	4	5 - 6	7 - 9
Tanga	n	1968	28	2	8	0
	% Carious	5.0%	7.0%	0%	0%	0%
	95% CI	4.1-6.1%	0.9-23.5%	0.0-84.2%	0.0-37.0%	0
Singida	n	1765	253	56	239	6
	% Carious	1.0%	0.8%	1.8%	1.7%	0.%
	95% CI	0.6-1.6%	0.1-2.9%	0.0-9.6%	0.4-4.3%	0.0-46%
Iramba	n	127	336	87	879	345
	%Carious	1.6%	1.2%	3.4%	1.0%	1.7%
	95% CI	0.1-5.7%	0.3-3.0%	0.7-9.8%	0.5-1.9%	0.6-3.8 %

Table 3.21. Prevalence of caries in M_2 according to TFI score in Tanga, Singida and Iramba.

Area		TFI scores				
		0 -1	2 - 3	4	5 - 6	7 - 9
Tanga	n	1756	156	30	11	0
	% Carious	2.7%	3.8%	3.3%	0%	0
	95% CI	2.0-3.5%	1.4-8.2%	0.1-17.2%	0.0-28.5%	0
Singida	n	1050	561	277	294	20
	% Carious	0.9%	0.3%	0%	1.4%	0%
	95% CI	0.5-1.8%	0.0-1.3%	0.0-1.4%	0.4-3.5%	0.0-16.8%
Iramba	n	26	96	460	803	299
	% Carious	0%	4.2%	1.7%	2.2%	3.0%
	95% CI	0.0-13.2%	1.1-10.3%	0.7-3.4%	1.3-3.5%	1.4-5.7%

CHAPTER 4

DISCUSSION.

4.1 CLINICAL METHODOLOGICAL DIAGNOSTIC CONSIDERATIONS.

The present study revealed a measurement error of 0.53 for the DI and 0.50 for the TFI, Kappa values of 0.83 for DI and 0.87 for TFI and measurement - remeasurement correlations of 0.89 for DI and 0.97 for TFI. Examiners performance may have influenced the recorded accuracy of both indices but the higher reproducibility of the TFI is notable since the TFI scale is much larger than the DI scale. A more detailed discrimination resulting in a larger scale of an index is in general at the expense of the reproducibility. That this principle did not bear on the TFI may be explained by the fact that its application did not raise any difficulty in scoring since the index is logically constructed and each score has been precisely described. The same experience has been reported by Wenzel and Thylstrup (1982) and by Myers (1983). In contrast, during application of the DI, problems were encountered in the lower range of the index. It was difficult to discriminate between, "no fluorosis, questionable and very mild" scores. This was probably due to the fact that according to the recommendation of the DI teeth were not dried before examination. The data confirm the experienced

problem during recording since duplicate measurement correlations for DI scores from ≥ 0.5 and ≥ 1 were lower than DI scores ≥ 2, whereas the correlation for the TFI scores was high throughout the scale (Table 3.2 and 3.3). Thylstrup and Fejerskov (1978) have argued that DI is not discriminative for severe dental fluorosis because the single category of DI's severe fluorosis fails to classify the varying degrees of enamel wear. They recommended the TFI for classifying the different categories of enamel pitting and wear in populations with high F^- exposure. This claim was found to be justified since in the present study in the high fluorosis area a much higher discrimination of severe forms of dental fluorosis could be assessed with the TFI than with the DI. This study has also established that the TFI revealed more fluorosis compared to DI in the low and moderate fluorosis areas. This finding is in agreement with a previous report (Thylstrup 1978), but in contrast to another study where identical prevalence levels of dental fluorosis were found with both indices, Burger et al. (1987). The fact that tooth surfaces were not dried in the latter study may explain the deviant finding. Differences in the prevalence of dental fluorosis between both indices occurs in the lowest score due to drying of the teeth when the TFI was used. It is therefore comprehensible in the present high fluorosis area where over 95% of the teeth

exhibited a DI score ≥ 1, that application of both indices resulted in comparable prevalence levels. Application of both indices on the same sample made it possible to analyze the correspondence of both indices and to calculate the conversion values for DI into TFI scores and vice versa (Table 3.5 and 3.6). The conversion values enable computation of a TFI score from the mean DI score and vice versa if the numbers of each score of the index are known. Whether the TFI has an interval scale, which has been claimed by Thylstrup and Fejerskov (1978) on the basis of the degree of pore volume (assessed histologically) can not be judged in this study since no parallel investigation was conducted. But if virtually everybody in a community has been exposed to comparable high amounts of F^-, an index with an interval scale will likely reveal a normal distribution of cases. The present sample from a high fluorosis area classified with TFI indeed showed approximately a normal distribution according to severity of fluorosis (Fig. 3.3). The communities with minor and moderate dental fluorosis exhibited a skewed distribution (Fig. 3.1 and 3.2). The combined data from the 3 areas with different F^- exposure (Mabelya et al. 1992) showed a bimodal distribution (Fig. 3.4) according to TFI. Since the combined data do not represent a homogeneous group with regard to F^- exposure, a bimodal distribution of TFI scores may indicate

heterogeneity with regard to F^- exposure.

Concluding from these results it was found that the TFI had an excellent reproducibility, despite its large scale.

The TFI was able to categorize mild forms of dental fluorosis with ease, due to drying of the teeth before scoring and its clear description of the categories in the lower end of the index. The DI lacked accuracy to discriminate the low dental fluorosis scores. Due to TFI ability to recognize very mild forms of dental fluorosis a higher prevalence of dental fluorosis was detected with the TFI than with the DI in the low and moderate dental fluorosis area. TFI also enabled discrimination of severe cases of dental fluorosis which were categorized in one score by DI. The observed pattern of distribution of dental fluorosis scores with the TFI seem to indicate that this index represents an interval scale. Despite the different objectives for which the DI and TFI were designed, the TFI represents a superior index and should in all instances be the index of first choice.

4.2. DENTAL FLUOROSIS RELATED TO WATER FLUORIDE, DIETARY FLUORIDE AND ALTITUDE.

It has been reported that the concentration of fluoride in drinking water can vary considerably with time (Larsen et al. 1989). In the present study communities using water sources which revealed in the first analysis F^- concentrations in the range of 0.1 - 1.0 ppm F^- were selected.

However, subsequent water samples in the following 2 years showed variations within the range of 0.1 - 1.0 and occasionally F^- concentrations of up to 1.5 ppm were found. Comparison of DI and TFI demonstrated TFI to be a superior index. With TFI, both mild and severe degrees of dental fluorosis could be determined more precisely and accurately than with the DI and hence TFI was used in this study.

In the Tanga communities at sea level, 22.8% of the children experienced dental fluorosis, 2.0% of the children exhibited severe dental fluorosis of TFI $\geq$ 5. Intentional F^- supplements for prevention of dental caries were virtually not practised and magadi was not consumed in these communities. Average F^- concentrations in drinking water ranged from 0.2 - 0.8 ppm F^- in different communities, with an occasional peak of 1.0 ppm F^- during short periods.

The daily high temperatures in these coastal areas and dietary habits of frequent tea and fish consumption may have attributed to the observed dental fluorosis. Under these conditions the average and median F^- concentration in drinking water which did not exceed 0.6 ppm F^- except in Boma with 0.8 ppm F^- seem still to be too high in avoiding objectionable dental fluorosis.

In Singida and Iramba, fish and tea were less consumed but milk was more consumed than in Tanga. Daily temperatures in Singida and Iramba at 1500m altitude were lower than in Tanga at sea level. F^- concentrations in drinking water were comparable. These factors gave rise to the expectation that dental fluorosis would occur less frequently in Singida and Iramba than in Tanga. However this was not the case. Communities in Singida and Iramba exhibited a higher prevalence and severity of dental fluorosis than in Tanga. A similar finding has been reported in Kenya where communities at high altitude had more dental fluorosis than those at sea level. In the absence of other fluorosis associated variables, altitude related hypobaric conditions were considered to be the causative factor for the observed high levels of dental fluorosis at high altitude (Manji et al. 1986b).

The present study revealed the consumption of magadi as an additional fluorosis associated variable. In Tanga at sea

level, magadi was not used but in Singida and Iramba this food additive was frequently consumed. Consumption of magadi seems to explain the differences in prevalence and severity of dental fluorosis between Tanga and Singida and Iramba. The magadi samples collected contained fluoride in the range of 28 - 9000 ppm F^-. The amount of magadi added to the cooking pot for 6 - 8 persons was on average 21 grams in a study in Kibosho in the Kilimanjaro area.

Mothers in Kibosho reported to have introduced magadi to their infants meal in the weaning period between 4 - 9 months (mean 6.9) after birth. They also stated that they had always used magadi and that small children shared the meal with adults (van Palenstein Helderman et al. 1993).

The impact of magadi consumption on dental fluorosis is further substantiated when Singida and Iramba are compared in more detail. Communities in both areas live at 1500 m altitude with similar daily temperatures. Their dietary habits and the F^- content in drinking water were comparable. Yet children in Iramba experienced more severe dental fluorosis than children in Singida. The fluorosis associated factor appeared to be the use of magadi. However, not the frequency of its use (Table 3.13) was associated with the level of dental fluorosis. A clear association was observed between the average fluoride content of magadi used in these communities

(Table 3.18) and the prevalence and severity of dental fluorosis (Figure 3.17). Kiomboi in Iramba with highest F^- levels in magadi exhibited the highest prevalence and severity of dental fluorosis, whereas Sepuka in Singida with the lowest F^- levels in magadi showed the lowest prevalence and severity of dental fluorosis. Kinyeto in Singida took an intermediate position both for the F^- content of its magadi as well as for the prevalence and severity of dental fluorosis.

This observed association between F^- exposure and dental fluorosis is further substantiated by F^- analysis in urine samples from infants. Urine samples from Kiomboi in Iramba revealed twice as high F^- levels than urine samples from Singida, whereas F^- levels in urine from Tanga where magadi is not used was the lowest. A possible altitude related hypobaric effect on dental fluorosis can not be excluded with the present data, but supplementary F^- intake through magadi consumption seems to be a definite factor in the prevalence and severity of dental fluorosis in the present communities at high altitude.

Regarding the within mouth distribution of dental fluorosis there is yet no conformity in opinion. Some studies have reported that incisors and the first molar display less severe dental fluorosis than the canine, premolars and second molars (Nanda et al. 1974, Larsen et al. 1985, Manji

et al. 1986b) while other studies have shown the same pattern as explained above except that the maxillary incisors were among the most severely affected teeth (Möller 1965, Möller et al. 1970, Möller and Poulsen 1975). Another study reported an increase in severity of dental fluorosis from anterior to posterior teeth (Thylstrup and Fejerskov 1978).

The discrepancy in such findings may be attributed to differences in F^- exposure of the studied communities.

The present study revealed 2 patterns of within mouth distribution of dental fluorosis. In Tanga, the low fluorosis area and in Singida, the moderate fluorosis area, within mouth distributions of fluorosis were similar, with incisors and first molars being less affected than canines, premolars and second molars. However in Iramba, the high fluorosis area the within mouth distribution levelled out to a weak increase in severity from anterior to posterior teeth. Some authors believe that enamel thickness determines the within mouth distribution of severity of dental fluorosis (Thylstrup and Fejerskov 1978, Thylstrup 1978) but if so it does not explain the different within mouth distributions of dental fluorosis in low and high fluorosis areas. A more plausible explanation for the within mouth distribution may be found in the exposure time to F^- of the different teeth during their enamel formation.

Starting time of enamel formation of incisors and first molars is close after birth and the end of enamel formation is around the age of 40 months (Watson and Lowrey 1962). 50% of infants in Tanzania are being breast-fed until the age of 23 months (Matee et al. 1994). Since mother's milk is very low in F^- (Spak et al. 1983, Ekstrand et al. 1984), incisors and first molars have had only limited exposure to F^- in contrast to the canine, premolars and the second molar who have a longer exposure to F^- since their end of enamel formation is between the age of 70 to 90 months (Watson and Lowrey 1962). It might be argued that exposure to high F^- concentrations prevailing in Iramba is so toxic that it results in comparable severe dental fluorosis for all teeth irrespective of the variable exposure periods of the different teeth. Forsman (1974) and Mann et al. (1987) have reported sex effects on the level of dental fluorosis. Although in Tanga communities boys exhibited statistically significant higher levels of dental fluorosis than girls, the difference was small. A sex effect could not be substantiated in the other areas It has been reported that enamel damage occurs after eruption of teeth depending on the degree of hypomineralization (Thylstrup 1978, Baelum et al. 1986, Ng'ang'a et al. 1990). This would imply an increasing severity of dental fluorosis with increase in age. A comprehensive study on post-eruptive changes in

dental fluorosis could only show a significant increase in the proportion of teeth with TFI ≥ 6 between 10 - 12 and 13 -15 years old children who lived in a high fluorosis area. However if all scores were included in the analysis no significant difference in dental fluorosis could be found between the 10 - 12 and 13 - 15 years old children (Baelum et al. 1986). In the present study all scores of all children were included in an analysis on the age effect. An age effect on dental fluorosis was not seen. This is in keeping with the study of Baelum et al. (1986).

Strong epidemiological evidence points to magadi as the cause of severe dental fluorosis seen in this study. It is noteworthy to mention that not all magadi raise health problems, since magadi with a F^- content at the lower limits of the observed range (28 - 9000 ppm F^-) can not cause severe dental fluorosis. Magadi is widely used in Tanzania, but not everywhere, particularly not in coastal areas. It is used to shorten the cooking process of beans and certain vegetables in order to reduce the costs for fire wood and charcoal and it is considered to be a flavouring agent. Attempts to control the prevalence and severity of dental fluorosis should focus on a selective ban of magadi rather than a total ban, since the latter approach is not attainable taking into account the established habit and its economic consequences.

4.3. DENTAL CARIES IN RELATION TO DENTAL CARIES.

The caries prevalence and caries experience in Tanga is in agreement with previous reports on dental caries in Dar es Salaam and Morogoro (Kerosuo et al. 1986, Frencken et al. 1986, 1990, Manji et al. 1986, Rugarabamu et al. 1989, Mabelya et al. 1993). Dar es salaam, Morogoro and Tanga have similar F^- content in drinking water.

Lower levels of caries in Singida and Iramba than in Tanga could be attributed to a higher F^- exposure as is indicated by higher dental fluorosis score and higher F^- content in urine in children from Singida and Iramba. However other factors such as ethnic and socioeconomic variables, nutrition and dietary habits may have partly or fully contributed to the observed differences in caries prevalence. Likewise, the observed higher caries prevalence in the high fluorosis area Iramba as compared to the lower fluorosis area in Singida could either have been caused by a different F^- exposure resulting in pitting and disruption of the enamel surface rendering the tooth more prone to caries and/or by differences in the above mentioned variables. The previous finding of a higher prevalence of caries in populations with higher levels of dental fluorosis (Retief et al. 1979, Driscoll et al. 1986 Warnakulasuriya et al. 1992) was in agreement with the

present finding. The suggestion from literature that severe dental fluorosis renders teeth more susceptible to caries can neither be confirmed nor rejected on the basis of population comparison since other variables may have accounted for the observed differences in caries prevalence between populations.

In an attempt to address this problem, an analysis on the relationship between caries prevalence and severity of dental fluorosis was conducted on tooth level for Singida and Iramba separately (Table 3.22). The results show a comparable prevalence of caries in molars irrespective of whether the molars experienced pitting and disruption of their enamel surface (TFI $\geq$ 5) or whether their enamel surface was intact (TFI < 5). It is therefore concluded that severe dental fluorosis in Iramba and Singida do not render teeth more susceptible to caries.

The higher DMF values found in the first than in the second molars in Tanga and Singida are in agreement with other studies conducted in Tanzania (Gardegaard and Fejerskov 1983, Kerosuo et al. 1986, Frencken et al. 1986, Manji et al. 1986, Mosha et al. 1988, Rugarabamu et al. 1990 and Mabelya et al. 1993) and elsewhere in the world.

In contrast more second molars than first molars exhibited caries in Iramba. This observation has so far not been made in Tanzania. A similar finding has been firstly reported

for 12 - 14 year old children in Uganda (Jensen et al. 1973). In the following years similar findings have been reported in Zambia (Westwater 1977), Nigeria (Akpata and Jackson 1978, Akpata 1981) and Botswana (Johnson and Gjermo 1989). It has been interpreted as evidence of rapid increase in caries prevalence due to rapid dietary changes associated with urbanization in these African communities (Jensen et al. 1973), the state of nourishment during calcification of the molars (Westwater 1977), the morphological condition of the fissures (Akpata 1981). The amounts of plaque around the second molars (Enwonwu 1981) have also been suggested as are explanation. A recent study offered good evidence that a higher caries prevalence in second molars than in first molars is caused by changes to a more cariogenic diet during the post eruptive maturation period of the second molar (Johnson and Gjermo 1989). The study population were boarders of secondary schools and those children originating from poor rural settings where they consumed a traditional diet during childhood and primary school time exhibited more caries in second molars than in first molars. The present sample comprised of primary school children who still stayed at home in a traditional setting and consequently the theory offered by Johnson and Gjermo (1989) cannot explain the present observation.

In conclusion, the difference in the caries prevalence and caries experience between the three areas in this study cannot with certainty be attributed to differences in F^- exposure. The explanation for a higher prevalence of caries in second molars than in first molars in Iramba remains obscure. The present study seems to support the hypothesis that teeth with severe dental fluorosis (TFI ≥ 5) are not more prone to caries than teeth with mild to moderate dental fluorosis (TFI <5).

CHAPTER 5.

GENERAL DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1. GENERAL DISCUSSION

Dental fluorosis is a phenomenon caused by F^- ingested and absorbed into the blood stream during the period of mineralization of teeth under formation.

The slight forms of dental fluorosis, either lines or diffuse chalky areas are due to higher than normal pore volume of the sub-surface enamel (Fejerskov et al. 1975, Thylstrup and Fejerskov 1978, Fejerskov et al. 1988). In case of slight dental fluorosis, the enamel surface is hard and smooth, but in severe cases, pitting and other forms of gross hypoplasia which can affect the anatomical appearance of the tooth are often observed. Secondary staining by incorporation of organic salivary compounds, bacterial material, and food substances occurs and can get quite dark within a few years after eruption and is usually objectionable.

Until recently, Dean's Index of dental fluorosis (Dean 1934) has been widely used in diagnosing this condition, but several doubts have been raised against this index. Several authors have formulated new indices in order to improve the diagnosis of dental fluorosis (Zimmerman 1954,

Möller 1965, Young 1973, Al— Alousi et al. 1975, Jackson et al. 1975, Thylstrup and Fejerskov 1978, Small and Murray 1978, Murray and Shaw 1979, FDI 1982 and Horowitz 1986). Limited literature seems to suggest that the index designed by Thylstrup and Fejerskov (1978) can meet the shortcomings of the DI.

Before the study on dental fluorosis in a Tanzanian population was carried out, a comparative study on a suitable index to be used in this study was conducted. Two indices, the DI and TFI were applied on the same subjects by two examiners each using only one index to diagnose dental fluorosis.

Application of TFI did not raise any difficulties in scoring since this index is logically constructed and each score is precisely described.

On the contrary, problems were encountered in the application of the lower DI scores since it was difficult to discriminate between, "no fluorosis, questionable and very mild" scores. This was confirmed by the analyzed data which revealed a lower duplicate measurement correlation for the lower DI scores than the higher scores. The TFI had an overall better reproducibility than the DI despite the fact that its scale is larger than the DI.

The TFI had more ability to disclose mild forms of dental

fluorosis than DI which is due to drying of the teeth before examination. Dean did not recommend to dry the teeth. The TFI has a more extended scale for severe fluorosis thus allowing for higher discrimination of severe forms of dental fluorosis. The scores of TFI in a community (Iramba) with high levels of dental fluorosis showed a nearly normal distribution, in contrast to the DI scores. It is therefore speculated that the TFI may have an almost interval scale though this can not be judged from these findings. The TFI was considered to represent a superior index of dental fluorosis compared to the DI and it was therefore used in this study.

High levels of dental fluorosis have been reported from several African countries which can not be explained by F^O in the drinking water (Möller et al. 1970, Olsson 1978, Grobler et al. 1986, Manji et al. 1986a, Brouwer et al. 1988, Lewis et al. 1992 Ng'ang'a and Valderhaug 1993). In an attempt to explain the high prevalence and severity of dental fluorosis, climate (Grobler et al. 1986, Brouwer et al. 1988, and Lewis et al. 1992), altitude (Manji et al. 1986b) and diet and malnutrition (Murray and Wilson 1948) have been suggested as possible factors.

To have a clear understanding about the relationship between dental fluorosis and F^- exposure, this study was

designed therefore to investigate the effect of climate, altitude and dietary fluoride in three Tanzanian populations. These populations were using drinking water which had comparable low F^- concentrations. The studied populations were drawn from Tanga at sea level, Singida and Iramba both at 1500 m altitude.

Remarkable differences were noted in the prevalence and severity of dental fluorosis between the three populations. Children from Tanga (sea level) experienced the lowest level of dental fluorosis whereas children from Iramba at 1500 m experienced the highest level of dental fluorosis. The prevalence of dental fluorosis was 22.8% in Tanga, 78,0% in Singida and 99.3% in Iramba. Virtually no children (2.0%) in Tanga experienced severe dental fluorosis (TFI $\geq$ 5), whereas in Singida 28.9% and in Iramba 92.0% of the children exhibited that condition.

At sea level the mean maximum and mean minimum temperatures are higher than at 1500 altitude. The information obtained from school children and mothers, indicated that children from Tanga drank tea and eat fish more frequently but drank milk less than children from Singida and Iramba. This gave rise to the expectation that at sea level dental fluorosis would occur more frequently than at higher altitude areas

would occur more frequently than at higher altitude areas of Singida and Iramba, but the opposite was found. Communities from Singida and Iramba at 1500 m altitude exhibited more dental fluorosis than in Tanga. Similar findings have been reported for the Kenyan populations, and in the absence of other fluorosis associated variables altitude was considered to be the causative factor (Manji et al. 1986b).

This study established the consumption of magadi as an additional source of fluoride."Magadi" a volcanic salt $NaH(CO_3)_2 2H_2O$ was added to the cooking pot as a tenderizer to speed the cooking time. Magadi salt is found in numerous places in Tanzania, but the F^- content in magadi varies from place to place. Magadi samples collected contained fluoride in the range of 28 – 9000 ppm. In Tanga at sea level; magadi was not encountered among the studied sample but in Singida and Iramba this salt was frequently used.

The higher levels of dental fluorosis in Singida and Iramba as compared to Tanga could be explained by the use of magadi. This was further substantiated by F^- analysis in urine samples collected from infants from the three study areas. Urine samples collected from Singida and Iramba revealed significantly higher F^- levels than urine samples

Singida and Iramba were compared. Both communities lived at the same altitude of 1500m with the same climatic conditions, low F^- in the drinking water and comparable dietary habits. Nevertheless a higher prevalence and severity of dental fluorosis was found in children from Iramba than in children from Singida. This was attributed to the use of magadi with a higher F^- content.

Concerning the within mouth distribution of dental fluorosis, some authors have reported that incisors and first molars are least affected by dental fluorosis and have found more fluorosis in second molars and premolars (Nanda et al. 1974, Larsen et al. 1985 and Manji et al. 1986b), while Thylstrup and Fejerskov (1978) have reported an increase in severity of fluorosis from the anterior to the posterior teeth. In this study both two patterns of distribution were observed. In Tanga, the low fluorosis area and Singida, the moderate fluorosis area, the within mouth distribution of fluorosis was similar with the incisors and first molars being less affected than canines, premolars and second molars. However in Iramba a different within mouth distribution of fluorosis was seen whereby the severity levelled out to a weak increase from anterior to posterior teeth. Some authors believe that enamel thickness determines the within mouth distribution of severity of

dental fluorosis (Thylstrup and Fejerskov 1978, Thylstrup 1978), but if so, it does not explain the different within mouth distributions of dental fluorosis in low and high fluorosis areas. A more plausible explanation for the within mouth distribution is given in the present study, being the exposure time to F^- of the different teeth during enamel formation.

The caries prevalence and caries experience in Tanga was comparable with previous reports on dental caries in Dar es Salaam and Morogoro (Frencken et al. 1986, Manji et al. 1986c, Kerosuo et al. 1986, Rugarabamu et al. 1990, Mabelya et al. 1993). Dar es Salaam and Morogoro are similar to Tanga with respect to the low F^- content in drinking water and the virtually absence of magadi. Lower levels of caries in Singida and Iramba may be attributed to a higher F^- exposure through magadi consumption but also other factors such as ethnic and socioeconomic variables, nutrition and dietary habits may have partly or fully contributed to the observed lower prevalence of caries. An analyses on the relationship between caries prevalence and severity of dental fluorosis revealed that molars with pitting and disruption of their enamel surface experienced a similar caries prevalence as molars with less severe dental fluorosis. This finding strongly indicates that severe

forms of dental fluorosis in Iramba and Singida do not render teeth more susceptible to caries.

More first than second molars exhibited caries in Tanga and Singida. This pattern of within mouth distribution of caries is in keeping with previous reports on caries in Tanzania and elsewhere in the world. However in Iramba more carious second molars than carious first molars were observed. Only a few caries studies on African communities have reported similar findings (Jensen et al. 1973, Westwater 1977, Akpata and Jackson 1978, Akpata 1981, Johnson and Gjermo 1989). Several explanations for this phenomenon have been put forward in the literature but none of them offer a plausible explication for the present observations.

5.2. CONCLUSION.

The TFI by (Thylstrup and Fejerskov 1978) is a superior index of dental fluorosis and should in all instances be the index of first choice. It enables reproducible scoring, recognizes very mild forms of dental fluorosis and discriminates severe forms of dental fluorosis.

For characterization of an area with respect to F^- exposure, in the past, the fluoride content in drinking water was considered sufficient. However the findings of this study indicate that the uptake of F^- ions from food tenderizing magadi or similar food supplements may be many times higher than from water. Strong epidemiological evidence points to magadi as the cause of severe dental fluorosis. It is noteworthy to mention that not all magadi raise health problems, since magadi with a F^- content at the lower limit of the observed range (28 – 9000 ppm F^-) can not cause severe dental fluorosis.

The caries prevalence and caries experience in Tanga was comparable with previous reports on dental caries in Dar es Salaam and Morogoro, both areas with low F^- content in drinking water and virtually no magadi. Lower levels of caries in Singida and Iramba may be attributed to a higher F^- exposure through magadi consumption.

Severe forms of dental fluorosis in Singida and Iramba do not seem to compromise the caries protective effect of F^-.

5.3. RECOMMENDATIONS.

Dental fluorosis is perceived by the people in an endemic fluorosis area in Tanzania as an aesthetic problem for which they desire cosmetic dental treatment (Van Palenstein Helderman and Mkasabuni 1993). Tanzania has several endemic fluorosis areas and the possibility that the majority of these areas exist as a result of high F^- supplements from food (like magadi) cannot be ignored. All the more since recently a community in the Kilimanjaro area has been identified with severe dental fluorosis. The people consumed water with a low F^- content but ingested frequently magadi with a high F^- content (Van Palenstein Helderman et al. 1993). By banning magadi with high F^- content, and substitute it with magadi with low F^- content dental fluorosis and possibly skeletal fluorosis could be controlled in endemic fluorosis areas. This urges further and more extensive investigations on water analysis, on dietary habits and local customs regarding food preparations in endemic fluorosis areas in order to identify the main F^- source as a first step in the control of fluorosis.

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