CHRONOLOGICAL AGE, DENTAL AGE AND NUTRITIONAL STATUS AMONG 3-5-YEAR-OLDS WITH EARLY CHILDHOOD CARIES IN NAIROBI, KENYA.

V60/87644/2016: JOYCE ATIENO OMUOK, BDS (UoN).

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NOVEMBER, 2020.

DECLARATION

I, Omuok Joyce Atieno, declare that this is my original work, and it has not been submitted in any other institution for the award of any degree.

Signature …………………………………… Date…….……………………

DEDICATION

In memory of my mother, Elizabeth, without whom I would not be where I am today.

SUPERVISORS' APPROVAL

We have approved this research work as supervisors of the University of Nairobi.

GLADYS N. OPINYA, BDS (UoN), CAGS, MSc.D (BOSTON USA), PhD (UoN)

Professor of Paediatric Dentistry, Department of Paediatric Dentistry and Orthodontics,

School of Dental Sciences, University of Nairobi.

Signature…………………………………..……… Date…………………………

EDITH NGATIA, BDS (UoN), MSc (UoN)

Public Health Nutritionist & Dental Surgeon,

Senior Lecturer, Human Nutrition, Department of Paediatric Dentistry and Orthodontics,

School of Dental Sciences, University of Nairobi.

Signature………………………………………. Date…………………………

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LIST OF ABBREVIATIONS

WHO	World Health Organization
ECC	Early Childhood Caries
S-ECC	Severe Early Childhood Caries
BMI	Body Mass Index
HAZ	Height-for-age Z-score
WAZ	Weight-for-age z-score
WHZ	Weight-for-height z-score
EC-PEM	Early Childhood – Protein-Energy Malnutrition
FM	Body Fat Mass
DXA	Dual-energy X-ray Absorptiometry
TDS	Tooth Development Stages
DAA	Dental Age Assessment
OPG	Orthopantomogram
DMFT	Decayed Missing Filled Teeth (permanent dentition)
dmft	Decayed Missing Filled Teeth (deciduous dentition)
defs	Decayed, Extracted, Filled, Surfaces (deciduous dentition)

DEFINITION OF TERMS

Chronological age: The total number of years an individual has lived, used most commonly in psychometrics as a standard against which certain variables like behaviour and intelligence are measured.

Dental age: Dental age is the state of maturation of an individual's teeth and is usually assessed up to 18 years of age.

Nutritional status: Nutritional status is the body's condition concerning the body's level of nutrients and the ability of these nutrient levels to maintain healthy body metabolic processes.

Early Childhood Decay: The presence of one or more decayed (cavitated or non-cavitated lesions), missing (due to caries) or restored tooth surfaces in any deciduous tooth in children aged 71 months or younger.

Underweight: Underweight is when the weight for age is less than -2 standard deviations (SD) of the WHO Child Growth Standards median.

Overweight: Overweight is when the weight for height is greater than +2 standard deviations (SD) of the WHO Child Growth Standards median.

Obese: Obese is when the weight for height is greater than +3 standard deviations (SD) of the WHO Child Growth Standards median.

Wasting: Wasting is when the weight for height is less than -2 standard deviations (SD) of the WHO Child Growth Standards median.

Severe wasting: Severe wasting is when the weight for height is less than -3 standard deviations (SD) of the WHO Child Growth Standards median.

Stunting: Stunting is when the height for age is less than -2 standard deviations (SD) of the WHO Child Growth Standards median.

3-5-year-olds: For this study, this age category includes children aged 36-59 months.

ABSTRACT

Introduction: Dental caries is becoming an increasingly common occurrence in children aged five years and below. Early childhood caries (ECC) if left untreated, may negatively impact on dietary intake and the child is at risk of being underweight, stunted or both.

Broad objective: The broad objective was to determine the relationship between chronological age, dental age, nutritional status and early childhood caries among 3-5-year-old children.

Study Setting: The study was carried out at the Lady Northey City County Dental Clinic.

Study design: The survey was descriptive and cross-sectional in design and was carried throughout five months.

Sampling and sampling technique: Purposive sampling was employed where every child aged 3-5 years presenting with ECC, and had an orthopantomogram (OPG) as a requirement for diagnosis were selected for the study.

Data Collection Instruments: Information on socio-demographics, oral hygiene habits and dietary habits was collected using a semi-structured questionnaire. The WHO caries diagnostic criteria (2005) was used for assessment of dental caries. Nutritional status was assessed using anthropometric measurements. The determination of dental age was done using the method by Demirjian.

Data Analysis: Analysed using SPSS version 25.0 for windows. The WHO Anthro Statistical Programme was used in the analysis of nutrition data. Statistical tests were performed for different variables to establish relationships between them.

Results: The mean chronological age for the 171 children who participated in the study was 4.09±0.54, se=0.042years (range 3 - 4.92 years). The mean estimated dental age for the children was 4.59±0.75, se=0.57. The 136 (79.5%) whose dental age was not delayed had a mean dental age of 4.79 ± 0.62, se=0.05, (range 3.30 -

6.70 years) while 35 (20.5%) whose dental age was delayed had a mean 3.82 ± 0.73, se=0.12, (range 2.20 -4.80 years). The differences in the mean age between those with delayed dental age and those without delay in dental age were statistically significant with a Levene's test for equality of variances with F=4.649, df= (169, 47), p=0.000.

There was no significant relationship between dental age and dmft (correlation coefficient r=0.045, p=0.563). The relationship between nutritional status and ECC was not statistically significant using Spearman's correlation.

A significantly strong and positive association was noted between height for age z score and dental age where a Spearman's correlation r=0.314, p=0.000 and weight for age z score r=0.202, p=0.008 at 95% CL.

Conclusion: Most of the children's dental age was advanced when compared to the chronological age. The dental age had associations with underweight and stunting. There was no relationship between dental age and ECC. Hence the severity of early childhood caries may not be a good indicator of delayed dental age. There was however no relationship between nutritional status and ECC.

Recommendations: There may be need to establish a reference dental age dataset for Kenyan children of African descent. When determining the dental age, stunting and underweight should be taken into consideration.

CHAPTER ONE

1.0 INTRODUCTION AND LITERATURE REVIEW

1.1 INTRODUCTION

Dental caries is a known global public health problem. ECC is experienced in both developed and developing countries. ECC affects a child's life quality with adverse effects ranging from pain, infection, inability to feed correctly and inadequate sleep. A child may be forced to miss school days due to pain and infection caused by ECC, and this affects academic performance. Socialisation is also affected because of the unsightly nature of gross caries.

An individual's growth is influenced by many factors including genetics, race, nutritional status, hormones, socio-cultural environment and climatic conditions[(1)]. However, the mineralisation of teeth is less affected by these factors than other growth parameters[(2–4)]. Also, dental age shows the least variability concerning chronologic age, when compared to other maturity indicators [(2,5,6)].

The estimation of dental age is of importance because of its application in criminal, medical, legal and civil practices, archaeological and anthropological studies. It is highly invaluable in orthodontics and paediatric dentistry as it affects diagnosis, treatment planning and treatment of paediatric patients. During medico-legal processes involving uncertain or unknown birth records, dental age supplements other indicators of maturity in chronological age estimation [(2)]. Dental age assessment using tooth development is more reliable than using tooth eruption because tooth emergence into the oral cavity is a brief occurrence, whereas development can be referred to at any age [(7)].

1.2 LITERATURE REVIEW

1.2.1 EARLY CHILDHOOD CARIES

1.2.1.1 Definition of early childhood caries (ECC)

Early childhood caries (ECC) has been defined as when there are one or more carious teeth (cavitated or non-cavitated lesions), missing (due to caries) or restored tooth surfaces in any deciduous tooth in children aged 71 months or younger [(8)]. Any sign of smooth-surface caries is categorised as severe early childhood caries (S-ECC) in children younger than three years of age [(9)]. S-ECC in children aged three to five is the presence of one or more teeth with cavities or filings on the smooth surfaces in the deciduous maxillary anterior teeth. Also, a score involving four or more smooth surfaces of teeth at age three, or five or more teeth with cavities or fillings at age four and six or more than six surfaces of the primary teeth are filled or affected by dental decay at age five years is considered to be S-ECC [(9)].

1.2.1.2 The prevalence of early childhood caries in Kenya

ECC is regarded as a severe public health problem both in developed and developing countries. According to the Kenya National Oral Health Survey Report (2015), 5-year-olds had a higher prevalence of dental caries (46.3 %) as compared to other age groups [(10)].

1.2.1.3 Consequences of early childhood caries

The consequences of ECC include an increased risk of developing new carious lesions in both the deciduous and permanent dentitions. Developing a higher frequency of hospitalisation and emergency treatments (due to odontogenic infections and pain), increased costs and time of treatment, inadequate or poor physical development (more so in height/weight). There is an increase in days with restrictive activity, loss of productive school days, decreased learning abilities and generally low life quality [(9)].

1.2.2 NUTRITIONAL STATUS

1.2.2.1 Definition of nutrition and nutritional status

Nutrition is the intake of food concerning the body's dietary needs [11]. A poor diet can lead to reduced body immunity, increased susceptibility to various diseases, mental and physical development impairment, and decreased productivity in general. Nutritional status is the body's condition concerning the body's level of nutrients and the ability of these nutrient levels to maintain healthy body metabolic processes [12].

1.2.2.2 Factors affecting the nutritional status of children aged 5 years and under

A child's nutritional status is influenced by several factors ranging from social, economic and environmental factors. Geographic and regional disparities in malnutrition have been reported [13], with some regions in Kenya having a higher malnutrition prevalence than others. In Kenya and Zambia, children from wealthy households with electricity are less likely to have stunting [14]. Gender and age also play a role. The boys have a higher risk of being stunted than the girls [13–15]. Younger children are less likely to be stunted than older children in this age group [13–15]. The breastfeeding duration also affects nutritional status. Children who are weaned early have an increased risk of being underweight [16]. Immunisation status is another major role player since up-to-date vaccinations are protective against some childhood illnesses. A child who has suffered from an upper respiratory tract infection or any other disease in the past month is highly likely to be underweight [16]. Children belonging to mothers who are better educated are less likely to have stunting [14]. A child living with non-biological parents has a higher likelihood of stunting [16].

1.2.2.3 Methods of assessing nutritional status

An individual's overall nutritional status is determined using anthropometry. It is non-invasive and inexpensive. Age, sex, and length/height and weight are the building blocks that makeup anthropometry. An index is what results when any two of these variables are used together. In children, nutritional status is usually assessed using the following three indices:

i. Weight for age

ii. Height for age (length for age for children of the age of 2 years and below)

iii. Weight for height (weight for length for children aged two years and below)

Malnutrition (underweight, stunting and wasting) can be characterised by weight, height, and body mass index (BMI) deficiency or excess. BMI is expressed in kg/m^2 and is used in children aged 24 months and above [(17)]. BMI is classified into four categories which correspond with specific percentile ranges in children and particular ranges of scores in adults; underweight, healthy, overweight and obese [(17)].

Low weight for age index signifies an age-specific underweight condition, and it indicates both present (acute) and past (chronic) undernutrition but does not differentiate between chronic and acute conditions [(18)]. Reduced height for age index signifies chronic malnutrition (stunting) condition or a past under-nutrition, but it cannot determine the short-term malnutrition changes [(18)]. Reduced weight for height identifies children with either acute or current under-nutrition or wasting (useful when the precise ages are challenging to determine) and is used for deciding short-term effects like food supply seasonal changes or short-term nutritional stress brought about by an illness [(18)].

1.2.3 CHRONOLOGICAL AGE

Chronological age is the number of years an individual has lived, used most commonly in psychometrics as a standard against which certain variables like behaviour and intelligence, are measured [(19)].

1.2.3.1 Methods of assessing chronological age

Chronological age is evaluated by referring to birth records: birth certificates or birth notifications. In the current world, accurate records of dates of birth exist, and this information can be gotten from most parents and caregivers. There are instances, however, where birth dates are not reliably documented, more so in developing countries. In such cases correlating the physical, dental and skeletal maturity of an individual is used to assess age. Given the fixed pattern of the eruption of deciduous dentition in children, Towlson and Peck [(20)] estimated chronological age by using the total number of erupted teeth. This study concluded that owing to the variability in eruption at any given chronological age, the number of erupted teeth does not accurately estimate dental age [(20)].

The use of radiographs such as those of the hand and wrist in the assessment of skeletal age can be useful in chronological age estimation. A high correlation exists between dental age and skeletal age while chronological age has an inconsistent association with both skeletal and dental ages [(21,22)].

Knowledge of chronological age is highly paramount in a child's nutritional status assessment. The four measures used in anthropometric assessments are sex, age, weight and length/height. When two of these variables are used in combination, they are called an index. Usually, height and weight vary and increases with increase in chronological age. In paediatric dentistry practice, chronological age determines the course of treatment taken in managing dental caries, in behaviour modification and management during treatment, and consideration of whether a carious tooth is to be extracted or restored.

1.2.4 DENTAL MATURITY AND DENTAL AGE

Dental maturity is usually expressed as a dental age [(2)]. Dental age is the state of maturation of an individual's teeth and is generally assessed up to 18 years of age. Dental age is a maturity indicator. Maturity indicators are distinct events in a series of processes (e.g. dental, sexual, skeletal) that show an individual's uneven maturation

[23]. Maturational processes, the relationship between maturity and size together with sexual dimorphism are independent and are not associated with the passage of chronological time, but to the progression of the individual to a mature state from a state of immaturity [23]. Thus, the chronological age of an individual does not always tally with dental age.

Growth and development are significantly under the influence of hereditary (genetics), nutritional, sexual, metabolic, functional, cultural, social and environmental factors. In age assessment, teeth are preferable over skeletal methods because of their durability in archaeological contexts, minimal remodelling and continuous development over the entire juvenile period [1]. Dental development is less influenced by environmental factors when compared to skeletal growth and development [1]. Tooth eruption is less variable than skeletal maturation. Tooth formation is less variable than tooth eruption [6]. As a biological maturity indicator in children, dental development is more reliable[1,24,25]. When compared to other maturational factors, dental development has been shown to correlate more closely with chronological age in children, adolescents and young adults [3,5,6]. From the analysis monozygotic and dizygotic pairs of twins, it is believed that dental development/tooth formation timing is mostly genetically determined[6].

There are several methods of dental age assessment. The two most commonly used methods are the use of dates of tooth eruption and tooth calcification/mineralisation of a single tooth or several teeth [7]. Gingival emergence (tooth emergence) as a method of estimating the dental age has several disadvantages. The disadvantages may include; local factors influence such as premature loss of deciduous teeth, crowding/insufficient space in the dental arch. The impaction of teeth or tipping; influenced by systemic factors such as nutritional factors; limited use between ages 30 months to 6 years and beyond 13 years (except for third molars whose eruption is highly varied and also tends to be absent in 29% of the population) [7,26]. The eruption also depends on the timing of observation, given that it is a discontinuous process [7]. Tooth emergence (gingival emergence) is usually incorrectly termed as tooth eruption. Tooth eruption is a continuous process. Tooth emergence is a brief event in this process and therefore the chance that the time of observation may coincide with the specific gingival emergence timing is very small (27).

The use of developing teeth, which is least influenced by environmental and systemic factors, is thus a more reliable method of estimating dental age (6,26).

1.2.4.1 The need for dental age estimation

Sub-Saharan Africa records the lowest registration of births levels (44%), with Eastern and Southern Africa having about 44 million children aged under five unrecorded (28). Dental age estimation is therefore widely used to estimate chronological age, for both medical and legal purposes, in children without birth records (1).

Dental age estimation on panoramic radiographs is useful for orthodontists and paediatric dentists in choosing an appropriate treatment plan. It is used as an essential indicator in identifying abnormal development and eruption sequences so that intervention to prevent dental decay is put in place (1).

Estimation of age is an essential requirement in legal, judicial and criminal court proceedings (29). Other circumstances where age assessment is a requirement are; asylum seekers whose chronological ages are not known, young people accused of the crime, and convicted criminals who are claimed to be minors (less than 18 years) before sentencing (30). According to universal laws, any asylum seeker aged below 18 years should be considered a minor and reserves the right of abode in the country where asylum is claimed. Age assessment is sometimes required to help in the process of identification of subjects from mass disasters (31) and murder victims.

1.2.4.2 Imaging and dental age estimation

Dental and maxillofacial tissues imaging play a significant role in dental age assessment. Different assessment methods use different types of radiographs. There are several methods of estimating age. Among these, the radiographic approach is preferred since it is a reproducible, non-invasive and straightforward method (31,32).

These include intraoral radiographs, lateral oblique views of the mandible, panoramic radiographs and cone beam computed tomography (CBCT). Panoramic radiographs are widely used since they provide images of both maxillary and mandibular dentition. The calcification status can now be determined with precision due to technical advancements in digital radiography and CBCT [1].

1.2.4.3 Classification of dental age estimation methods

These can be classified broadly into two; the technique used and the subject's age. Based on the method of age estimation, there are four categories; histological method, chemical and physical analysis, visual method and the radiographic method. Among these, the radiographic technique is the most widely used. Based on the study subject's age, there are also four categories; age estimation in the prenatal period, in infants, in children and adolescents and adults [1,33]. Dental age estimation methods are used during the prenatal and postnatal period since tooth development can be observed from the sixth week of intrauterine life.

1.2.4.4 Estimation of dental age in children and adolescents.

In this group, dental age is estimated based on either eruption or calcification of teeth [32]. Several studies have confirmed that tooth development is by far a more reliable dental maturity indicator as compared to gingival emergence into the oral cavity [26,34,35].

Dental age estimations are based on the measurement of the pulp-tooth ratio, open tooth apices, and tooth development staging. There are various radiographic methods of assessing dental age which use developing teeth and these include:

i. The Demirjian Method [34,36]
ii. The Haavikko Method [37]
iii. Willem's Method [26]
iv. Nolla's Method [38]
v. Cameriere's method [39]
vi. Moores, Fanning and Hunt method [40]

vii. Kvaal's method [41]

Most methods use a few selected teeth. However, some methods use all permanent teeth (Nolla, Haavikko). The study of all the teeth is not only expensive and time-consuming but also presents technical challenges [7].

1.2.4.5 The Demirjian Method of Dental Age Estimation

This method was proposed in 1973 [34] and has emerged as the most widely used and researched method of estimating dental age in children and adolescents [7,32,42–44]. Demirjian method has been adopted because of its simplicity and the schematic and radiographic illustrations of tooth development which are accompanied by a description [42].

It was based on a system for the hand and wrist maturity estimation developed by Tanner et al. [32]. This method uses dental maturity scores (Demirjian's tables) and percentile curves derived from the evaluation of the OPGs of 4,756 French-Canadian children aged between 2-20 years [36]. These scores serve as a reference dataset used in chronological age evaluation for different population groups [29].

The Panoramic radiographs used in Demirjian's method are more comfortable to take as compared to intra-oral radiographs more so in children. They also give less radiation and capture all teeth. Also, the left mandibular region which is the area of interest in this method undergoes minimal distortion in a panoramic radiograph [7]. The Demirjian system of maturity determination is based on the shape and not the total length of developing dentition. Thus the 5-10% enlargement that may affect the left side of the radiograph is inconsequential [7].

The Demirjian classification of Tooth Development Stages (TDS) is a system that recognises eight tooth development stages beginning from initial calcification (Stage A) to complete root formation (Stage H). The simplicity and reliability of this method are due to the high inter- and interobserver agreement values [45].

A study comparing Demirjian and Cameriere's methods concluded that the latter showed a higher accuracy level in all age groups, while the former showed more relevant results for the German population that was under investigation [(46)]. Demirjian's method is accurate but has limitations when used in persons of eighteen years and above [(26)].

Several studies done in various population groups using this method concluded that it generally overestimated age; southern Chinese population (0.36 years in girls and 0.62 years in boys) [(29)], Norwegian children (0.3 years in girls and 0.2 years in boys) [(2)], a meta-analysis of 26 published studies (0.39 years in girls and 0.35 years in boys) [(47)], Nigerian children [(48)], Iranian children aged 3.5-13.5 years (0.21 years in girls and 0.15 years in boys) [(42)], 6-13 year-old Iranian children (0.25 years in girls and 0.34 years in boys) [(43)], eastern Turkish children (0.2-1.9 years in girls and 0.4-1.3 years in boys) [(49)], western Turkish children (0.28-0.87 years in girls and 0.10-0.7years in boys) [(50)], Venezuelan children (0.62+/- 0.93 years) [(51)], Indian children (0.04 years in girls and 0.14 years in boys) [(52)], Norwegian children (0-7.5 months in girls and 1.5-4.0 months in boys) [(2)], Chinese children (0.0071-1.25 years in girls and –1.0 to 1.3 years in boys) [(44)], Serbian children (0.42 years in girls and 0.45 months in boys) [(53)] and Belgian Caucasian (0.7 years in girls and 0.4 years in boys) [(26)].

Demirjian et al. in their original publication [(34)] stated that the standards they had derived from the French-Canadian sample may not be applicable in other populations and that adaptations should be obtained for other population samples.

Following the Demirjian's method, there are different data sets for dental age estimation (adapted scoring systems) that have consequently been set up for different ethnic groups. These new data sets were developed following several global studies that demonstrated the inappropriateness of applying the French-Canadian data set used by Demirjian to various ethnic groups. Some of the new data sets include those of the southern Chinese population [(54)], Belgian Caucasian [(26)], South Indian [(55)], Finnish [(56)] and the Afro-Trinidadian dataset and the UK dataset for Caucasians [(57)]. A universal dataset for dental age estimation has been set up by the Dental Age

Research London Information Group (DARLInG) for the facilitation of the development of these reference datasets.

The adapted scoring systems based on the original method by Demirjian have been validated and been shown to give more precise population estimations in the specific populations for which they were adapted [(26)]. However, just like Demirjian's maturity scores, these modified scores may not be valid when used in other populations [(26)].

Some studies seem to approve the applicability of Demirjian's method, especially for the Swedish population [(2,46,58–60)]. A dataset prepared either from a similar or a different population group can be used in dental age estimation [(29)].

Despite the overwhelming evidence that this method overestimates dental age, it is the method which has been selected for this study. The selection was because it is the most widely used, therefore, it is possible to compare data on maturity scores of the sample population to those of other numerous communities all over the world that have used the same method. In literature, not much information is known about the applicability of the Demirjian method in the Kenyan population and the African population in general. Should there be an overestimation of age, subsequent studies on the Kenyan population can help come up with a specific data set of adopted maturity scores from the Demirjian method, which has been done for other communities to improve on precision and validity.

1.2.5 THE RELATIONSHIP BETWEEN CHRONOLOGICAL AGE, DENTAL AGE, NUTRITIONAL STATUS AND EARLY CHILDHOOD CARIES

1.2.5.1 Early childhood caries and nutritional status

Several studies have tried to determine the relationship between BMI and ECC/S-ECC. The results are varied and conflicting— some associate S-ECC with underweight and failure to thrive, suggesting that S-ECC may lead to a low BMI [(17)]. The significant association between ECC and overweight is associated with the shared risk factors between the two variables (high sugar diet) according to some studies. Others have not found any significant association between ECC and nutrition [17].

A study by Alvarez et al. reported that peak caries activity is significantly higher in wasted children and in those who were both stunted and wasted when compared with healthy controls. The study concluded that malnutrition resulted in increased caries experience in the deciduous teeth, affected the dental caries age distribution and delayed tooth development [61].

A longitudinal study reported that children who were both stunted and wasted in infancy had by the age of four years recovered from the malnutrition. The beginning of their curve had shown a significantly higher caries experience in the deciduous teeth than those who had healthy growth [62]. Children with low weight for age and those from families of low-income have a higher risk of dental caries experience, compared to those with a healthy weight and from good socio-economic backgrounds [63]. A child with S-ECC is 1.23 times more likely to become underweight when compared to his/her caries free peers [64].

A higher dmft-DMFT index has been found in obese study subjects in comparison to healthy controls [65]. A significant association has been observed between high BMI and dental caries in both permanent and primary dentition [66]. BMI z-scores that are significantly higher has been recorded in children with S-ECC when compared to their caries free peers [17].

Insignificant relationships between increasing dmft and the deficiency in BMI, weight and height have been reported in other studies [67]. A study involving children with S-ECC found that BMI percentile was not correlated with number of teeth with pulpal involvement or with dmft. A survey by Costacurta et al., yielded conflicting findings: with the BMI classification (underweight, healthy weight, pre-obese and obese), the association between increase of dmft-DMFT and pre-obesity/obesity was not significant, but with FM% classification (Body Fat Mass Percentage - WHO cut-offs), the pre-obese/obese subjects had higher caries indexes than their regular weight counterparts, both in deciduous and permanent teeth. Besides, with the FM%

(McCarthy cut-offs) classification, a higher caries index was found in obese children compared to pre-obese and normal-weight children both in deciduous and permanent teeth, but their dmft-DMFT value was comparable with that of underweight children [65].

BMI misclassifies the status of adiposity of children when compared to DXA (Dual-energy X-ray Absorptiometry), which provides a more specific assessment of body composition and careful screening. The conflicting data in the literature between dental caries and obesity could be explained by the misclassification of childhood obesity (determined by the BMI) [65].

Diet is essential in the development of dental caries. High refined foods and snacks consumption, primarily those rich in sucrose, is associated with a high dental caries prevalence [68].

1.2.5.2 Early childhood caries and dental age

It is a well-known fact that ECC can result in the premature loss of primary teeth and this can have many consequences. A lack of literature exists on the relationship between dental maturity and dental caries. Most studies available focus on the premature loss of primary molars and the eruption of their permanent successors. A survey by Fanning showed that the rate of formation of premolars was not affected following the extraction of the deciduous precursor [69].

Regarding the effect of premature loss of primary molars, there are varied and sometimes contradicting findings in the literature. It seems the variations are dependent upon the timing of the extractions. If the removal is done before complete premolar crown formation (five years and below), then the premolar tooth eruption is delayed [69,70]. If the extraction is done at a later period when the premolar has advanced root formation (between 8-10 years), then an eruption is greatly accelerated [69,70].

Retardation in eruptive movement and gingival emergence of a tooth following the extraction of its predecessor could result from scar tissue formation which mechanically resists eruptive changes [69,71]. Acceleration of a permanent successor tooth eruption can occur if the deciduous successor is infected with abscess formation. The dental alveolar infections have been attributed to bone destruction which accompanies long-standing odontogenic infections. Bone destruction creates a path of minimal resistance for the erupting successor which may sometimes erupt with an immaturely developed root [69,71].

When the predecessor is not extracted, successor tooth eruption can still be affected. Gingival emergence of premolars (both maxillary and mandibular) is accelerated by 2-8 months when the predecessors had dental caries or had been restored but had not been extracted [72].

1.2.5.3 Nutritional status and dental age

Healthy growth in children can only occur when there is an adequate and appropriate dietary intake of all the required nutrients. Proper nutrition is necessary for body function, healing, energy expenditure and metabolic stress. Nutrients essential for tooth development are phosphorus, calcium, vitamins A, C and D. A small amount of fluoride incorporation during development makes the tooth resistant to dental caries. A deficiency in nutrients could result in dental and bone (hard tissues) hypoplasia, or hypomineralisation or both.

Malnutrition affects tooth development. Protein-energy malnutrition is the most pressing in Kenya, with infants, pre-school and school children being affected the most [13]. Dental age is retarded in underweight children, those with protein-energy malnutrition [73] and anaemic children [74]. Delayed eruption and exfoliation of deciduous teeth [61,62,75] and delayed eruption of permanent teeth [75] has been observed in underweight children. Obesity has been associated with advanced tooth formation [6,76,77].

1.2.5.4 Chronological age and dental age

Dentition development varies among different populations, and therefore, chronological age cannot be used to investigate maturity with precision [78]. The development of teeth correlates more closely with chronological age in young adults, adolescents and children, when compared to other factors of maturation [3,5,6].

1.3 STATEMENT OF THE PROBLEM

The prevalence of dental caries is on the rise. The Kenya National Oral Health Survey Report (2015) placed dental caries prevalence among children aged five years at (46.3 %), which was higher than in other age groups [10]. The pain resulting from untreated dental caries may interfere with the child's nutrition, sleep, learning/schooling, development and growth, among others. Dental caries can result in the premature loss of teeth which has several effects on dental age, occlusion, and can induce the development of psychological problems, and difficulty in eating.

Only 38 % of children are registered by the age of five years in Eastern and Southern Africa, leaving approximately 44 million children (5 years of age and below) unregistered [28] and therefore without documents to prove their actual age. In such cases use of dental age and other methods to estimate chronological age becomes very vital. In Kenya today, no standardised method of dental age assessment is in place. Most dentists use eruption age/ eruption sequence to estimate age, yet this is highly variable and unreliable compared to tooth formation.

1.4 JUSTIFICATION OF THE STUDY

Early childhood caries can affect both dental age and nutritional status. There is inadequate information on the relationship between dental age and nutritional status among children with ECC. The methods used to assess dental age generally do not factor in the effect of ECC and nutrition on dental age. The survey aimed to establish information on the relationship between these variables and to try and quantify to what extent nutrition and ECC affect dental age, which may influence policy in the assessment of dental age for varying uses. The study also assessed the validity of using the Demirjian dental age estimation method in Kenyans of the African race as information on this is scarce. The findings from this study shall contribute to scientific knowledge as currently there is a scarcity of information on ECC, chronological age, dental age and nutritional status.

1.5 STUDY OBJECTIVES

1.5.1 Main Objective

To determine the relationship between dental age, chronological age, nutritional status and early childhood caries in children aged 3-5 years.

1.5.2 Specific objectives

1. To determine the relationship between ECC and dental age.
2. To determine the relationship between ECC and nutritional status.
3. To determine the relationship between nutritional status and dental age.
4. To compare chronological age and dental age in 3-5-year-old children with ECC.

1.6 HYPOTHESES

1.6.1 Null hypotheses

1. There is no relationship between early childhood caries and dental age in 3-5-years-olds in Nairobi, Kenya.

2. There is no association between early childhood caries and nutritional status in 3-5-years-olds in Nairobi, Kenya.

3.There is no association between the dental age and nutritional status in 3-5-years-olds in Nairobi, Kenya.

4. There is no relationship between chronological age and dental age in 3-5 years-olds in Nairobi, Kenya.

1.7 VARIABLES

1.7.1 Independent variables

i. Chronological age
ii. Gender

1.7.2 Dependent variables

i. Dental age
ii. Decayed, missing, filled teeth
iii. Weight for age
iv. Weight for height
v. Height for age

1.7.3 Sociodemographic variables

i. Care-giver's level of education
ii. Care-giver's occupation
iii. Care-giver's marital status
iv. Number of siblings
v. Birth order

1.7.4 Confounding variables

i. Oral hygiene status
ii. Dietary practices
iii. Gender

CHAPTER TWO

2.0 MATERIALS AND METHODS

2.1 STUDY AREA AND POPULATION

2.1.1 Study area

The research was carried out in Nairobi County, Kenya which is the capital city of Kenya with an estimated population of 2,750,547 [81].

The study was explicitly carried out at the Lady Northey Hospital, which is located along Statehouse Road, Nairobi. This hospital sees 153 patients (averagely) of the age of 5 years or younger each month.

2.1.2 Study population

The study population included children aged 3-5 years attending dental clinics at the Lady Northey Hospital.

2.1.2.1 Inclusion criteria

i. Children aged 3-5 years. Age was determined in full months (36-59 months).
ii. Children with ECC.
iii. Children of the African race in the Kenyan population.
iv. Children whose caregivers had to give consent.
v. Children who gave assent.
vi. Children with OPGs taken as a requirement for diagnosis.
vii. Availability of complete patient records (date of birth, date of the radiograph).
viii. Good quality of radiographs.

2.1.2.2 Exclusion criteria

i. Children with impacted teeth or localised oral pathologies/anomalies that would affect dental development.
ii. Children with systemic syndromes or diseases (congenital anomalies) affecting skeletal and dental development.

iii. Children without ECC.
iv. Children with present or history of orthodontic treatment.
v. Children with severe malocclusion.
vi. Aplasia of at least two corresponding teeth on both sides of the mandible.

2.2 METHODOLOGY

2.2.1 Study design

The study was a descriptive cross-sectional and carried out in five months.

2.2.2 Sampling technique

A selection of children with ECC from Lady Northey Hospital was made. Purposive sampling was employed where every child aged 3-5 years were examined. Only those presenting with ECC were selected for the study until the required sample size was obtained.

2.2.3. Determination of the sample size

Fishers formula was used to calculate the sample size: **n =** $\underline{\mathbf{z^2P(1- P)}}$ **; where** $\mathbf{C^2}$ **=n =** $\underline{\mathbf{1.96^2 \times 0.463(1 - 0.463)/\ }}$ $\mathbf{0.05^2}$ **' and z** = z value' **P** = Estimated prevalence of dental caries among 5-year-olds according to the Kenya National Oral Health Survey Report (2015) (46.3 %) [(10)]. Since the prevalence of dental caries from the same hospital is high (95.5%), this suppressed the sample size. Therefore, there was a loss of statistical power. **C** = 1 – confidence (1 – 0.463) and **<u>n= 382.</u>**

Data obtained from Lady Northey indicates that an average of 153 patients below the age of 5 years attended the clinic per month. Given that data was to be collected throughout two months the sampling frame for the study was 306. Since the sampling frame is less than 10,000, the finite population correction was used to estimate the correct sample size, hence; $n_{f=}$n/ 1+n/N; where, nf = the desired sample, 382 hence 382/ 1+/306= the calculated sample size of **170.24** and an additional 10% to account for attrition:17.024; therefore n_f=187.26≈187or rounded off to 190; hence n_f=190.

2.3 DATA COLLECTION AND ANALYSIS

2.3.1 Data collection instruments

Information on the sociodemographic background and dietary habits of all the children who meet the inclusion criteria was collected using a semi-structured questionnaire.

2.3.2 Chronological age

Each patient's chronological age was calculated by subtracting the date of birth from the date when the radiograph (OPG) was taken.

2.3.3 Dental caries experience

Dental mirrors and WHO (11.5) dental probes were used in conducting oral examinations under natural light. The child sat on a dental chair, facing natural light. Before dental caries diagnosis, teeth were dried using a piece of gauze. The World Health Organization (WHO) 2005 caries diagnosis criteria was used. Dental caries was diagnosed when there was a clinically detectable loss of tooth substance and when such loss has been treated with fillings or extraction. Dmft index was used to determine the dental caries prevalence.

2.3.4 Oral hygiene status

The oral hygiene status of the child was established based on the Loe and Silness index for gingival health and the Silness and Loe index for plaque score.

2.3.5 Nutritional status

Anthropometric measurements were used in the nutritional status assessment. With the children erect and barefoot, their height was measured using a standard height board to the closest 0.5cm, and weight was measured using a Salter scale to the nearest 0.1 kg. The WHO child growth standard reference was used to evaluate nutritional status using the indices of WAZ, HAZ and WHZ. Any child below +/-2SD was classified as malnourished.

2.3.6 Dental age

All Orthopantomograms (OPGs) included in the study were done at the University of Nairobi Dental Hospital, Radiology Department. The OPG machine model which was used was the Kodak 9000c. The OPG images were processed digitally.

Dental age was assessed by determining the degree of maturation of seven left mandibular teeth (excluding the third molar). Each tooth was assigned a rating from "A" to "H" (Appendix XV). A to H are the eight stages of tooth development. Next, the developmental stages were converted to maturity scores by using published gender-specific conversion tables (Demirjian's maturity scores- Appendix XVIII). The scores for each tooth were then added to arrive at a total maturity score which was converted to dental age using separate standard tables or graphs given for each gender. According to Demirjian, the tooth development stages the stages are labelled 0 for no calcification and A-H for the eight calcification stages (Appendix XVI) [(34)].

2.4 DATA VALIDITY AND RELIABILITY

2.4.1 Pretesting of data collection tool

A pre-test of caregivers' questionnaire was done in the actual field situation in the presence of all research team members after they had been recruited.

2.4.2 Calibration of the principal investigator

A paediatric dentist, nutritionist and a radiologist calibrated the principal investigator. Every tenth child was clinically re-examined and every 10th radiograph re-examined to determine inter-examiner and intra-examiner reproducibility. For all patients, a regular examination and measurement procedure was employed. The scores of interest for calibration analysis were dmft, gingival index, plaque score, weight, height and dental age.

Cohen's Kappa index was used to calculate reliability. The results of the calibration were 1.00, 1.00, 0.85, 1.00, 1.00, 0.85 for intra-examiner and 1.00, 0.85, 0.80, 1.00, 0.85, 0.85 for inter-examiner values in relation to dmft, gingival index, plaque score, weight, height and dental age.

2.5 DATA ANALYSIS AND PRESENTATION

Data were coded, entered into a computer using SPSS program version 22 for windows. Data cleaning was done before analysis. Both univariate and multivariate analysis was done. Nutrition data was analysed using the WHO Anthro program. Bar graphs and line graphs have been used in the presentation of data.

2.6 MINIMISATION OF BIAS AND ERRORS

All the instruments were calibrated. The investigator carried out all the examinations. Trained assistants recorded the findings in the recording schedule. The study was restricted only to those who met the inclusion criteria.

2.7 ETHICAL CONSIDERATIONS

The research was authorised by the Research, Ethics and Standards Committee of the University of Nairobi and Kenyatta National Hospital, Kenya before the research was conducted. Permission to carry out research in Nairobi County was obtained from the National Commission for Science, Technology and Innovation (NACOSTI). Also, permission to conduct the study at the Lady Northey Dental Clinic was sought and obtained from the Nairobi City County Health Services.

Caregivers who had taken part in the study were told the purpose of the study, before signing a written informed consent. The children and their caregivers had the right to withdraw from the study at any given time without suffering any consequences. All children found to be either malnourished or with ECC were referred to relevant clinics for further management. The confidentiality of study participants and the protection of their identity was strictly observed. Reports from this study do not identify any participant. The data was stored safely, and only the investigator is the custodian.

2.8 STUDY LIMITATIONS

The date of birth of the study participants was not ascertained using birth certificates; instead, this information was sought from the primary caregiver who was the mother in the majority of the cases. However, any errors arising from this applies to all the participants.

There are many confounding factors influencing nutritional status, dental caries and dental age. Not all confounders, like genetics, were accounted for in this study.

The low birth weight recorded in children with ECC is more likely if they have pulpally involved teeth. This study did not distinguish children with pulpally involved teeth and those without, which may have affected the results of the study.

CHAPTER THREE

3.0 RESULTS

3.1 SOCIO-DEMOGRAPHICS

3.1.1 Distribution of the caregiver's marital status and the person who provided care: For one hundred and thirty-two (82%) children the caregiver of the child was the mother while 28 (16.10%) children the caregiver was the father, two (1.20%) had an aunty as the caregiver, and one (0.60%) child had the grandmother as the caregiver. One hundred and twenty-nine (75.9%) children lived with both parents while forty-one (24.1%) lived with single parents or caregivers., Figure 1. The mean number of people per household with whom the children lived with was four.

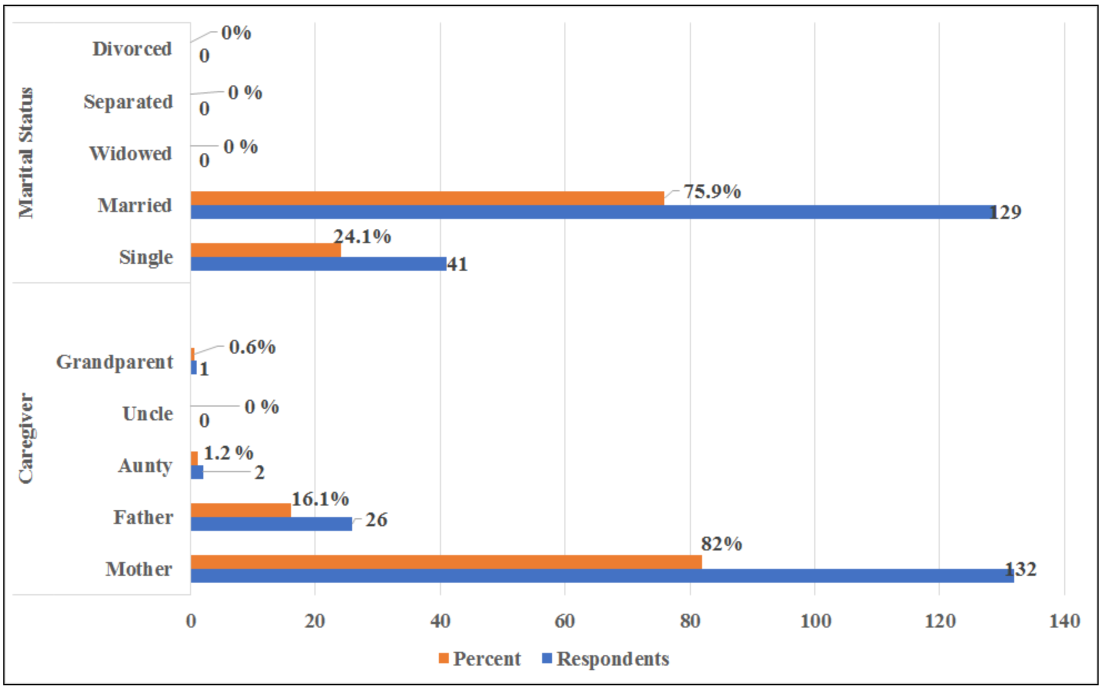


Figure 1: Distribution of the children's caregiver and the marital status of the caregivers.

3.1.2 The caregiver's level of education and the type of job:

There was one (0.60%) caregiver who had no formal training, twenty eighty (16.40%) had a primary school level of education, 75 (43.90%) had secondary school education 53 (31.00%) technical college level of education and 14 (8.20%) had a university level of education. Figure 2. The caregiver's job was described as professional 27 (16.0 %), those with clerical and white-collar jobs were 18(10.70%); those who were businessman/woman were 74(43.80%); those who had skilled manual jobs were 17 (10.10%); while unskilled workers were 6 (3.60%) and those who were unemployed. Figure 2.

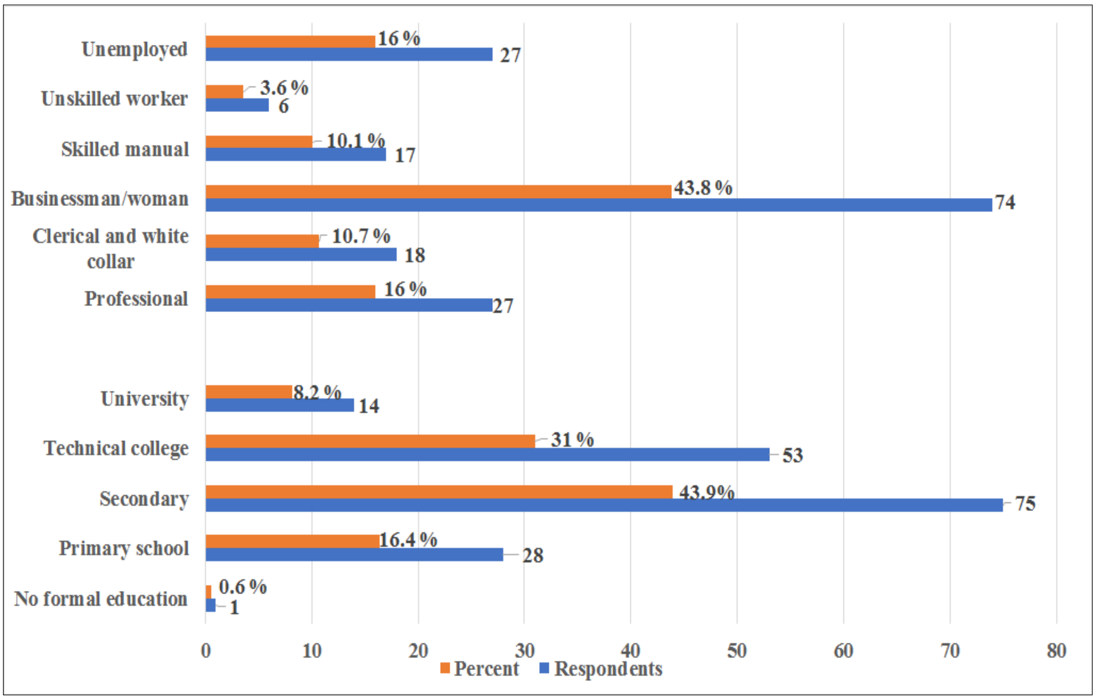


Figure 2: Distribution of the caregiver by the level of education and occupation.

3.1.3 Natal History

There was a total of hundred and seventy-one children aged between 3-5 of whom 3-4 were 71 (41.1%), and 100 (59.1%) were aged 4-5 years. The gestation period for both age groups was 36.7 weeks and the mean birth weight for those aged 3-4 years was 3.3 kg while those in the age category of 4-5 years the mean birth weight was 3.2 kg. The immediate postnatal history of the children was that 137(80.1%) of children had had had standard delivery while 34 (19.9%) had been born through caesarian section. All the one hundred and seventy-one children had been immunised, sixty-two (36.9%) had suffered from different illnesses a few days before recruitment into the study. The sickness was diarrhoea affected two (4.5%) children, and cough/cold affected 42 (95.5%), and none of the children had recently suffered from malaria. Thirty-one children had suffered from a chronic illness while 137 (81.5%) did not suffer from chronic diseases Figure, 3.

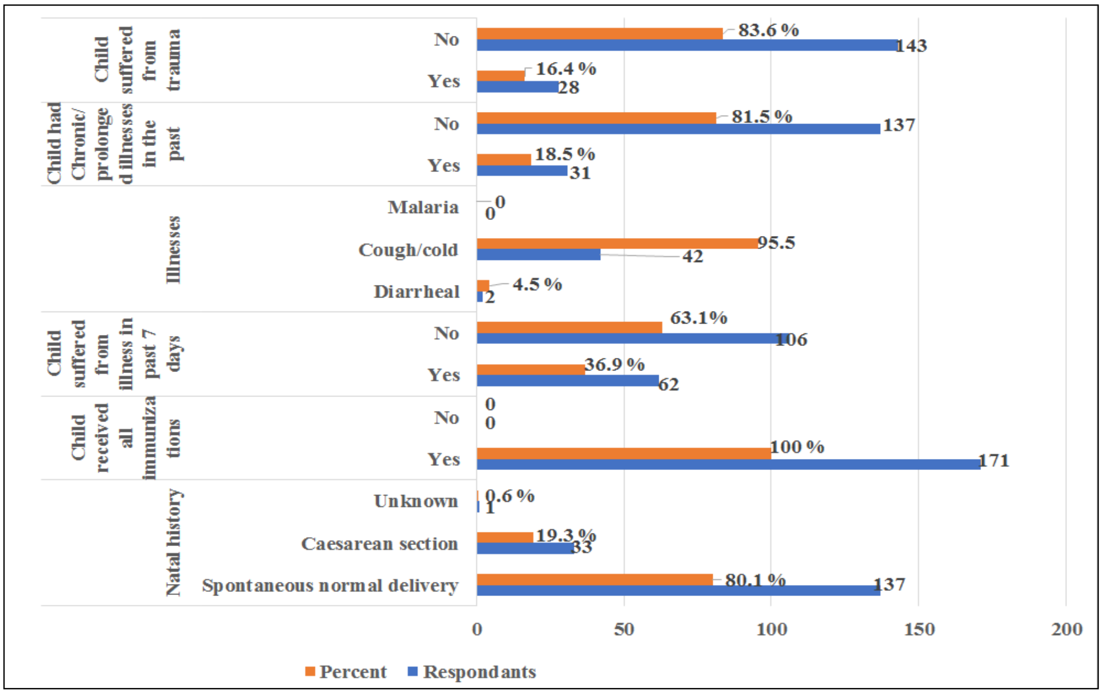


Figure 3: Postnatal history of 171 children aged 3-5 years.

For the children aged 3-4 years twenty-eight (39.4%) out of 71 had traumatic dental injuries while in the age category of the 4-5-year olds 33 (33%) out of 100 individuals had had traumatic injuries. In the 3-4 year age group the trauma occurred at a mean age of 24.1 months while in the 4-5 months age group the trauma occurred at 20.8 months post uterine, Figure 4. 0ut of the 171 children (16.4%) had suffered from illnesses. From the 3-4-year age group out of the 28, there were 11(39.3%) who had suffered from illness for a period 11.5±14.5 months while in the 4-5-year olds 17 (60.7%) had suffered from diseases for 12.4±14.8 months.

3.1.4 Feeding Habits during the infancy period

One hundred and forty-one (82.50%) children aged 3-5 years had exclusive breastfeeding in their early infancy. Twenty-seven (15.80%) had breastfeeding and bottle-feeding, and three (1.8%) had exclusive bottle feeding. There were 163 (95.90 %) children who breastfed on demand while seven (4.10 %) were not. The duration of bottle feeding was eighteen months for those aged 3-4 years and twenty months those aged 4-5 years. The duration of breastfeeding in both the groups of 3-4 and 4-5-year-olds was twenty-one and twenty-two months respectively, Figure, 4.

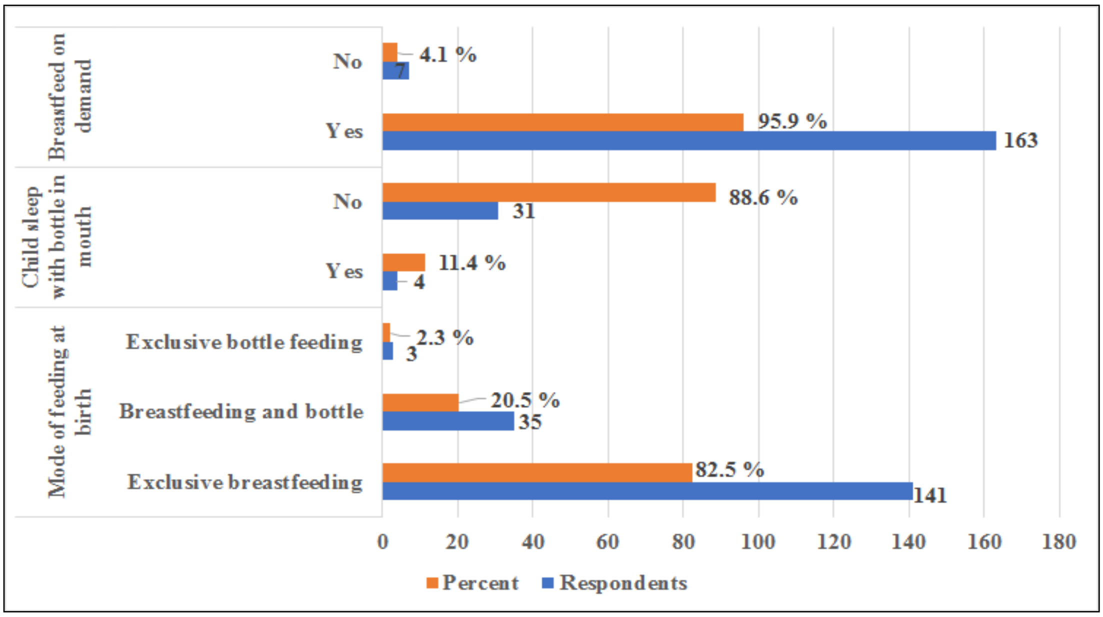


Figure 4: Infancy feeding habits for the children involved in the study, n=171

3.1.5 Distribution of the children by gender and age categories

In total 208 children were recruited into the study, out of whom 37 (17.7%) were excluded as they dropped out as they were not interested in taking the orthopantograms they wanted treatment for their children without radiographs. The remaining 171 children whose parents had returned the orthopantograms had their data for anthropometrics, ECC, recorded. There were 84 (49.1%) males while the females were 87 (50.9%).When children were categorised by age groups, where there were 38 (45.2%) boys aged 3-3.9years while the girls in the same age category 33 (38%). For the age category of 4-4.9, there were 46 (54.8%) boys while the girls were 54 (62.1%), Figure 5.

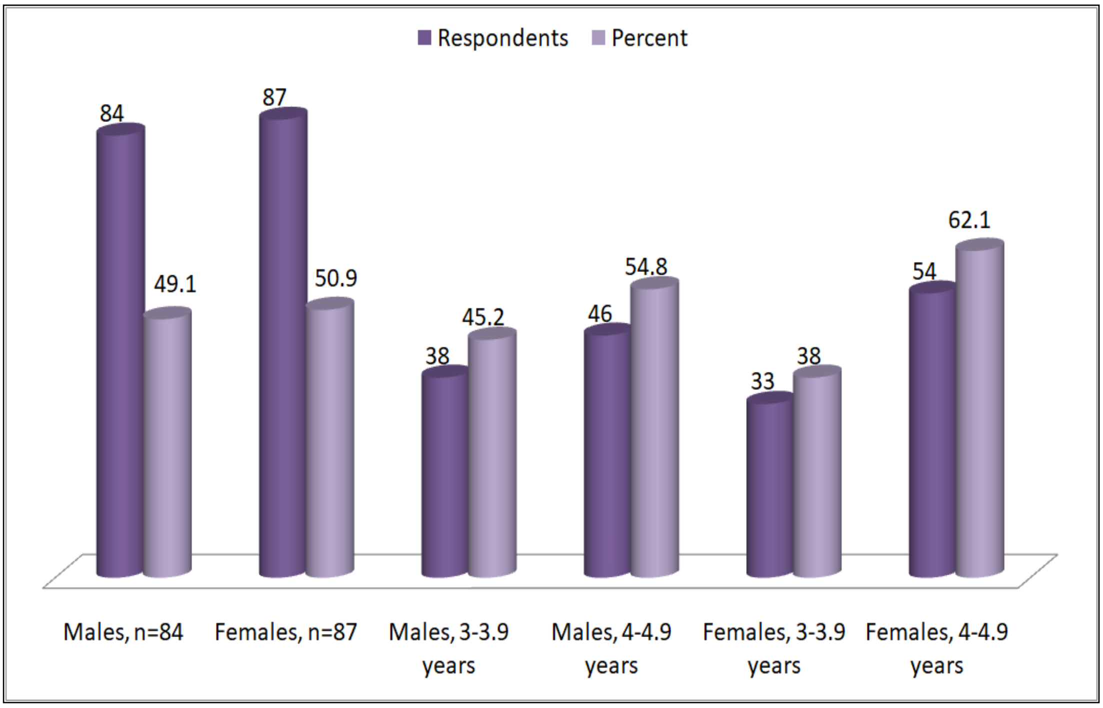


Figure 5: Distribution of the children by gender and by age group

When the children were categorised into age groups, the 3-3.9 year-olds were 71 (41.5%), and those in the 4-4.9 age category were 100 (58.5%), Figure 6.

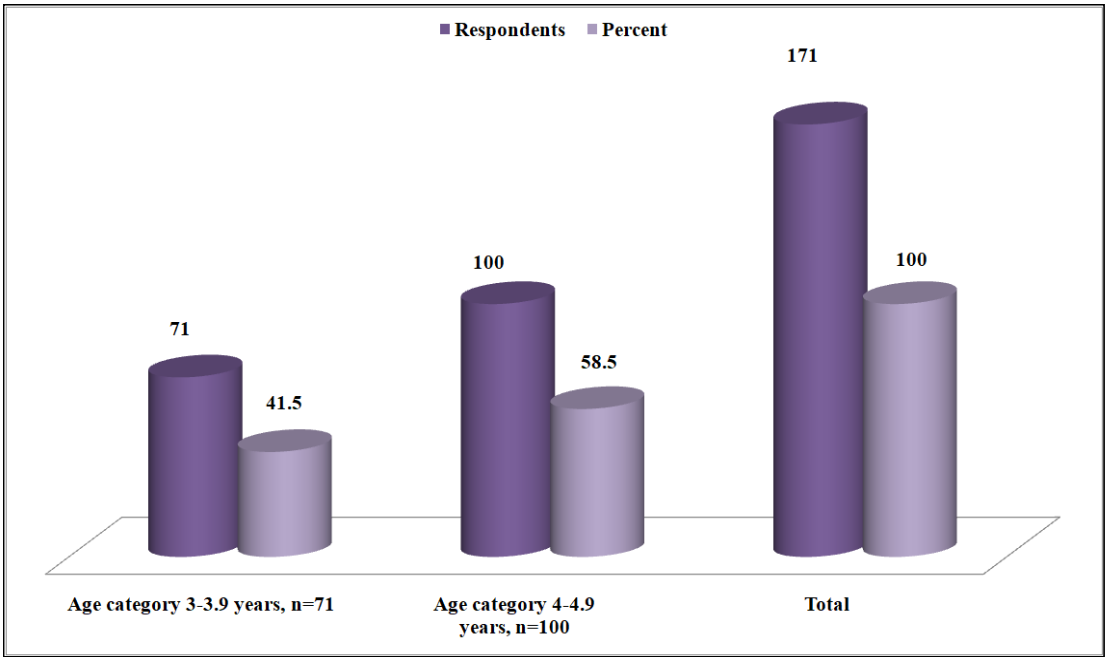


Figure 6: Distribution of the children by age categories

3.2 CHRONOLOGICAL AGE

3.2.1 Chronological age by gender

The mean chronological age for boys aged 3-3.9 years was 3.53±0.29years, se=0.05, (range 2.92-3.92 years) while the mean age for the girls in the same age group was 3.55±0.3 years, se=0.05 (range 3.00-3.92 years). For the age, category 4-4.9 years the mean age for the boys was 4.45±0.26, se=0.04, (range 4-4.92 years) and the girls had a mean chronological age of4.50±0.28years, se=.04 years (range 4.00-4.92 years) Figure 7.

The differences in the mean ages by gender was insignificant with an independent samples test, with Levene's F=0.043, df= (169, 169), p=0.179.

The mean chronological age for boys aged 3-4.9 years was 3.53±0.29, se=0.05 (range 3-3.92 years) while the girls had a mean age of 3.55±0.3 years, se=0.05 (range

3-3.92 years). The boys in the age category of 4-4.9 years had a mean chronological age of 4.45±0.26, se=0.04 (range 4-4.92 year) while the girls in the same age group had a mean chronological age of 4.5±0.28, se=0.04 (range 4-4.92years). The differences in the mean chronological age by gender and age category was insignificant when analysed with an independent samples test where a Levene's test for equality of variances had F= .019, df=169, p=0.190 at 95% CL.

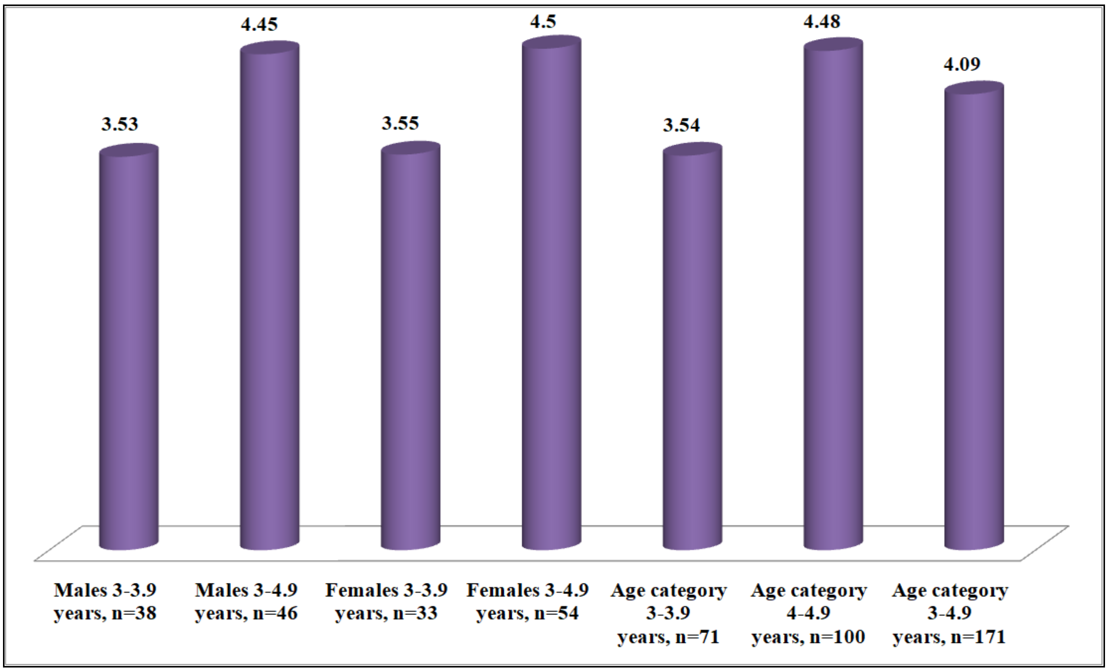


Figure 7: The means for chronological age by gender, n=171

3.2.2 Chronological ages by age groups

The mean age for 171 children was 4.09±0.54, se=0.042years (range 3-4.92 years). The children aged 3-3.9 years were 71 (41.5%) and had a mean chronological of 3.59±0.29 (58.5%). Children aged 4-4.9 years were 100 (58.5%) and had a mean age 4.48±.27, se=.03 (range 4.00-4.92 years) Figure 8. However the differences in the mean age by age group was significant with an independent samples test, with Levene's equal variance assumed F=0.362, df= (169, 149), p=0.000 at 95% CL The mean differences in chronological age by age category were significant with an independent samples test where Levene's test for equality of variances had F=0.528, df= (169, 144), p=0.000 at 95% CL.

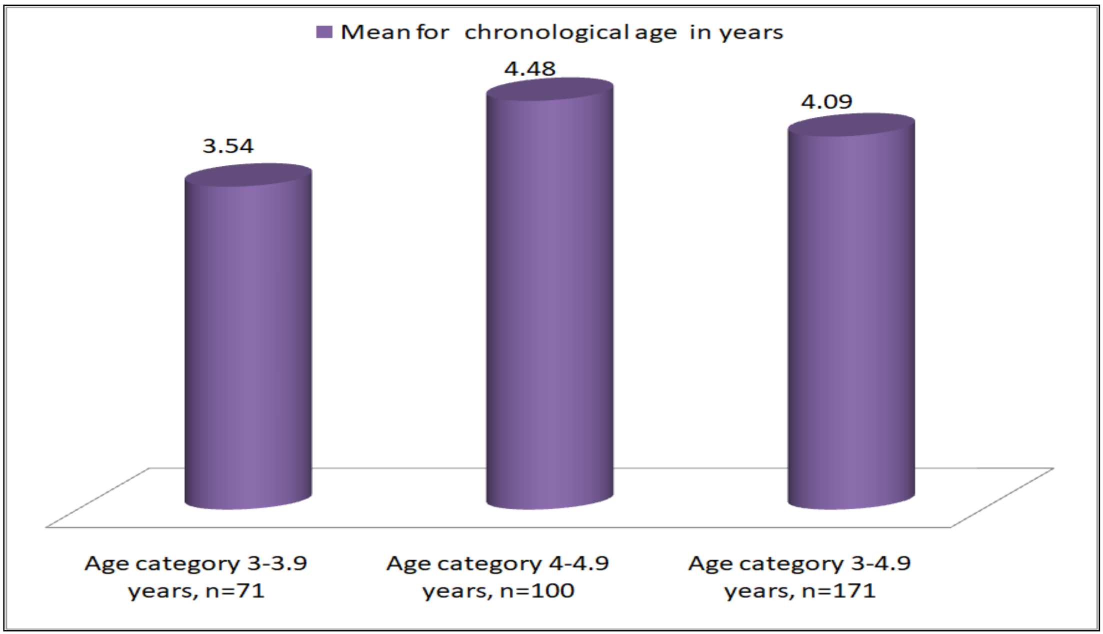


Figure 8: The means for chronological age

3.3 ESTIMATED DENTAL AGE

3.3.1 The mean estimated age by age group

The mean estimated dental age for the 171 children was 4.59±0.75, se=0.57, (range 2.20-6.7 years); The mean estimated dental age for children aged 3-3.9 was 4.13±0.77 years, se=0.09, (range 2.2-5.7 years) and those in the age category of 4-4.9 years had a mean estimated dental age of 4.92±0.54, se=0.05, (range 3.4- 6.7 years), Figure, 9. The differences in the dental age by age category were found to be significant with an independent samples test where a Levene's where equal variance was assumed F=21.438df=(169, 117), p=0.000 at 95% CL

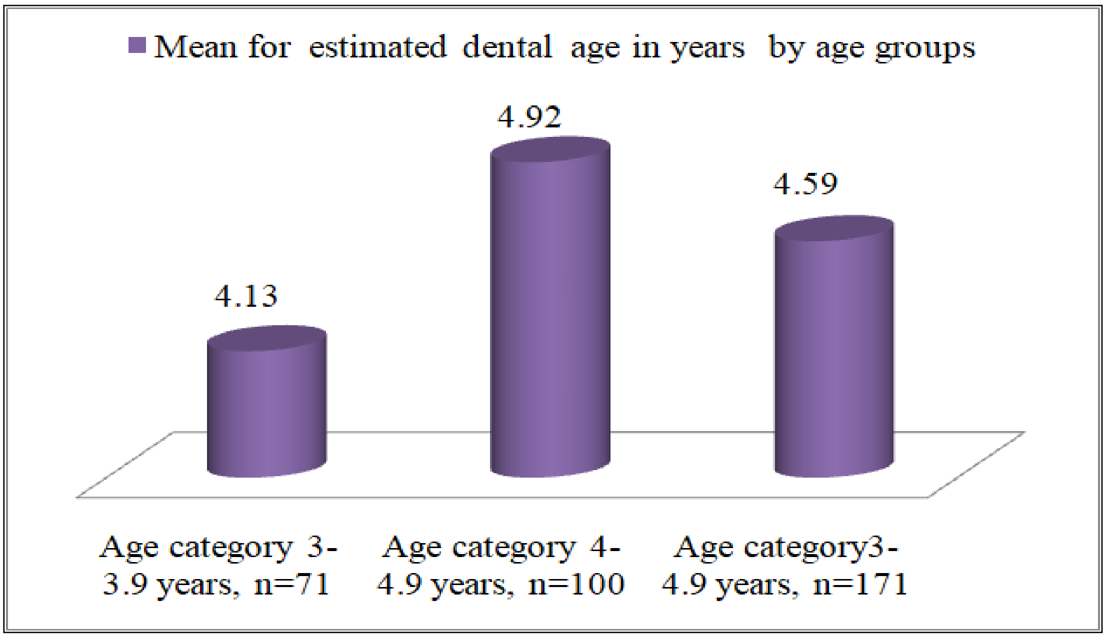


Figure 9: The mean estimated dental age by age groups

3.3.2 The mean estimated dental age by gender

Eighty-four (49.1%) boys aged 3-4.9 had a mean estimated dental age of 4.68±0.72 years, se= 0.08, (range 2.20 to 5.90 years); while 87 (50.9%) girls had a mean dental age of 4.50±0.77, se=0.08, (range 2.6- 6.70) Figure 10 . The mean estimated dental age for boys aged 3-3.9 was 4.31±0.84, se=0.14, (range 2.2-5.7 years) while the mean estimated dental age fro the girls was 3.92±0.64, se=0.11 (range 2.6-5 years). In the age category of 4-4.9 years, the boys had a mean estimated dental age of 4.99±0.41, se=0.06(range 3.8- 5.9 years) while the girls in the same age category had a mean estimated dental age of 4.85±0.62, se=0.08 (range 3.4- 6.7 years), Figure 10.

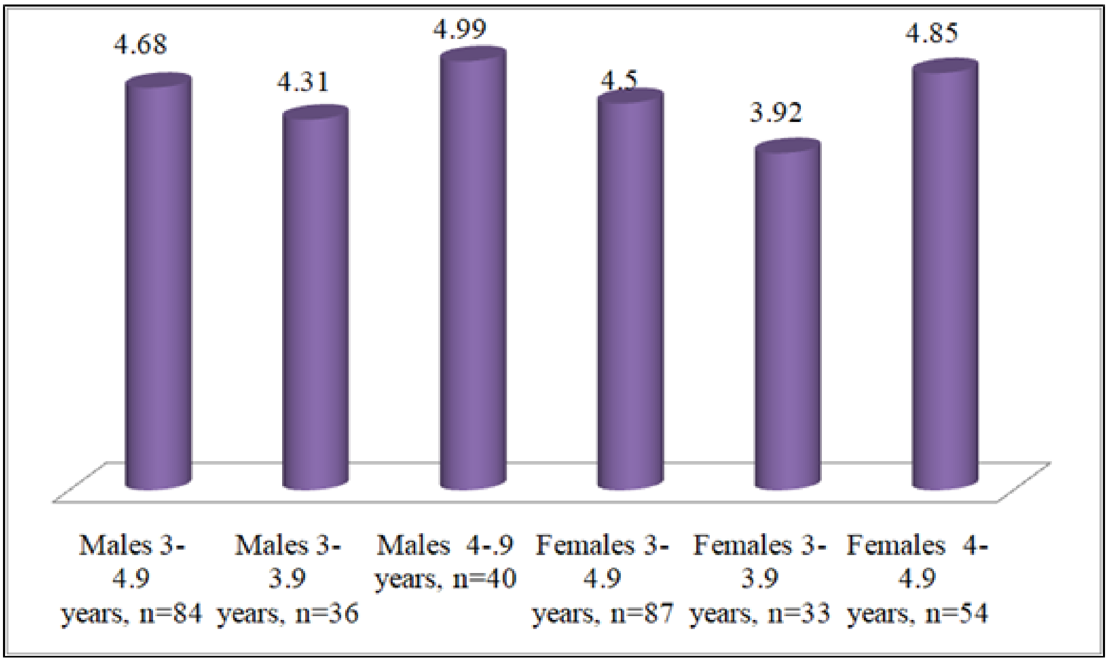


Figure 10: The mean estimated dental age by gender

The differences in the dental age for girls and boys was not significant when an independent samples test the Levene's with equal variance not assumed was insignificant with F= 0.108, df=169, 168), p=0.102.

3.3.3 Estimated Dental Age Delayed and Not Delayed

The mean dental age for the 171 children was 4.59±0.75, se=0.06 (range 3.3-6.7 years) out of whom 136 (79.5%) children had a mean dental age which was not delayed, and the mean age was 4.79± 0.62, se=0.05, (range 3.30 -6.70 years). However, those whose dental age was delayed had a mean dental age of 3.82 ± 0.73, se=0.12, (range 2.20 -4.80 years), Figure 11.

The differences in the mean age between those with a delayed dental age and those without delay in dental age were statistically significant with independent samples

Test with a Levene's test for equality of variances with F=4.649, df= (169, 47), p=0.000.

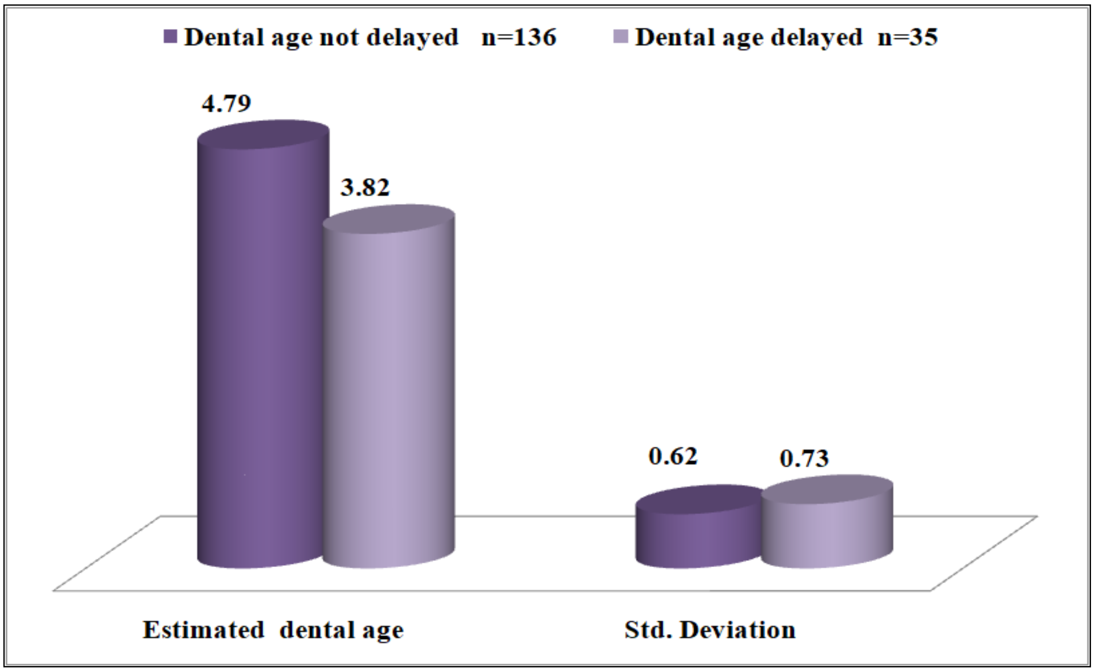


Figure 11: Differences between the dental age for the delayed and not delayed

3.4 ORAL HYGIENE STATUS

3.4.1 Plaque score and gingival index

One hundred and sixty-one out of 171 children in the study were examined for plaque scores and gingival bleeding ten children the index teeth were missing. The mean plaque score was 2.1±0.7; while the mean gingival index was 1.1±0.6, se=0.1. The mean plaque score for 71 (41.5%) children aged 3-4 years was 2.1±0.7, se=0.1, and the gingival index was 1.01±0.6, se=0.1 while100 (58.5%) children aged 4-5years had a mean plaque score of 2.0±0.6, se=0.1 and a mean gingival index of 2.1±0.6, Figure 12.

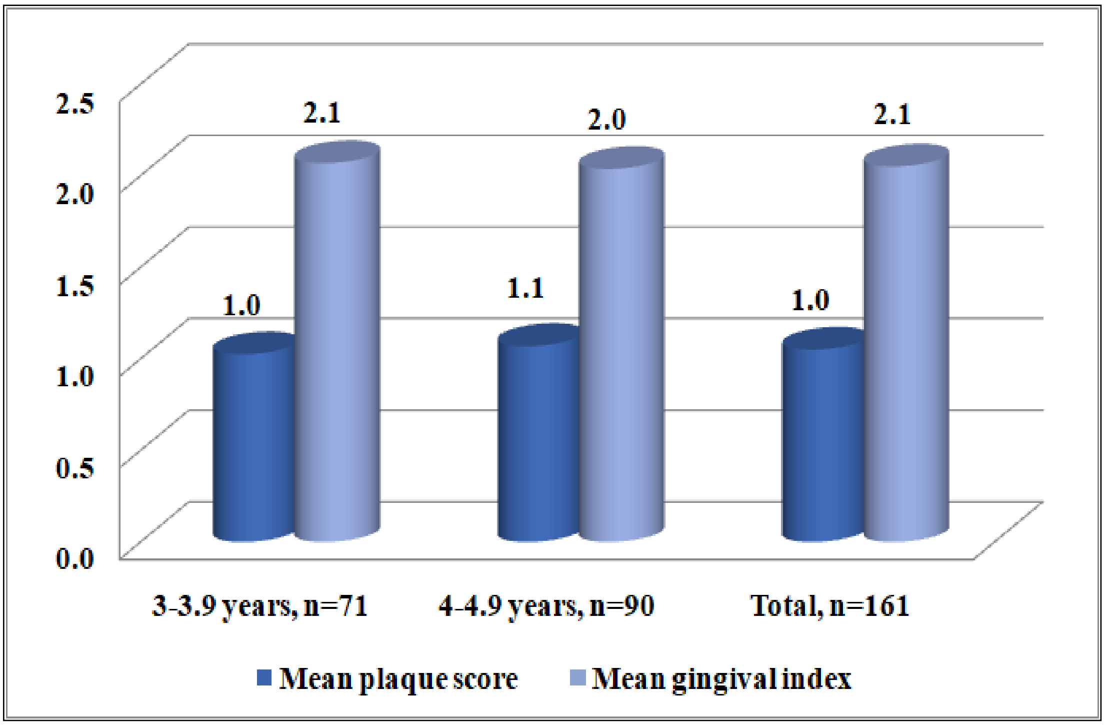


Figure 12: Oral hygiene status by age and chronological age

3.4.2 Oral hygiene status by age

12 individuals were missing index teeth and were excluded from this assessment. A total of 159 individuals aged between 3-5 were assessed for oral hygiene, where 12 (7.5%) children had good oral hygiene, sixty-one (38.4%) had fair oral hygiene and eighty-six (54.1%) had poor oral hygiene. The severity of gingivitis was that 85(52.8%) had mild gingivitis; 74 (46.0%) had moderate gingivitis, and two (1.2%) had severe gingivitis, Figure 13.

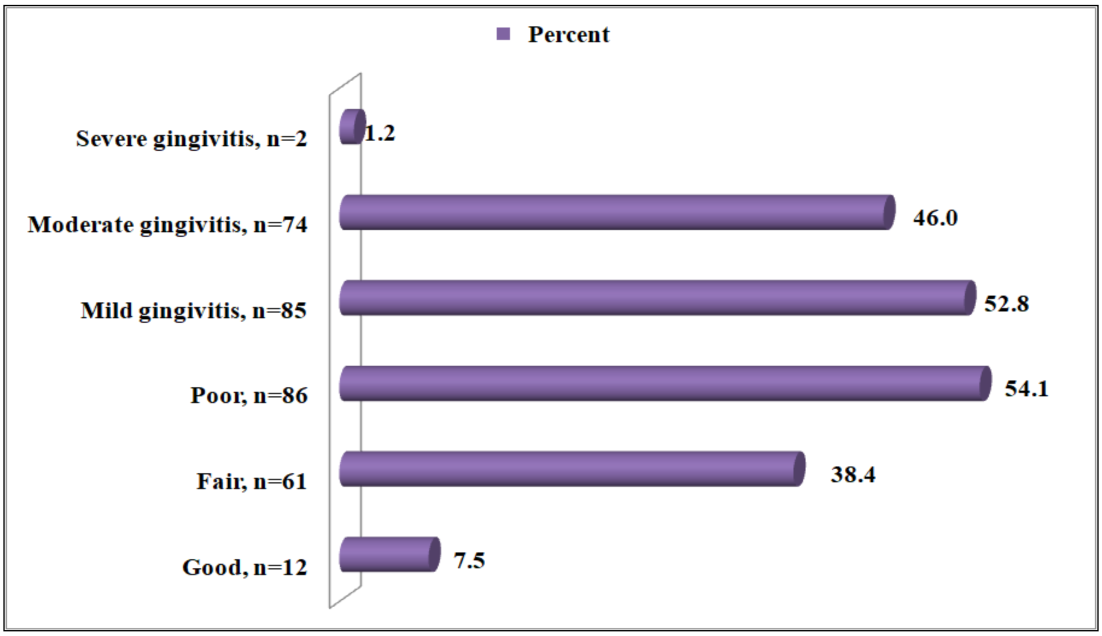


Figure 13: Oral hygiene status and severity of gingivitis

Oral hygiene status was based on plaque scores (PS); excellent (no plaque), good (PS of 0.1-0.9), fair (PS of 1.0-1.9) and poor (PS of 2.0-3.0). The severity of gingivitis was assessed based on gingival index (GI) as follows: mild (GI of 0.1-1.0), moderate (GI of 1.1-2.0) and severe(GI of 2.1-3.0).

3.4.3 The severity of gingivitis by age and gender

3.4.3.1 Age: The 3-3.9-year-olds had 71 (41.5%)children out of whom 37 (52.1%) had mild gingivitis, thirty-four (47.8%) moderate gingivitis however there were no children in this age category that had severe gingivitis. The 4-4.9 age group had 90 (52.%) children out of whom 48(53.4%) had mild gingivitis, there were 40 (44.4%) with moderate gingivitis, and two (2.2%) had severe gingivitis, Figure 14.

3.4.3.2 Gender: There 78(%) boys in whom the distribution of the severity of-of gingivitis was mild 36 (46.1); moderate 41 (52.6%) and severe gingivitis affected one (1.3%) boy. The girls were 83 (48.5%), out of whom were 49 (59%)were affected with mild gingivitis, 33 (39.8%) had moderate gingivitis, and one (1,2%) had severe gingivitis Figure 14.

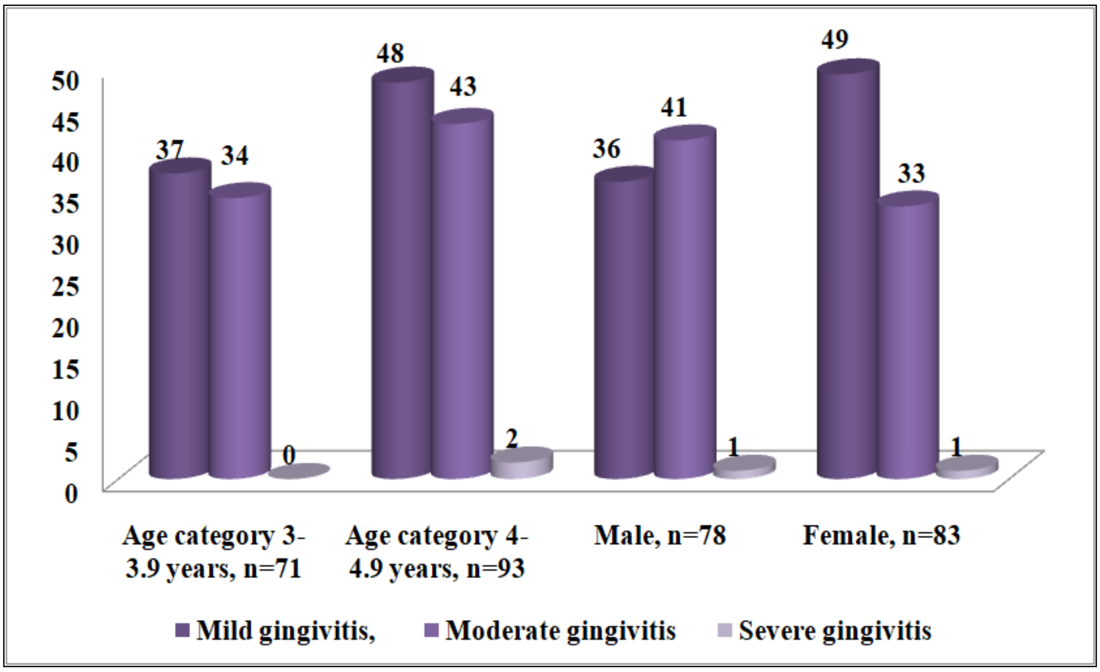


Figure 14: Severity of gingivitis by age and gender

3.4.4 Oral hygiene and ECC

The children who had good oral hygiene had a mean dmft of 20.2, while those with a fair OH had a mean dmft of 20.05 while those with poor oral hygiene had a dmft of 19.94, Figure 15.

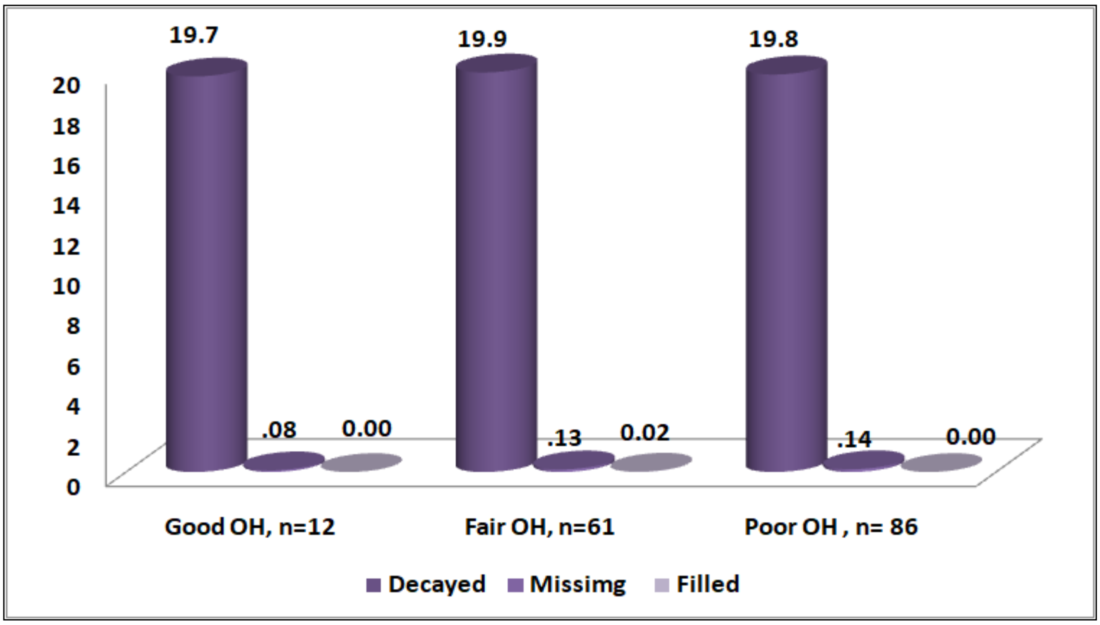


Figure 15: ECC and oral hygiene status

3.5 EARLY CHILDHOOD CARIES

3.5.1 Severity of ECC in the study group

The mean dmft for the 171 individuals was 11.03 ± 4.62, se=0.35 (range 1-20 decayed teeth). The decayed component of the dmft was 10.81±4.43, se=0.34, (range between 1to 20 decayed teeth), missing part 0.22±0.78, se=0.34 (range (0-7 missing teeth), filled component of dmft was 0.01±0.08 se=0.01, (range 0-1 filled teeth). The decayed component formed 98% of the dmft while the missing component 1.9% and the filled component was 0.01 %, Figure 16.

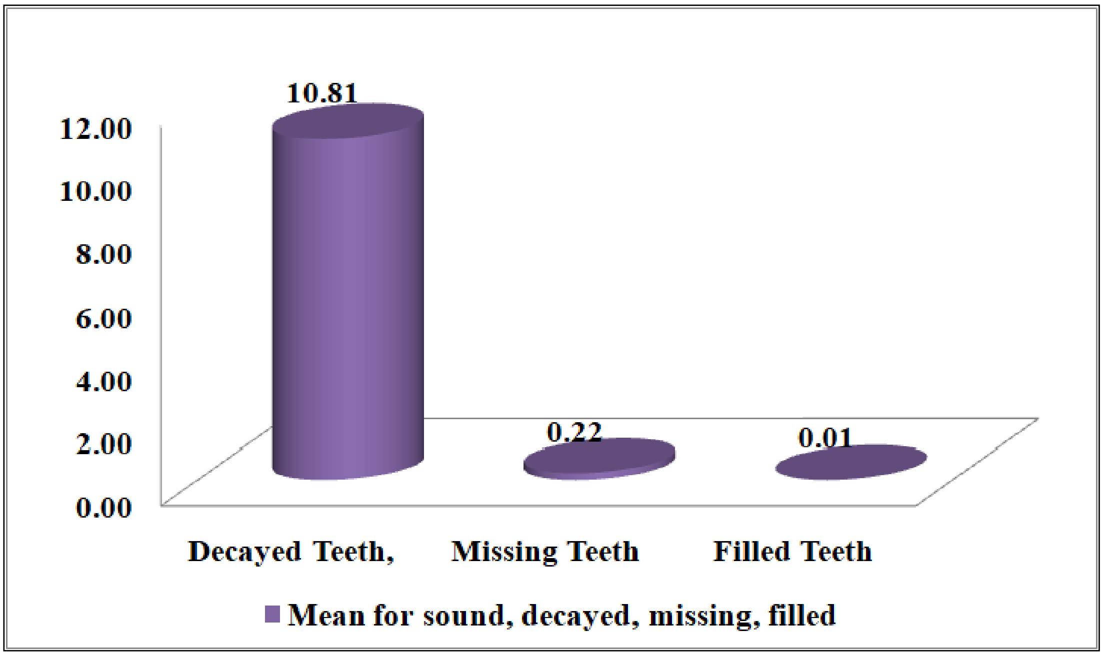


Figure 16: The decayed, missing, filled components of the dmft

3.5.2 Gender and ECC:

The mean dmft for 84 (49.1%) boys aged 3-5 years was 11.29 ±5.04 **se=**0.55, and 87 (50.9%) girls had a dmft of 10.78±4.18 se =0.45, Figure 17. The differences in the dmft between gender were not statistically significant with an independent samples test where a Levene's I indicated F= 4.207, df= (169, 161), p=0.479.

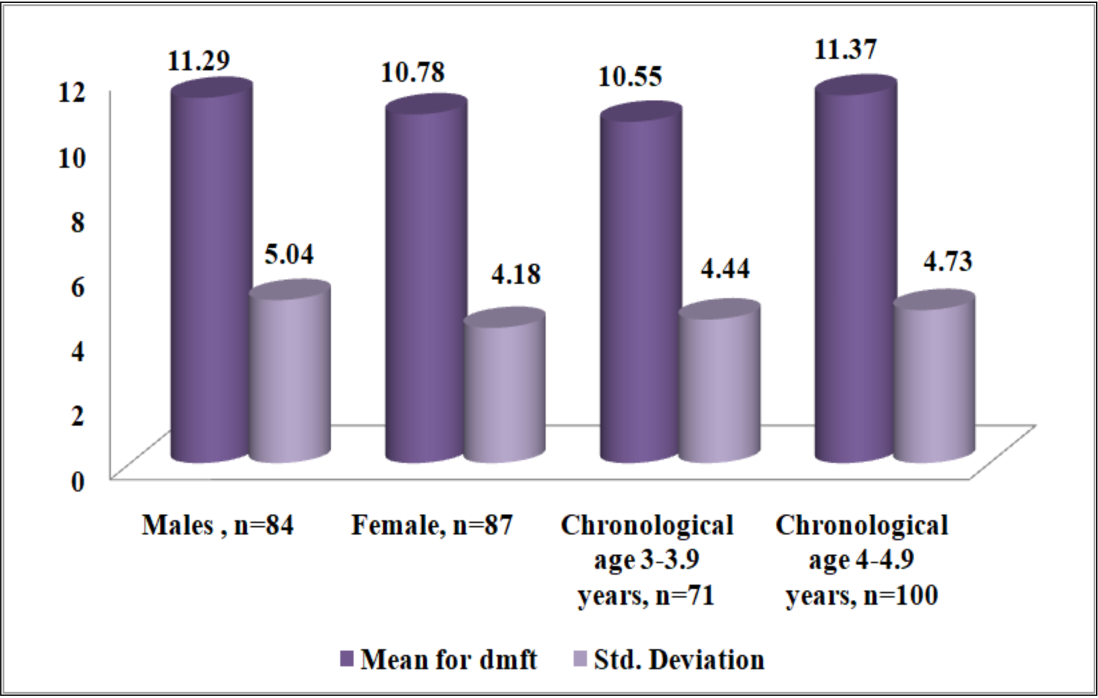


Figure 17: Distribution of dmft by gender and chronological age

3.5.3 Chronological age and ECC

The mean dmft for the 71 (41.5%) children aged 3-3.9 year was 10.55± 4.44, se= 0.53 while 87(50.9%) individuals aged 4-5-year olds had a mean dmft of 11.37± 4.73, se=0.47, Figure 17. The differences in the dmft between age groups were not statistically significant with an independent samples test where a Levene's indicated F=1.216, df= (169, 156), p=0.248

3.5.4 Dental maturity and ECC

Out of the 171 children aged 3-5 years, 136 (79.3%) of the children had a dental maturity that was not delayed with a mean dmft of 11.06±4.74, se= 0.41; while 35(27.3%) whose mean dental maturity was delayed had a mean dmft of 10.91±4.17, se=0.70. The differences in dmft between the children whose dental maturity was statistically not significant when analysed with an independent samples test where a Levene's for equal variances was assumed with F=1.534, df= (169, 59), p=0.860. There were insignificant associations between delayed dental maturity and dmft, with a Spearman's, correlation r=-0.003, p=0.965

3.5.5 Estimated dental age and ECC

There were 158(92.4%) children who had severe ECC, and the estimated dental age was 4.58±0.76 years, se=0.06 years; while 13 (%) children had mild to moderate ECC and their mean estimated dental age was 4.62±0.65 years, se=0.18 years. The differences in the means were insignificant with an independent samples test where a Levene's had F= 1.209, (169, 15), p=0.861 at 95 % CL.

3.5.5.1 Hypothesis

Spearman's correlation indicated that there were no relationships between dental age and dmft with correlation coefficient r=0.045, p=0.563. Therefore, the null hypothesis that there was no correlation between early childhood caries and dental age in 3-5year-olds in Nairobi, Kenya with a statistically not significant Spearman's correlation coefficient r=0.045, p=0.563, is accepted.

3.6 NUTRITIONAL STATUS

3.6.1 Weight for Height Z Scores

3.6.1.1 All Children Weight for Height Z Scores

The weight for height for age z scores (WHAZ) involved 171 children whose mean WHAZ score was -0.22±0.97SD of whom none had severe wasting, while six (3.5%) had moderate wasting and 23 (12.9%) had a z score of <+1SD. None was overweight or obese, Figure18.

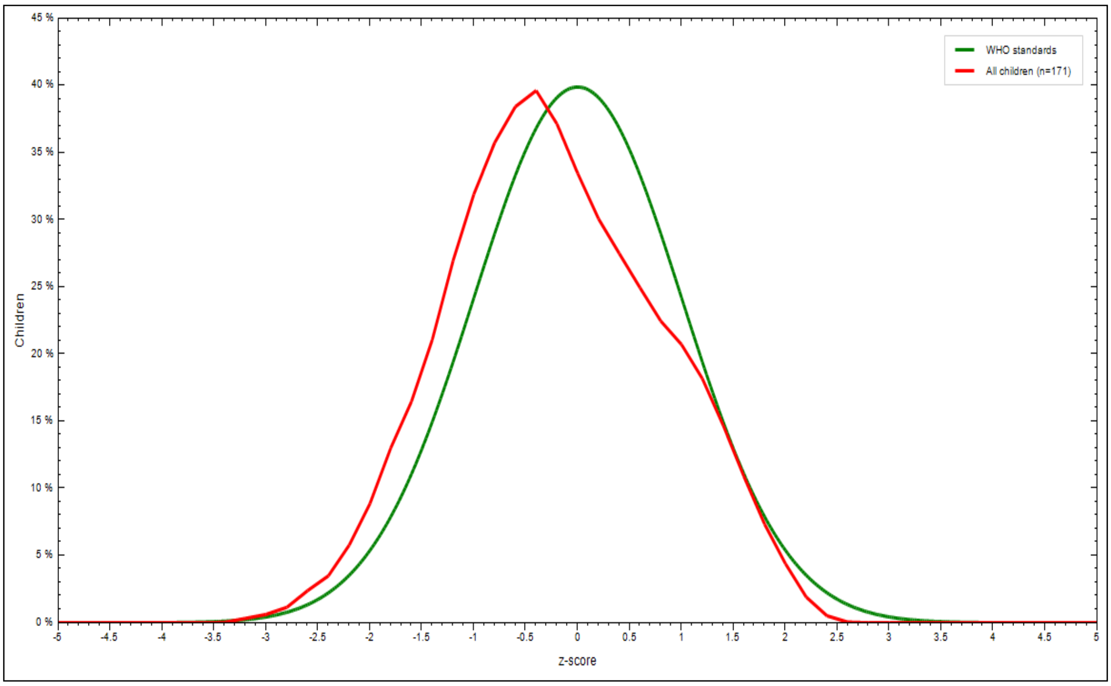


Figure 18: Distribution for the weight for height for age z scores for children aged 36-59 months with WHO reference standards, n=171

3.6.1.2 Weight for Height Z Scores by age group

In the 36-47 months age group, there were 73 children with a mean WHAZ score of -0.22±0.97SD. There were no children with severe wasting or moderate to severe obesity. However, 12 (15.1%) of the children had a z score of <+1SD and 2 (1.4%) had moderate wasting. The 48-60 age group had 98 (57.3%) individuals, and there was none with severe wasting however 5 (5.1%) of the boys and girls had moderate wasting with <-2SD while 11 (11.2%) had a z score of <+1SD. The rest had a healthy weight for height with none being overweight or obese, Figure, 19.

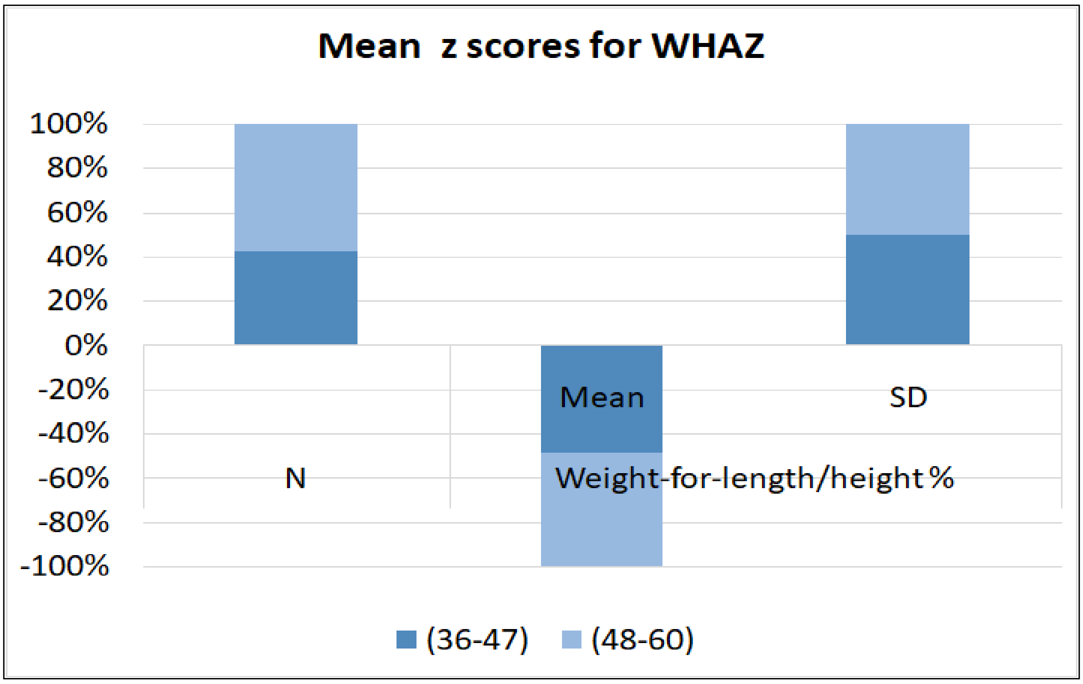


Figure 19: The weight for height mean z-scores for the age group for children aged 36=59 months

3.6.1.3. Weight for Height Z Scores by gender

There were 84 males in the study, and none had severe wasting or moderate to severe obesity. The mean WHAZ for the males was -0.23±0.94SD with 3 (2.4%) children having moderate wasting and 9 (10.7%) children having a z score of <+1SD. The number of female children in the study was 87. They had a mead WHAZ of -0.21±1.01. None of the females moderate or severe obesity and none had severe wasting. However, 4 (4.6%) children had moderate wasting, and 13 (14.9%) had a z score of <+1SD, Figure 20.

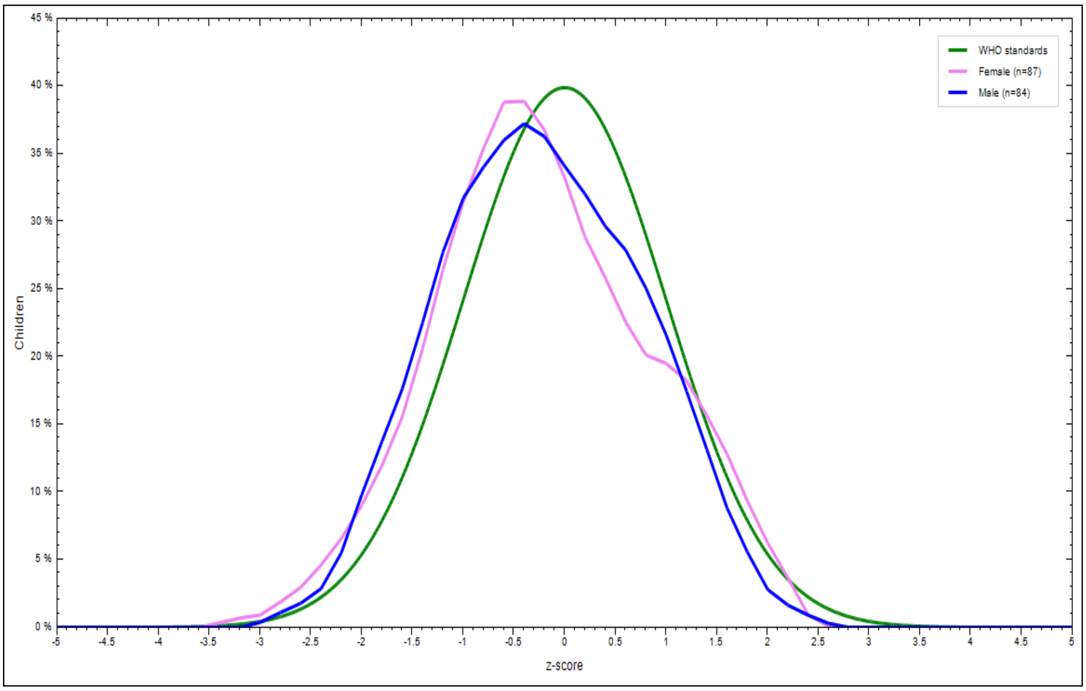


Figure 20: The weight for height for age mean z scores for females and males age aged 36-59 months compared to WHO reference standards, females (n=84), males (n=87)

3.6.2 Weight for Age Z Scores

3.6.2.1 All Children Weight for Age Z Scores

The mean weight for age Z scores (WAZ) score for 171 children aged between 36-59 months was <-0.43±0.94SD, however, one child (0.6%) was severely underweight with a z score of <-3SD, while five (2.9%) of the children were moderately underweight with <-2SD. When the weight for age is compared with the WHO standards, it is skewed to the left of the median, Figure 21.

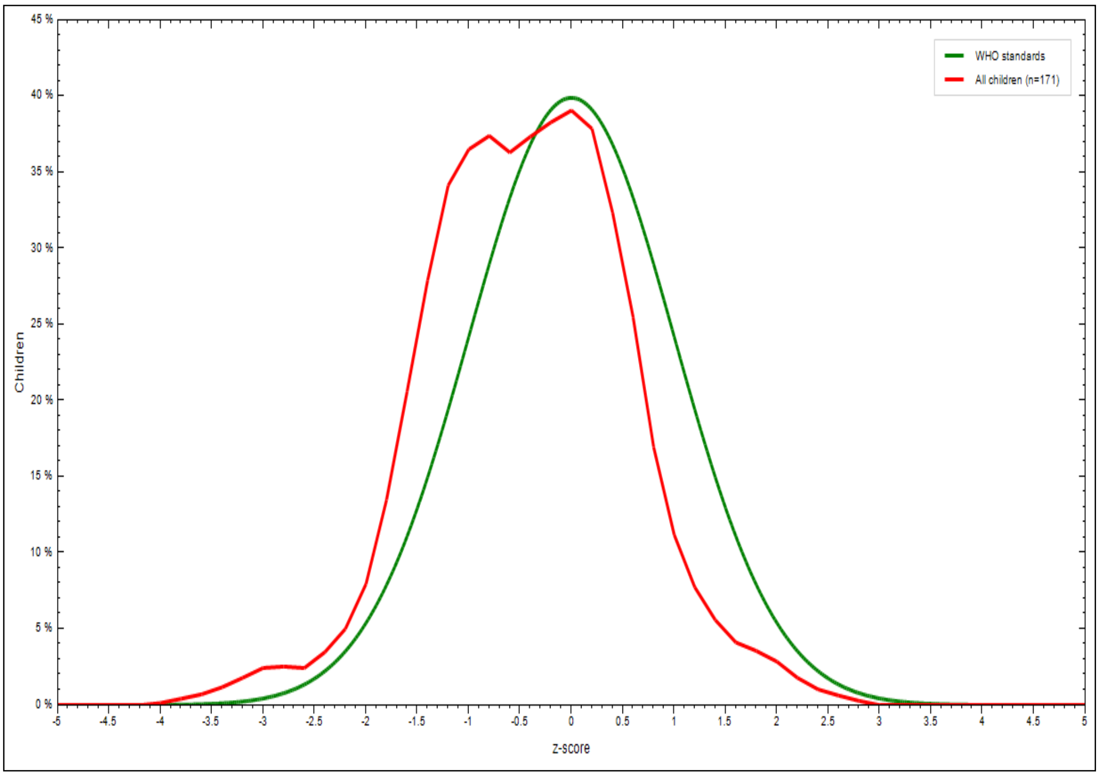


Figure 21: Distribution for the weight for age z scores for children aged 36-59 months with WHO reference standards, n=171

3.6.2.2 Weight for Age Z Scores by age group

When the children were categorised into age groups according to the WHO Anthro software, the children in the 36-47 months age group was 73 (42.7%) with a mean WAZ score of <+0.39±0.86SD. The children aged between 48-60 months were 98 (57.3%), and they had a mean WAZ score of <-0.45±1SD, Figure 22.

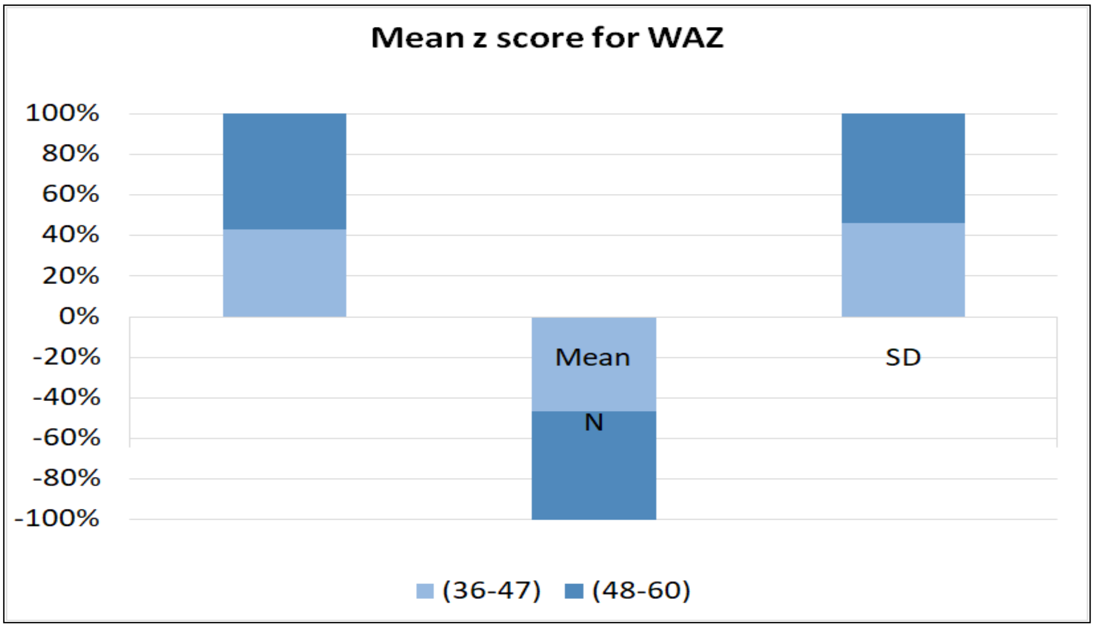


Figure 22: The weight for age z-scores for age groups for children aged 36-59 months

3.6.2.3 Weight for age Z Scores by gender

Out of the 171 children, 84 were males with a mean WAZ z-score of -0.46±0.97 SD. Two (2.4%) children had moderate wasting (< -2SD). The mean WAZ z-score for the 87 female children was -0.4±0.92 SD. One female child (1.1%) had severe wasting while three (3.4%) had moderate wasting. Figure 23.

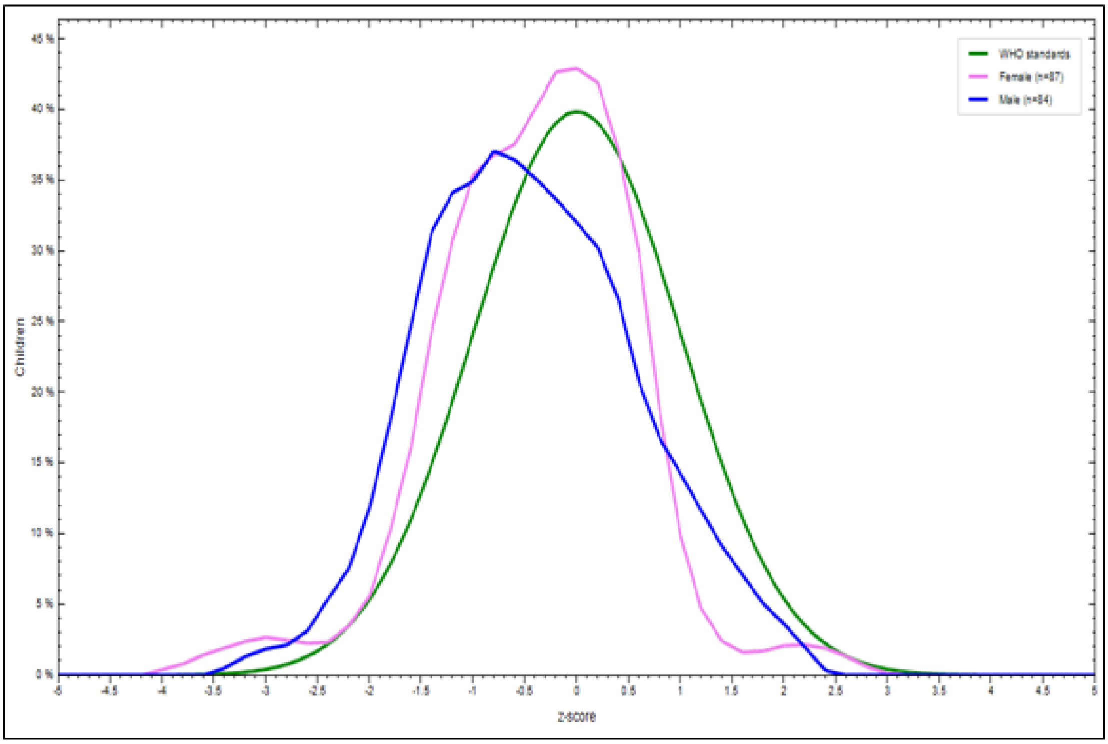


Figure 23: Weight for age mean z scores for males (n=84) and females (n=87). aged 36-59 months

3.6.3 Height for Age Z Scores

3.6.3.1 All Children Height for Age Z Scores

The mean z score for the 171 children aged 36-59 months was <-0.48±1.03SD out of whom two (1.2%) of the children were severely stunted with a z score of <-3SD; while ten (5.3%) of the children had moderate stunting with a Z score of <-2SD, Figure 24.

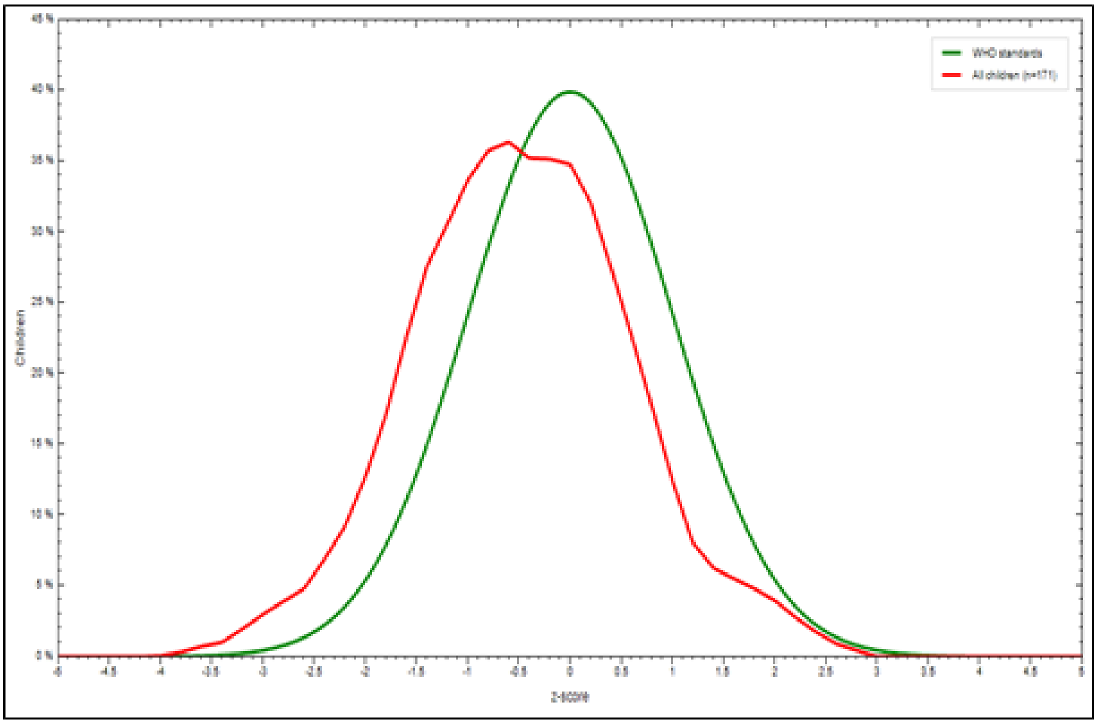


Figure 24: Distribution of the children aged 36-59 months by height for age z scores

3.6.3.2 Height for Age Z Scores by age group

The 36-47 months age had 73 (42.7%) children, and the mean WAZ score was <+0.42±0.99SD, with five children 2.7%) having moderate stunting, and none of the children had severe stunting in growth. Those aged 4-4.9 years were 98 (57.3%) with a mean WAZ score of <-0.53±1.06SD of whom thirteen (7.1%) had moderate stunting, and four (2%) were severely stunted, Figure 25.

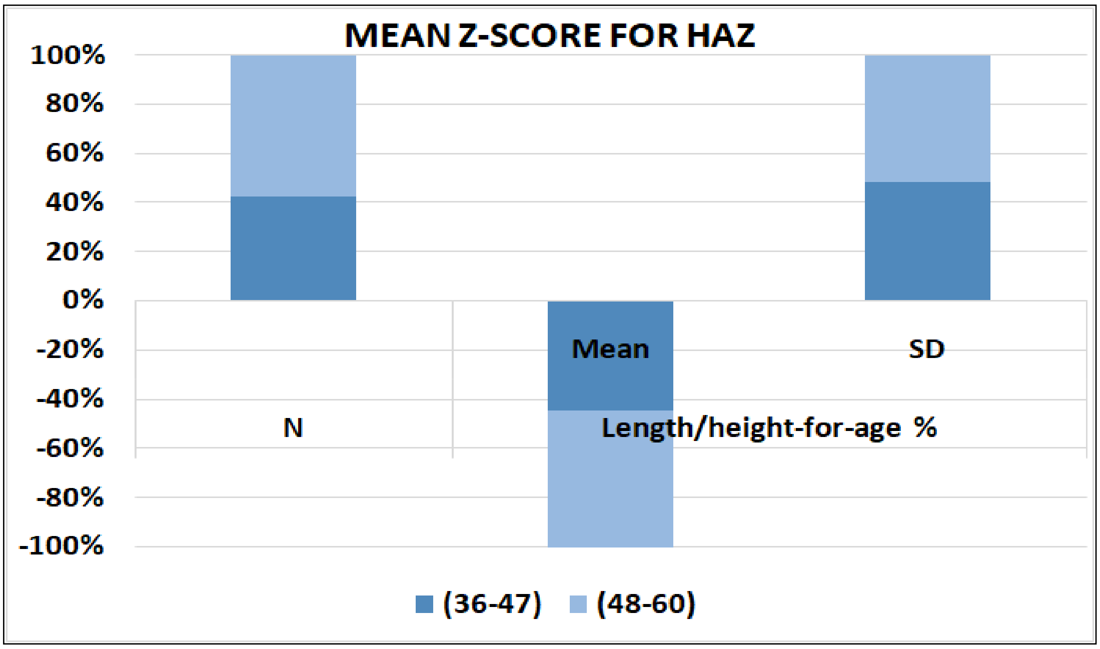


Figure 25: The height for mean age z-scores for children aged 36-59 months

3.6.3.3 Height for Age Z Scores by gender

The mean HAZ z-scores for the male children were -0.53±1.08 SD. Out of the 84 boys, 5 (6%) had moderate wasting with a z score of % < -2SD. The girls, on the other hand, had a mean HAZ z-score of -0.44±0.98 SD. Two girls (2.3%) had severe wasting (< -3SD) while 4 girls (4.6%) had moderate wasting (< -2SD) , Figure 26.

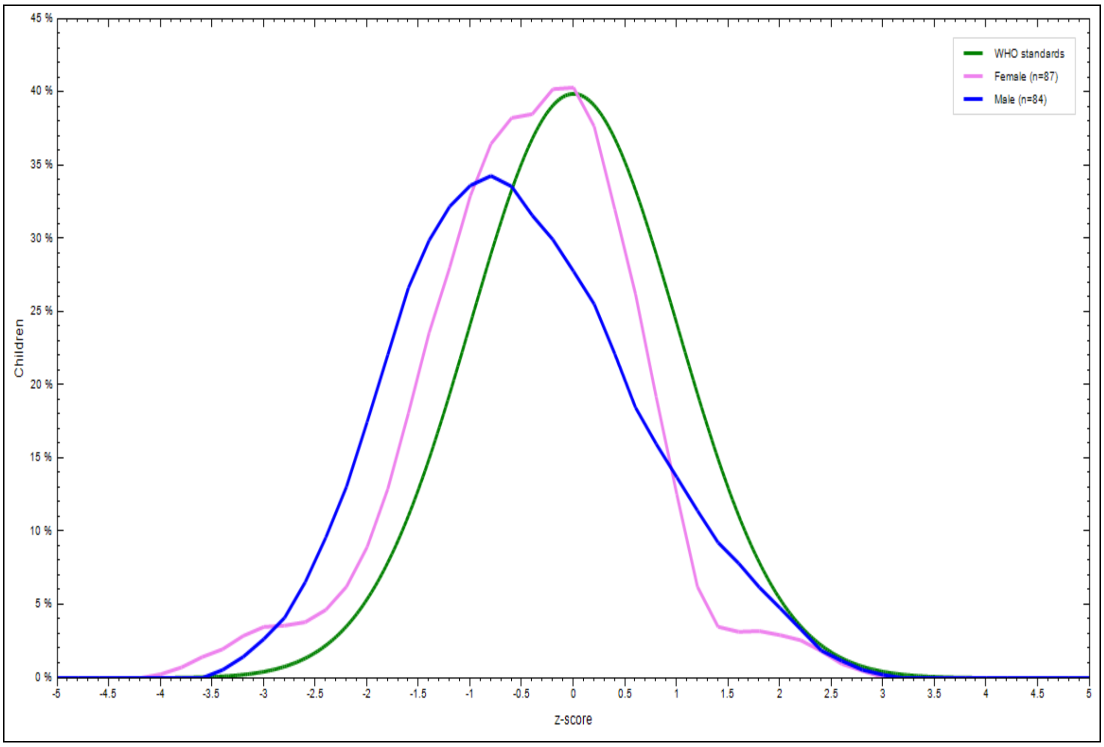


Figure 26: The height for age mean z scores for males (n=84) and females (n=87).

3.6.4 Nutritional Status and ECC

3.6.4.1. Weight for Height Z Scores and Severity of ECC

The mean length/height-for-age Z-score of thirteen (7.6%) children who had mild to moderate ECC was0.03SD± 0.79SD, se=0.22 SD while 158(92.4%) who suffered from severe ECC had a mean WHZ score of <-0.24SD±0.99SD, se=0.08 SD, Figure 27.

The difference between the mean length/height for age z score of 13(7.6%) who suffered from mild to moderate ECC was not significant when compared to the length/height-for-age Z-score WHZ for 158 (92.4%) individuals who had severe ECC with an independent samples test where a Levene's test for equality of variances where F=0.862, df= (169, 15), p=0.267

3.6.4.2 Weight for Age Z scores and Severity of ECC

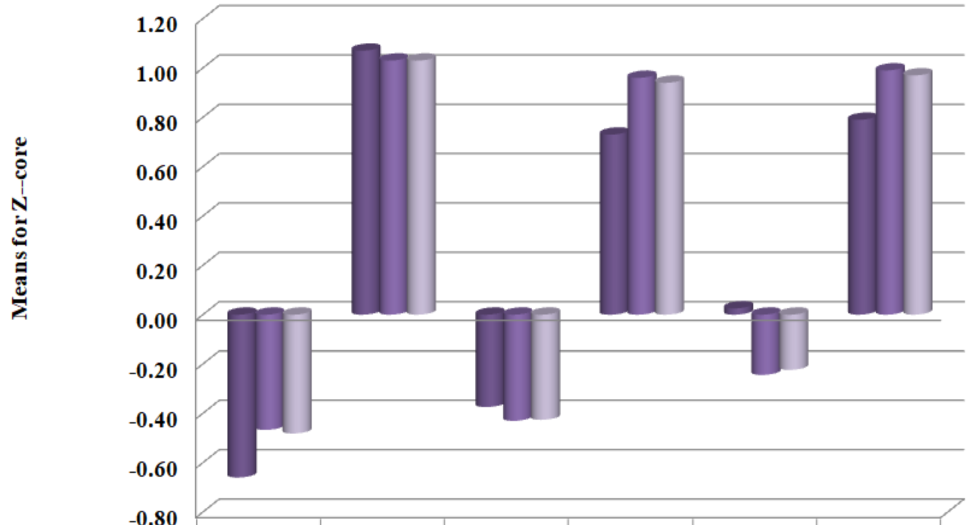
The mean weight for age z score of thirteen (7.6%) children who had mild to moderate ECC was <-0.37SD±0.73SD, se =0.20SD while 158(92.4%) who suffered from severe ECC had a mean WAZ score of <-0.43SD± 0.96SD, se=0.08SD. Figure 27.

The mean WAZ of <-0.37SD±0.73SD for 13(7.6%) who suffered from mild to moderate ECC was not significant when compared to the mean WAZ of <-0.43SD± 0.96SD for 158 (92.4%) individuals who had severe ECC with an independent samples test where a Levene's test for equality of variances where F=1.335, df= (169, 15), p=0.800

3.6.4.3 Height for Age Z Scores and the Severity of ECC

The Length/height for age z score (HAZ) for thirteen (7.4%) children who had mild to moderate ECC was <-0.66SD±1.07SD, se=0.30SD; while 158 (92.4%) who suffered from severe ECC the mean HAZ was <-0.47SD±1.03SD, se=0.08, Figure 27.

The difference between the mean HAZ of<-0.66SD±1.07SD for 13(7.6%) who suffered from mild to moderate ECC was not significant when compared to the HAZ of <-0.47SD±1.03SD for 158 (92.4%) individuals who had severe ECC with an independent samples test where a Levene's test for equality of variances where F=0.064, df= (169, 13), p=0.540



	Mean z score for WHZ	Std. Deviation	Mean z score for WAZ	Std. Deviation	Mean z score for HAZ	Std. Deviation
Mild to Moderate ECC, n=13	-0.66	1.07	-0.37	0.73	0.03	0.79
Severe ECC, n=158	-0.47	1.03	-0.43	0.96	-0.24	0.99
Total	-0.48	1.03	-0.43	0.94	-0.22	0.97

Figure 27: Distribution of the children by nutritional status Z-scores for WHZ, HAZ, WAZ, and ECC, n=171

3.6.4.4 Statistical test

The nutritional status did not have a statistically significant relationship with early childhood caries for the 171 children with a Spearman's correlation: between weight for height z score and dmft r=-0.064, p=0.405; between height for age z-score and dmft r= -0.063, p=0.411; and between weight for age z score and dmft r=-0.099, p=0.198.

3.6.4.5 Hypothesis

Therefore, the null hypothesis that there exists no association between early childhood caries and nutritional status in 3-5-olds in Nairobi, Kenya is accepted as the respective Spearman's correlation r for wasting, stunting, underweight and leanness/ wasting was WHZ, r= -0. 064; HAZ r= -0.063, and WAZ, r=-0.099.

3.6.5 Nutritional Status and Dental Age

3.6.5.1 Weight for Height for Z scores and dental age

One hundred and thirty six(79.5 %) children whose dental age was not delayed and the mean for WHZ as <-0.2SD±1SD, se=0.09SD;(range -2.72SD to 1.93SD) while thirty five with delayed dental age had a mean WHZ , of <-0.31SD±0.88SD, se= 0.15 SD, (range <-2.14SD to 1.68 SD) Figure 28 .

3.6.5.1.1 Statistical test: independent samples test

The differences between the weight for height z score (WHZ) for children whose dental age was not delayed and those whose dental age was delayed was not statistically significant with a Levene's test for the equality of variances where F=2.174, df= (169, 50), p=0.506 at 95% CL.

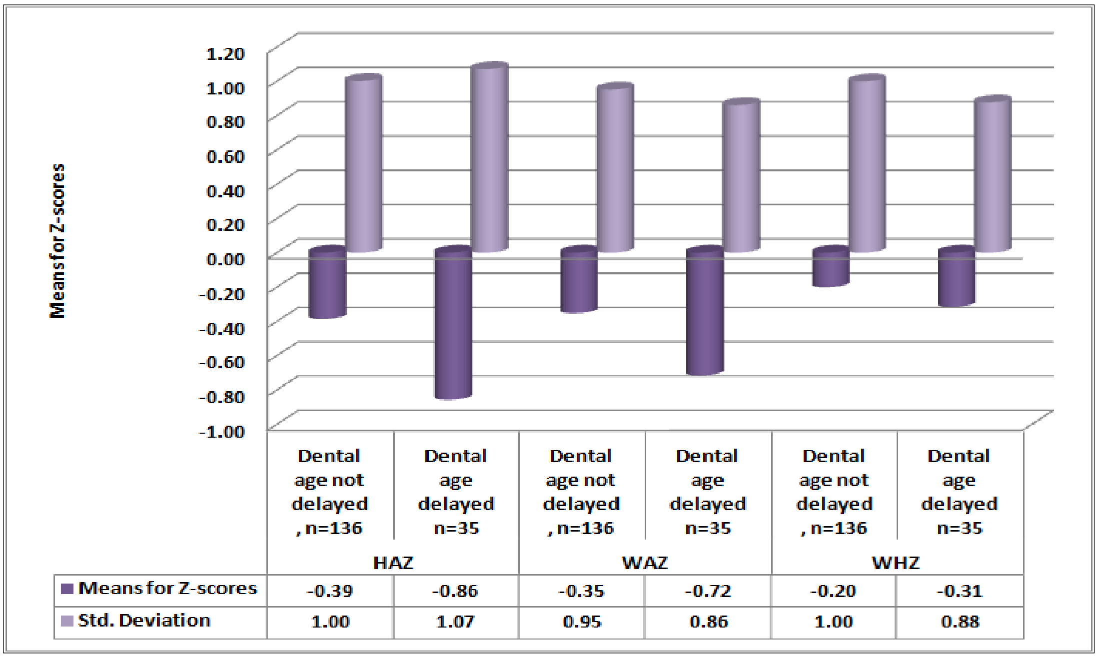


Figure 28: The nutritional status of the children with mean dental age, n=171

3.6.5.2 Weight for age Z score and dental age

One hundred and thirty six(79.5 %) children whose dental age was not delayed and the mean for WAZ as <-0.35SD±0.95 SD, se=0.08 SD;(range <-3.40SD to 2.29 SD) while thirty-five with delayed dental age had a mean WAZ , of <-0.72SD±0.86SD, se= 0.15 SD, (range <-2.79SD to 0.97 SD) Figure 28.

3.6.5.2.1 Statistical test: independent samples test

Significant differences for length/height for age z score -WAZ between the children whose dental age was delayed and those whose dental age was not delayed with an independent sample test with a Levene's test for equal variance where F=0.532, df= (169, 57), p= 0.041

3.6.5.3 Height for age Z score and dental age

There were 136(79.5 %) children shoes dental age was not delayed, and their mean HAZ was -0.39SD±1SD, se= 0.09SD, (range <-3.30SD to 2.21 SD); while 35 children whose dental age was delayed had a mean HAZ of <-0.86SD±1.07, se=0.18 SD, (range <-3.02SD to 1.62 SD) Figure 28 .

3.6.5.3.1 Statistical test: independent samples test

A Levene's test for equality of variances indicated significant differences for length/height for age z score -WHAZ between the children whose dental age was delayed and those whose dental age was not delayed where F=0.504, df= (169, 50), p=0.016 at 95% CL.

3.6.5.4 Associations between Nutritional Status, Dental Maturity and Dental Maturity

3.6.5.4.1 Nutritional status and dental maturity

The mean dental maturity for the 147 children was -0.5± 0.59 years, se=0.05. Dental maturity of 113 (76.9%) children with normal nutritional status was -0.5±0.57, se=0.05. Twenty-seven (18.4%) with mild wasting, had a mean dental maturity of -0.49±0.63, se=0.12; and seven (4.8%) children with moderate wasting, had a mean dental maturity of -0.5±0.75 years, se=0.28.

3.6.5.4.1.1 Spearman's statistical test

Significant relationships between the height for age z score for the 171 children were observed where a Spearman's correlation r=0.321, p=0.000 and weight for age z score r=.224, p=0.003 at 95% CL. However, the association between WHZ score and dental maturity was not significant with r=.032, p=.679.

3.6.5.4.2 Nutritional status and dental age

The children involved in the nutritional status were 147, and their mean dental age was 4.58 ± 0.76years, se=0.06. The national status of the children was categorised as normal mild, moderate. There were 113 (76.9%) had normal weight for height for age z score and their mean dental age was 4.59 ± 0.76 years, se=0.07. Twenty-seven (18.4%) with mild wasting, had a mean dental age of 4.49±0.79, se=0.15 and seven (4.8%) children with moderate wasting, had a mean dental age of 4.74 ± 0.87 years, se=0.33 years, Figure 29.

3.6.5.4.2.1 Spearman's statistical test

A significantly strong and positive association was noted between height for age z score and dental age for the 171 children where a Spearman's correlation r=0.314, p=0.000 and weight for age z score r=0.202, p=0.008 at 95% CL. However, the association between weight for height z-scores and dental age was not significant with r=0.009, p=0.909 at

95% CL.

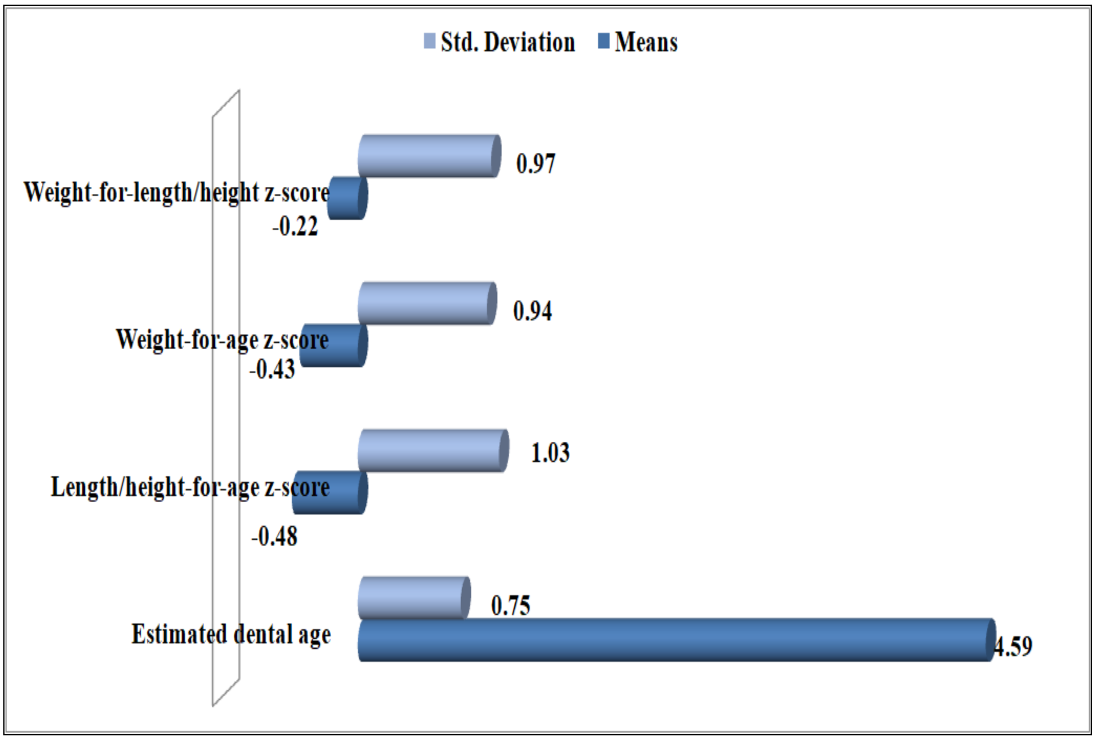


Figure 29: The estimated dental age and the nutritional status of children, n=171

3.6.5.5 Null Hypothesis

Therefore, the null hypothesis that there exists no association between the dental age and nutritional status in children aged 3-5 -year-old in Nairobi, Kenya is accepted when WHZ is used as the parameter for nutritional status as a Spearman's correlation was not significant with WHZ, r=0.009, p=0.909 at 95% CL.

However, the null hypothesis that there exists no association between the dental age and nutritional status for children aged 3-5-year-old in Nairobi, Kenya is rejected as the height for age z scores and weight for age z scores as parameters correlated with dental age where a Spearman's correlation HAZ r=0.314, p=0.000; WAZ r=0.202, p=0.008 respectively.

CHAPTER FOUR

4.0 DISCUSSION

4.1 SOCIO- DEMOGRAPHICS

Several socioeconomic factors have been associated with the prevalence of dental caries. These include the level of education of the parents, household overcrowding and the number of children [63].

4.1.1 Distribution of the caregiver's marital status and the person who provided care

For one hundred and thirty-two (82%) children the caregiver of the child was the mother while 28 (16.10%) children the caregivers was the father, two (1.20%) had an aunty as the caregiver and one (0.60%) child had the grandmother as the caregiver. The current observations are similar to other studies that show the mother is the primary caregiver (77.6-90.5%) in preschool children [83] and children from low-income families in Brazil [84].

One hundred and twenty-nine children in this study lived with both the father and mother while forty-one lived with single parents. In Kenya, 66% of women and 51% of men are either married or living in an intimate union with women (11%) more likely to be divorced, separated or widowed than men (5%) [85]. Families with multiple caregivers especially those with elders have been shown to influence access to preventive dental care [86]. The mean number of people per household with whom the children lived, in this study, was four. The mean number of persons per household is comparable to the average household size in Kenya which is 3.9 members [85].

4.1.2 The caregiver's level of education and the type of job

One (0.60%) caregiver had no formal education, twenty-eight (16.40%) had primary school level of education, 75 (43.90%) had a secondary school education, 53 (31.00%) had a technical college level of education, and 14 (8.20%) had a university level of education. The observation in this survey is comparable to a study done in the same hospital where 48.9% of the fathers and 41.9% of the mothers had completed secondary school education[87]. According to the Kenya Demographic Health Survey (2015), 7% of adults are illiterate, 25.7% have incomplete primary school education, 24.6% completed primary schooling, 15.8% did not complete secondary schooling, 15.7% completed secondary schooling while only 11.2% had more than secondary school education [85]. Men are more likely to be literate (92%) compared to women (88%) [85].

The caregiver's job was described as professional in 27 (16. %), clerical or white-collar jobs in 18(10.70%), businessman/woman in 74 (43.80%), skilled manual jobs in 17 (10.10%), unskilled work in 6 (3.60%) and unemployed in 27 (16.0%) of the respondents. In Kenya, 80% of men and 61% of women are unemployed [85]. Of the employed Kenyans, men are mostly employed in domestic service, unskilled manual and agricultural positions while women are mostly in the domestic service and agricultural positions [85]. The differences translate to almost half the population being in the two highest wealth quantiles (49% of men and 48% of women) with only a small proportion being in the lowest wealth quantile (14% of men and 16% of women) [85].

Several studies have shown that children from lower socioeconomic classes experience a higher prevalence of dental caries [63,88–90]. The documentation proves that socioeconomic factors and social deprivation are indeed crucial determinants of dental caries prevalence.

Significant associations have been reported to exist between the mother's level of education and the prevalence of dental caries [63,89,90], or the level of education of both parents [91]. The lack of knowledge and the beliefs about primary teeth have been shown to create barriers to early preventive dental care [86].

Costa et al. however showed that the mother's level of education was not significantly associated with ECC [84]. It is important to note that despite mothers being aware of risk behaviours that result in poor infant oral health outcomes, not all risk behaviours are changed. The low level of change in risk behaviour may be influenced by a mother's level of autonomy in decision-making within the family, her cultural influences and beliefs, her past dental experience and access to dental care as well as her coping skills and supportive networks [(92)]. In Kenya, women head one-third of the households [(85)].

A negative correlation was found between a mother's nutritional status, level of education and wealth and the proportion of underweight and wasted children [(93)].

In Kenya, children living in rural areas and those from poorer households are more likely to be malnourished [(93)]. A longitudinal cohort study in Portugal showed that girls and boys from high socioeconomic status (SES) groups were fatter, heavier and taller than those from low and average SES groups [(94)]. Enwonwu in his study of Nigerian children had similar findings where physical development (height and body weight) was retarded in the malnourished and underprivileged village children compared with their peers from higher socioeconomic areas [(95)].

Children from low and middle socioeconomic class (SEC) have a delayed mean emergence age for the mandibular and maxillary incisors compared to children from a high SEC. Socioeconomic effects are mixed for molars and premolars [(96)]. Even though a higher economic status has been associated with early dental development, children in the USA, Belgium, Australia, and Iran had a lower mean age of emergence of all permanent teeth compared to their Nigerian counterparts [(96)].

4.1.3 Natal History

One hundred and seventy-one children aged between 3-5 years of whom 3-4 year-olds were 71 (41.1%), and 100 (59.1%) were aged 4-5 years. The gestation period for both age groups was 36.7 weeks and the mean birth weight for those aged 3-4 years was 3.3 kg while those in the age category of 4-5 years the mean birth weight was 3.2 kg. The immediate postnatal history of the children was that 137(80.1%) children had had normal delivery while 34(19.9%) had been born through caesarian section. All the one hundred and seventy-one children had been immunised. This percentage is much higher than that of the Kenya Demographic Health Survey (KDHS) revealed that 79% (KDHS 2014) [85] and 77% (2008-09 KDHS) [93] of children aged 12-23 months received all essential vaccines.

Sixty-two (36.9%) had suffered from different illness a few days before recruitment into the study. The illnesses were diarrhoea which affected two (4.5%) children, and cough/cold affected 42 (95.5%), and none of the children had recently suffered from malaria. Thirty-one children had suffered from a chronic illness while 137 (81.5%) did not suffer from chronic illnesses. However, none of the chronic illnesses were conditions known to affect skeletal or dental development. During the Kenya Demographic Health Survey of 2014, 99% of children under the age of 5 years had shown symptoms of acute respiratory infection, 24% had a fever, and 15% had diarrhoea, two weeks before the survey [85]. The high prevalence of early childhood diseases is evidence that children under the age of 5 years are vulnerable to common communicable diseases.

For the children aged 3-4 years twenty-eight (39.4%) out of 71 had traumatic dental injuries while in the age category of the 4-5year-olds, 33 (33%) out of 100 individuals had had traumatic injuries. In the 3-4 years, the age group the trauma occurred at a mean age of 24.1 months while in the 4-5 months age group the trauma occurred at 20.8 months post-uterine life. Out of the 171 children (16.4%) had suffered from illnesses in the past. From the 3-4-year age group out of the 28, there were 11(39.3%) who had suffered from illness for a period 11.5±14.5 months while in the 4-5year-olds, 17(60.7%) had suffered from illnesses for 12.4±14.8 months.

4.1.4 Feeding Habits during the infancy period

WHO-UNICEF guidelines recommend that a child is exclusively breastfed for the first six months of life, and after that continues with breastfeeding with nutritionally adequate complementary foods up to a minimum of two years of age [97]. One hundred and forty-one (82.50%) children aged 3-5 years had exclusive breastfeeding in their early infancy. Twenty-seven (15.80%) had breastfeeding and bottle- feeding and three (1.8%) had exclusive bottle feeding. A study looking at breastfeeding practices in Nairobi concluded that more than three-quarters of the mothers did not use bottles [98]. However, despite 99.0% of women in one study breastfeeding, only 12.6% breastfed their children exclusively for the first six months [99]. There were 163 (95.90 %) children who breastfed on demand while seven (4.10 %) did not breastfeed on demand. Nocturnal breastfeeding or breastfeeding more frequently has been associated with increased dental caries risk [100,101].

The duration of bottle feeding for those aged 3-4 was eighteen months while those aged 4-5 the duration of bottle feeding was twenty months. S-ECC has been correlated with the use of a feeding bottle on demand during the day or its use at night as a substitute for the pacifier [101]. In early childhood, breastfeeding can protect a child against dental caries. Studies have shown that breastfed children, when compared to bottle-fed children, are less affected by dental caries [102].

The duration of breastfeeding in both the groups of 3-4 and 4-5-year-olds was twenty-one and twenty-two months respectively. These findings are comparable to that of a study of pre-school children in Nairobi where the mean breastfeeding duration was 20.17 months [98]. In Kenya, the median duration of breastfeeding is 21.0 months, being longest in the Eastern region (24.5 months) and shortest in Nairobi (19.1 months) [85]. Children breastfed for more than 12 months have an increased risk of developing dental caries when compared to children breastfed for less than 12 months [100,101].

Studies have shown statistically significant associations between age at which breastfeeding is terminated and more extensive patterns of dental caries. Children who have never been breastfed or those who are breastfed beyond the age of 24 months show a higher prevalence of dental caries [89]. The frequency of breastfeeding also affects ECC prevalence. A birth cohort study of children in Brazil showed that the adjusted risk of S-ECC was higher for children breastfed 7 or more times a day [88]. Discontinuation of breastfeeding and the use of bottle feeding has been associated with a more likelihood of wasting in children (odds ratio 1.6) [99]. Studies have shown statistically significant associations between age at which breastfeeding is terminated and more extensive patterns of dental caries.

4.1.5 Distribution of the children by chronological age and gender

The mean chronological age for 171 children aged 3-5-year-old was 4.12±0.54 years (range 3-4.98 years). However, when the children were categorised into age groups the mean chronological age for 71 (41.5%) children 3-4-year-olds was 3.59±0.29, se=0.03 years; the 100 (58.5%) individuals aged 4-5-year olds had a mean chronological age of 4.50±0.29, se=0.03 years. The boys were 84(49.1%), and their mean chronological age was 4.14±0.53, (range2.92-4.92 years) while 87 (50.9%) girls had a mean chronological age of 4.14±0.55, (range 3-4.92 years).

The differences in the mean chronological age by gender was insignificant with an independent samples test p=0.190 at 95% CL. The mean differences in chronological age by age category were significant with an independent samples test p=0.000 at 95% CL.

4.2 ESTIMATED DENTAL AGE

4.2.1 The mean estimated dental age by gender

Eighty-four boys aged 3-5 had a mean estimated dental age of 4.68±0.72 years, se= 0.08, (range 2.20 to 5.90 years); while the girls had a mean dental age of 4.50±0.77, se=0.08, (range 2.6- 6.70). Associations between gender and the estimated dental age were negative and not significant, with a Pearson's correlation coefficient, p=0.102, at 95% CL. Similarly, the differences in the estimated dental age by age group and gender were not significant p=0.189 at 95% CL.

These findings are similar to those of an Indian study where no statistical differences in dental age estimation were found between males and females [(104)]. Kihara et al. while using Willem's method of dental age estimation on a Kenyan population found similar results with no statistically significant difference between the tooth maturity for girls and boys in most of the dental maturity stages. The girls were noted to be significantly ahead of the boys in the root development of the canines [(105)].

When the eruption of teeth is used to determine dental age, girls are ahead of boys in both African and Asian races in Kenya [106]. The mean age of emergence of all permamnent teeth was earlier in Nigerian girls [96].

4.2.2 Estimated Dental Age Delayed and Not Delayed

The mean dental age for the 171 children was 4.59±0.75, se=0.06 (range 3.3-6.7 years) out of whom 136 (79.5%) whose dental age was not delayed had a mean dental age of 4.79± 0.62, se=0.05, (range 3.30 -6.70 years). However, those whose dental age was delayed had a mean dental age of 3.82 ± 0.73, se=0.12, (range 2.20 -4.80 years)

The differences in the mean age between those with a delayed dental age and those without delay in dental age were statistically significant with independent samples

test with a Levene's test for equality of variances with F=4.649, df= (169, 47), p=0.000.

The Demirjian method of dental age estimation has been shown to overestimate dental age in several studies involving various world populations, including the former Yugoslav Republic of Macedonia (1.17± 0.98 years) [107], Spanish Caucasian (0.76±0.01 years for boys, 0.88±1.09 years for girls) [108], southern Chinese [29], Belgian Caucasian [26], Norwegian [2], Turkish [50], and Nigerian [48] children among many other populations.

Other studies have however found the Demirjian method to underestimate age in populations like Venezuelan Amerindian (mean underestimation of -0.1±1.04 years for girls and -0.23±0.93 years for boys) [108]. The Kuwaiti children in a study by Qudeimat and Behbehani had a delayed dental age (0.69 years, SD=1.25 years, CI=0.58 years) [109] and advanced in Northern Turkish children (mean difference between dental and chronologic ages; boys 0.36-1.43, girls 0.50-1.44) [110].

The Demirjian method was developed using dental maturity scores of the French-Canadian population. In their original study, Demirjian et al. admitted that although the maturity scoring system could be applied universally, the conversion of maturity scores to dental age depended on the population under consideration [34]. In as much as scores for the different stages may not vary much between populations, the maturity standards (centiles for maturity at given ages) may vary appreciably [36,111]. The upside of this is that this scoring system can be used with relatively small population samples to study the differences in average maturity between different populations [36]. Since the Demirjian method is the most commonly used method in dental age assessment study researches, comparisons between populations are made easy.

However, Liversidge [112] concluded that adapting dental maturity scores for age or age for scores for different population groups is probably unnecessary since Demirjian's dental maturity method is inappropriate to assess population differences in dental maturity. Liversidge concluded that the Demirjian method of 1973 is designed to assess maturity for a single child and is unsuitable for comparing groups [82].

In 1976, Demirjian and Goldstein introduced an updated system of the original 1973 version. The new system was applicable from 2.5 to 17 years compared to the 1973 one which was applicable from ages 3-17 years. Also, the standardising population sample was more significant and included two different sets of four teeth, which was different from the original seven teeth of the 1973 version. Some studies have shown that the seven teeth system overestimates age more than the four teeth system [107].

It has therefore been recommended that the polynomial compound formula is used to predict dental age with more accuracy for results of international maturity standards on different populations [113]. There is a need for new graphs and tables produced for specific populations which transfer the maturity scores calculated by the Demirjian method into dental age are more accurate [114].

There have been attempts made to make the Demirjian method more accurate at estimating chronological age by tailoring it to specific populations. Chaillet et al. [115] came up with the International Demirjian method deriving values from 2-25 year-olds from 8 countries and different ethnic backgrounds. Demirjian's method was used for determining dental maturity scores, establishing gender-specific tables of maturity scores and development graphs. This method had an accuracy of ± 2.5 years, making it useful for forensic purposes. However, because of the inter-ethnic variability, it was less accurate than Demirjian's method developed for a specific country.

In Kenya, permanent teeth in African children have been shown to erupt earlier by 0.2-0.7 years than in Asians [(106)]. Kaur and Singh showed in their study that despite the rapid physical growth observed in American and British girls, dental emergence was ahead in Indian girls [(116)]. The eruption of teeth is generally earlier in Africans compared to other races. However, McGregor et al. in their study showed the number of teeth erupted in Gambian children lagged behind American and European children by up to 18 months of age, [(117)]. Nyström et al. in Finland demonstrated that even within the same homogenous population, there are differences in dental maturity with children in rural areas having a higher dental age than those living in the city ($p< 0.05$) [(118)].

The Demirjian method is the most commonly used method of dental age estimation because it is simple, fast and easy to apply [(108)]. However other methods are more accurate in specific populations such as the Chaillet method (Venezuelan Amerindian and Spanish Caucasian) [(108)], Willem's method for former Yugoslav Republic of Macedonia [(107)], Cameriere's method for Peruvian children [(119)].

Willem's method was shown to be slightly more accurate (98.62%) in estimating dental age in an Egyptian population compared to Cameriere (98.02%) in 5-16-year-olds [(120)]. Liversidge et al. evaluated the bias and accuracy of age estimation using developing teeth and demonstrated that the method that performed the best was the dental maturity scale of Willem's et al. [(26)] with a bias of 0.14±0.86 years. In a another study[(60)], Willems method [(26)] was again shown to be the most accurate, with Demirjian's method [(36)] overestimating age while both Nolla's [(38)] and Haaviko's [(121)] methods underestimated age. Rai et al. in India also found Willem's to the most accurate radiographic method of age estimation, followed by Haaviko, Cameriere, Nolla and lastly Demirjian [(104)].

Other methods of dental age estimation in children include the measuring of the open apices to teeth which is Cameriere's method [105]. The difference between observed age and predicted age (OA-PA) with this method varies across populations, Italian (-0.035 years) [122], European Caucasian (-0.114 years) [123], among others. An evaluation of the Chaillet's international maturity standards on Bosnian-Herzegovinian population found it inaccurate as it also overestimated age with the difference between dental and chronological age being 0.65±052 years for girls and 0.73±0.60 years for boys [113].

An analysis by age group by Liversidge et al. [124] showed that most methods estimated age with significant bias and standard deviation bias ranged from 0.86 to 1.03 years. An analysis by age group in the same study showed most methods under-aged older children and over-aged younger children. Bias is the mean difference between dental age and real age [124]. Measures of the accuracy of a dental age estimation method include the mean/median absolute difference, percentage aged to within 10% and to within six months of the real age [124].

Skeletal age can also be used to estimate chronological age. Some studies have shown that dental age is more accurate than skeletal age in estimation. Others have discovered that the combined technique of using both hand-wrist bones and teeth has higher accuracy than using either the teeth or bones alone [125].

Dental age and skeletal age are both under the influence of many factors including genetics, malnutrition, socioeconomic factors. However, dental age is less affected by environmental factors compared to skeletal age and is, therefore, more reliable in estimating chronological age [126].

4.3 ORAL HYGIENE STATUS

4.3.1 Plaque score and gingival index

One hundred and sixty-one out of 171 children in the study were examined for plaque scores and gingival bleeding. In twelve children, the index teeth were missing. The mean plaque score was 2.1±0.7; while the mean gingival index was 1.1±0.6, se=0.1.

The mean plaque score for 71 (41.5%) children aged 3-4 years was 2.1±0.7, se=0.1, and the gingival index was 1.01±0.6, se=0.1 while100(58.5%) children aged 4-5years had a mean plaque score of 2.0±0.6, se=0.1 and a mean gingival index of 2.1±0.6.

A study by Kemoli and Chepkwony [127] conducted in the same study area showed high plaque scores in 55% of the subjects, and that plaque accumulation occurred on more than one-third of the tooth surfaces but less than two-thirds. High plaque scores were reported among children whose mother (42.0%) and fathers (48.2%) had completed secondary school education, and whose fathers were in non-formal employment [127].

4.3.2 Oral hygiene by age

A total of 159 individuals aged between 3-5 were assessed for oral hygiene, where 12 (7.5%) children had good oral hygiene, sixty-one (38.4%) had fair oral hygiene and eighty-sixed (54.1%) had poor oral hygiene. The severity of gingivitis was that 85(52.8%) had mild gingivitis; 74 (46.0%) had moderate gingivitis, and two (1,2%) had severe gingivitis. Children afflicted with ECC have been shown to have difficulties in performing tasks of daily living like brushing their teeth due to the associated dental pain and discomfort [128]. This would explain the high percentage of poor oral hygiene observed in this study.

4.3.3 The severity of gingivitis by age and gender

4.3.3.1 Chronological age

The 3-4-year- olds were 71 (41.5%)children aged 3-4 years 37 (52.1%) had mild gingivitis, thirty-four (47.8%) moderate gingivitis however there were no children in this age category that had severe gingivitis. The 4-5 age group had 90 (52.%) children out of whom 48(53.4%) had mild gingivitis, there were 40 (44.4%) with moderate gingivitis, and two (2.2%) had severe gingivitis. These findings are similar to previous surveys that have shown that severe cases of gingivitis are less in younger children than in older children and adults [129,130]. As one progresses from early childhood to adulthood, the severity of gingivitis increases [129,130].

4.3.3.2 Gender

There were 78 boys in whom the distribution of the severity of gingivitis was mild 36 (46.1); moderate 41 (52.6%) and severe gingivitis affected one (1.3%) boy. The girls were 83 (48.5%), out of whom were 49 (59%)were affected with mild gingivitis, 33 (39.8%) had moderate gingivitis, and one (1.2%) had severe gingivitis. Gingivitis cases are severe in this study in males more than in females. A study of Brazilian 5-year- old children concluded that being of the male gender was one of the risk indicators of gingivitis [(131)].

4.4 EARLY CHILDHOOD CARIES

4.4.1 Severity of ECC in the study group

The prevalence of ECC was 100% as the criteria for selection were children with ECC. The mean dmft for the 171 individuals was 11.03 ± 4.62, se=0.35 (range 1-20 decayed teeth). The decayed component of the dmft was 10.81±4.43, se=0.34, (range between 1 to 20 decayed teeth), missing component 0.22±0.78, se=0.34 (range 0-7 missing teeth), and the filled component of dmft was 0.01±0.08 se=0.01 (range 0-1 filled teeth). The decayed component formed 98% of the dmft, the missing component 1.9% and the filled component was 0.01 %.

The low missing and filled components in this study can be explained by the fact that most of these patients were visiting the dental clinic for the first time. More than 90% of dental caries in the third world (low income) countries remain untreated [(132)]. The high prevalence of untreated caries is because the traditional method of restorative dentistry required to treat dental caries is beyond the financial capability of low-income nations, the majority of whom do not even have sufficient financial resources for essential health care services for their children [(132)].

A study by Kemoli and Chepkwony carried out in the same dental hospital as this study reported a prevalence of dental caries in the study group as 95.5%, and the dmft was 8.53 (±5.52 SD). The male children in this study had a dmft of 8.65 (Sd+5.54) while the females had a dmft of 8.37 (SD + 5.50). Wassuna et al. found a mean dmft of 7.5(± 19) in 3-5-year-olds with S-ECC at New Nyanza Provincial General Hospital[64]. Njoroge et al. in their study in the neighbouring county of Kiambu found a dental caries prevalence of 59.5% [133]. The high prevalence seen in this study and Kemoli and Chepkwony's study is because the study area is a dental hospital where the majority of the patients present with dental caries.

4.4.2 Gender and ECC

The mean dmft for 84 (49.1%) boys aged 3-5 years was 11.29 ±5.04 **se=**0.55, and 87 (50.9%) girls had a dmft of 10.78±4.18 se =0,45.

The differences in the dmft between gender were not statistically significant with an independent samples test, p=0.479. Several studies on early childhood caries have shown that there is no gender predilection in the prevalence of dental caries [63].

A study by Kemoli and Chepkwony carried out in the same dental hospital reported prevalence for dental caries in the current study was 95.5% with a mean dmft of 8.53 (±5.52 SD). The male children in this study had of dmft 8.65 (Sd+5.54) which was slightly higher than the females who had a dmft of 8.37 (SD + 5.50)(127). Willerhausen et al. in their study of elementary school children in a German city showed a difference in the number of natural, healthy teeth between boys and girls (p=0.0334) [66].

4.4.3 Chronological age and ECC

The mean dmft for the 71 (41.5%) children aged 3-4 year was 10.55± 4.44, se= 0.53 while 87(50.9%) individuals aged 4-5-year olds had a mean dmft of 11.37± 4.73, se=0.47. Research documentation indicates that there is an association between the age of the child and dental caries [63]. Willerhausen et al. showed from their study that the number of healthy teeth decreases with age (p=0.001) [66]. With the increase in age, the dmft also increases and this might be explained by the fact that the longer the teeth have been in the oral cavity, the higher their chances of developing dental caries.

4.4.4 Dental maturity and ECC

Out of the 171 children, 136 (79.3%) of the children whose dental maturity was not delayed had a mean dmft of 11.06±4.74; while 35(27.3%) whose mean dental maturity was delayed had a mean dmft of 10.91±4.17, se=0.70. The differences in the dmft were not significant with the independent samples test with a Levene's p=0.860; there were insignificant associations between delayed dental maturity and dmft, with a Spearman's, correlation, p=0.965. These results show that dental caries does not affect the mineralisation of the developing dentition.

4.4.5 Estimated dental age and ECC

There were 158 (92.4%) children who had severe ECC, and their estimated dental age was 4.58±0.76 years, se=0.06 years; while 13 (7.6%) children had mild to moderate ECC and their mean estimated dental age was 4.62±0.65 years, se=0.18 years. The differences in the means were insignificant with an independent samples test where a Levene's had F= 1.209, (169, 15), p=0.861 at 95 % CL. However, there is no association between estimated dental age and ECC (Spearman's correlation p=0.563).

There is inadequate research on the relationship between dental maturity, dental age and dental caries. Most studies look at the consequences of the premature loss of primary teeth and its effect on the eruption of the permanent successors. Dental caries if left untreated in children can result in the premature loss of primary teeth; with the premature loss of deciduous molars, if extractions are done before completion of the premolar crown formation, then the eruption of the premolar is delayed. However, if the deciduous tooth is lost at a time when the premolar has advanced root formation, then the eruption of the premolar is accelerated (69,70). However, according to Leroy et al., even in cases where the predecessor tooth has dental caries or is restored but is not extracted, the eruption of the successor is still accelerated by 2-8 months (72). Tooth eruption is influenced by a variety of factors, both local and systemic, and is, therefore, a less reliable indicator of dental age (26). In comparison, of all dental age estimation methods, tooth mineralisation is influenced the least by environmental and systemic factors and thus more reliable (6,26).

4.5 NUTRITIONAL STATUS

The Kenya National Demographic and Health Survey (KNDHS) of 2008-2009 report stated that 35% of children aged five years and below were stunted, 16%were underweight, and 7% are wasted [93]. The 2014 demographic survey varies from the Kenya Demographic Health survey of 2014 that had reports of 26% of children under the age of 5 stunted, 11% underweight and 4% wasted [85]. Trends from the KNDHS from 1993 to 2008 show little or no improvement in the nutritional status of Kenyan children [93]. An estimated 2.1 million children in Kenya are stunted [93]. There has been an increasing prevalence of obesity and overweight in Kenya as evidenced in the KDHS (2008-2009). In Kenyan pre-school children, 4 % are obese, and 18% are overweight [93].

In this study, using the WHAZ, 6 (3.5%) had moderate wasting; WAZ 1 (0.6%) was severely underweight, 5 (2.9%) were moderately underweight; HAZ 2 (1.2%) were severely stunted, 10 (5.3%) were moderately stunted. A study by Wassuna et al. of 3-5-year-old Kenyan children with S-ECC had comparable results where 27 (14%) were underweight, 10 (4.9%) were wasted, and 12 (6.1 %) were stunted [134].

4.5.1 Weight for Height Z Scores

The weight for height for age z scores (WHAZ) involved 171 children whose mean WHAZ score was -0.22±0.97SD. None of the children had severe wasting which is described by z scores of below minus three standard deviations (<-3D). Six (3.5%) children had moderate wasting (<-2SD) and 23 (12.9%) had a z score of <+1SD. None was overweight (>+2SD) or obese (>+3SD).

This index (WAZ) of nutritional status relates the body mass to body length or height. It describes the current nutritional status (acute malnutrition) [85]. An illness episode or inadequate food intake may fail a child to receive adequate food nutrition, with subsequent weight loss (wasting) in the period immediately preceding nutritional assessment [85].

4.5.2 Weight for Age Z Scores

The mean WAZ score for 171 children aged between 36-59 months was <-0.43±0.94SD, however, one child (0.6%) was severely underweight with a z score of <-3SD, while five (2.9%) of the children were moderately underweight with <-2SD. When the weight for age is compared with the WHO standards, it is skewed to the left of the median.

The WAZ index takes both chronic and acute malnutrition into account and is therefore considered a composite of the height-for-age and weight-for-height indices [(85)].

4.5.3 Height for Age Z Scores

The mean z score for the 171 children aged 36-59 months was <-0.48±1.03SD out of whom two (1.2%) of the children were severely stunted with a z score of <-3SD; while ten (5.3%) of the children had moderate stunting with a Z score of <-2SD.

The height for age index is an indicator of cumulative deficits in growth and linear growth retardation [(85)]. It is therefore not sensitive to recent, short-term changes in intake of the diet. Stunting is when an individual is short for their age, which indicates chronic malnutrition and can be affected by recurrent and chronic illness [(85)].

4.5.4 Nutritional status and ECC

Over time, interest in dental research has changed from the aetiology of dental diseases to how dental diseases affect the general health of individuals. According to Kathmandu et al. there are over 90% of dental caries untreated in preschool children with toothache being very common [(132)].

A review article by Alvarez of several cross-sectional surveys revealed that populations with higher dental caries prevalence in their deciduous dentition showed a lower prevalence of dental caries in their permanent teeth [(135).] However, longitudinal data from individuals show a higher caries index in the permanent dentition. In malnourished children, caries development is delayed as a consequence of delayed tooth eruption, with a shift to the right in deciduous dentition dental caries prevalence versus age curve. The same findings were confirmed in a study by Alvarez [61] where there was a shift to the right of the median for the age distribution of dental caries by 2.5 years for malnourished groups (wasted and stunted, wasted, stunted), compared with healthy children ($p< 0.01$). This shift was associated with a delay in both the eruption and exfoliation of the deciduous teeth in children who were malnourished [61].

4.5.4.1 Weight for Height Z scores and severity of ECC

The mean length/height-for-age Z-score of 13 (7.6%) children who had mild to moderate ECC was 0.03SD± 0.79SD, se=0.22 SD while 158 (92.4%) who suffered from severe ECC had a mean WHAZ score of <-0.24SD±0.99SD, se=0.08 SD.

The difference between the mean length/height for age z score of 13 (7.6%) who suffered from mild to moderate ECC was not significant when compared to the length/height-for-age Z-score WHAZ for 158 (92.4%) individuals who had severe ECC with an independent samples test where a Levene's test for equality of variances where $F=0.862$, $df= (169, 15)$, $p=0.267$

A longitudinal study by Alvarez brought out an association between malnutrition and dental caries where a prolonged episode of malnutrition in infancy (when most of the primary teeth are still being formed) that leads to both stunting and wasting, results in more caries by the age of 4 years [62]. The explanation behind this could be possible as a result of deleterious effects on amelogenesis [62] which would increase a tooth’s susceptibility to dental caries 3-4 years later. In the study by Alvarez et al., strong associations were noted between malnutrition and increased dental caries in the deciduous teeth. Children who suffered a single but prolonged malnutrition episode during infancy (i.e. stunting and wasting) had higher caries experience by the age of 4 years than did the children who had a less severe form of malnutrition or had no malnutrition at all [62]. However, where there were no differences in caries between the normal, stunted and wasted groups was explained by the fact that malnourished children experienced delayed eruption of the deciduous dentition, hence delayed dental caries development [62]. Similar findings were present in an earlier study by the same author where it was concluded that malnutrition resulted in increased dental caries experience, affected age distribution of dental caries, and delayed tooth development in the deciduous teeth [61]. In this study, peak caries activity was significantly higher in wasted and in wasted and stunted children, when compared with healthy controls [61].

Hilgers et al. showed that even after adjusting for age and gender, the mean caries average for permanent molars significantly increased with increased BMI (136). A study of 30-70-month-old Iranian children showed a statistically significant inverse association between BMI-for-age scores and the frequency of caries-free (P=0.001) and a significant direct association with S-ECC children (P=0.001). Overweight children in this study had a higher decayed, extracted and filled surfaces of deciduous teeth score (deft) compared to those of normal BMI- for-age scores [137]. A study showed that obese adolescents were more likely to have caries than the non-obese since there was a significant association between BMI and DMFT indices (P=0.01) in the severely obese group [138].

4.5.4.2 Weight for Age Z scores and severity of ECC

The mean weight for age z score of thirteen (7.6%) children who had mild to moderate ECC was <-0.37SD±0.73SD, se =0.20SD while 158(92.4%) who suffered from severe ECC had a mean WAZ score of <-0.43SD± 0.96SD, se=0.08SD.

The mean WAZ of <-0.37SD±0.73SD for 13(7.6%) who suffered from mild to moderate ECC was not significant when compared to the mean WAZ of <-0.43SD± 0.96SD for 158 (92.4%) individuals who had severe ECC with an independent samples test where a Levene's test for equality of variances where F=1.335, df= (169, 15), p=0.800.

The results from this study, therefore, do not support the belief that ECC adversely affects the weight of the child. There are however studies that have shown that underweight children are more likely to have S-ECC than children of normal weight/height [63]. Other studies have taken a slightly different approach whereby children with S-ECC were shown to have significantly less height and weight than their comparison peers (139,140). According to Wassuna et al., children with S-ECC were 1.23 times more likely to be underweight compared to children without dental caries (134). A similar study of 6-7-year-old first-grade children showed that for each new carious tooth surface, the child had increased odds of being at risk for being underweight by 3.1 % after adjusting for age and dental visits (141). Acs et al. in 1992 concluded that three-year-olds with nursing dental caries who had at least one tooth with pulpal involvement weighed about one kilogram less than the control children who did not have nursing caries (142). In this study, 8.7% of the children with caries weighed less than 80% of their ideal weight compared to only 1.7% of the comparison group, indicating that growth may be affected adversely by the progression of nursing caries (142).

'Catch-up growth' seen after comprehensive dental treatment has shown that the previous oral diseases negatively impacted nutritional intake and this gives further evidence on the effect of dental caries on growth (143). Following full rehabilitation, children with S-ECC gain weight (140). Acs et al. demonstrated significantly increased growth velocities following the therapeutic intervention in children with ECC through the course of the follow-up period (144). The catch-up growth was such that these children no longer statistically significantly differed in percentile weights from the comparison group (144).

However, another study failed to find any significant weight gain (catch-up growth) following complete dental rehabilitation in 2-7-year-old children with rampant caries (145). Also, a study found that the mean percentile weight of 2-7-year-old children with rampant caries was not below the 50th percentile (146).

In addition to improvements in body weight, dental treatment improves the child's Oral Health-Related Quality of Life (OHRQoL) since the child now experiences less/no pain, and can adequately feed and sleep. White et al. in their study evaluated the parents of children with dental caries who had undergone dental treatment and they reported that the parents perceived that their children were smiling more, performed better in school and had increased social interactions [147]. These findings of improved psychological and social wellbeing of the child have been supported by several other studies [145,146,148].

A study on malnutrition involving 2-6 year-olds with S-ECC by Clarke et al., where all the nutrition tests carried out, indicated that the children were malnourished [149]. However, compared to blood tests (serum albumin, serum ferritin, haemoglobin and mean corpuscular volume), the anthropometric measurements (ideal body weight, body mass index and measurement of the mid-arm circumference) detected fewer cases of malnourishment [149]. According to Clarke et al., BMI tests that used the fifth percentile on childhood charts to define malnutrition were insensitive since many malnutrition cases were missed. They, therefore, suggested that subjects with BMI values less than the 15^{th} percentile instead of the 5^{th} percentile should be regarded as malnourished; Clarke et al. found out that in young children, due to the presence of low values of haemoglobin and ferritin, S-ECC may be a risk marker for the development of otherwise unexplained iron deficiency anaemia. They, therefore, recommended that iron levels should be assessed in patients with S-ECC regardless of their anthropometric appearance [149].

Theories related to untreated dental caries have been put across to explain their impact on the nutritional status of children. Sheiham in a review article gave three reasons [143]. First, there is an infection, pain and discomfort associated with untreated dental caries which interferes with the intake of food [145,150]. Children with SECC have problems eating certain kinds of foods [129,150]. Secondly, severe dental caries is associated with disturbed sleep, irritability and pain [151,152]. The disturbed sleep may in return affect glucocorticoid production and therefore growth [143]. Third and lastly, that severe dental caries affects growth because chronic inflammation with pulpitis and dental abscesses which in turn affects erythropoiesis. The rationale is that the inflammatory cytokines like interleukin-1 (IL-1) can induce inhibition of erythropoiesis with resultant low haemoglobin and anaemia of chronic disease [143]. Anaemia of chronic disease (Anaemia of inflammation) is a mild-to-moderate anaemia which often develops in the setting of acute or chronic immune activation (chronic disease, infections or malignancy) and is the second most common type of anaemia (after anaemia of iron deficiency) [(153)]. It is mediated by inflammatory cytokines and is characterised by low serum iron (hypoferremia) and often increased reticuloendothelial stores of iron [(153)].

In Kenya, micronutrient deficiencies are highly prevalent among women and children aged five years and below. The most common deficiencies in Kenya according to the 1999 National Micronutrient Survey include vitamin A deficiency, zinc deficiencies, iodine deficiency disorders and iron deficiency anaemia, [(93).] Micronutrient deficiency contributes to childhood morbidity and mortality [(85)]. These micronutrients from direct supplementation, natural foods or fortified foods [(85)].

The OHRQoL (Oral health-related quality of life) is significantly poorer in children with untreated ECC than in children with ECC [(148,150,151)]. In Brazil, Moura-Leite et al. found that in preschool children, the impact of dental pain had a statistically significant association with gender, social class, dental caries, missing teeth, filled teeth and caries involving the pulp [(128)]. These children with dental caries also have a higher risk of emergency dental visits and hospitalisations due to dental pain and infections [(152,154)]. They also tend to have increased days with absence from school and restricted activity [(128,150,152,155)]. The child's educational development is interfered with as there is a diminished ability to learn. Emotional stress, including anger and instability due to interruption of school work, and play, has been associated with dental pain [(156)]. The child's self-esteem may also be negatively affected by the child being teased by other children as a result of aesthetic and phonetics problems. As a result, the child may adopt a silent demeanour or avoid smiling [(156)].

Oral pain due to dental causes has been shown to have a considerable impact not just on the child, but also the parents [(152,155)]. The parents are affected economically because of time taken off from work to visit the dentist [(152,155)].

Childhood obesity has also been linked to childhood dental caries. This may be due to common confounding factors such as poor oral hygiene and frequency of intake of cariogenic foods and drinks and in these children [136]. Willerhausen et al. also showed in their study that even after adjusting for age, a significant association between high weight and caries frequency in the deciduous (p=0.0067) and the permanent (p= 0.0002) remained [66].

However, the relationship between the presence of dental caries and being overweight is associated with a high intake of carbohydrates. It is however far more complex and cannot be explained by carbohydrate consumption alone [63]. This association may not be a cause-effect relationship since both dental caries and obesity are multifactorial conditions, and they both share risks with other chronic diseases [63]. According to Marshall et al., dental caries and obesity co-exist in children of low socioeconomic status [91]. However, children at risk of being overweight had higher caries rates than normal or overweight children [91]. A National Health and Nutrition Examination Survey in the United States III; the data showed no difference in caries rates by weight in younger children [155]. However, being overweight may be associated with decreased rates of dental caries in older children [156]. A study by Gerdin et al. had findings similar to those by Marshall et al. where obese, but not overweight children had more caries affected teeth than the non-obese [158]. In this study, BMI had an independent, though weak, effect on caries variation in multiple regression. Significant insight into overweight and obesity in children aged four-year-olds whose weight at ages five, seven, and ten years of age was within health range showed that they had significantly low caries prevalence than children who had normal body weight from 4 to 10 years of age [158].

Several other studies have however reported that there was no significant association between BMI-for-age and dental caries [84,157,159]. They also found that children who were overweight had a lower geometric DMFT (permanent dentition). The contradicting results are an indication that there was no clear evidence of an association between dental caries childhood obesity [160].

4.5.4.3 Height forAge Z scores and severity of ECC

The height for age z score (HAZ) for thirteen (7.4%) children who had mild to moderate ECC was <-0.66SD±1.07SD, se=0.30SD; while 158 (92.4%) who suffered from severe ECC the mean HAZ was <-0.47SD±1.03SD, se=0.08

The difference between the mean HAZ of<-0.66SD±1.07SD for 13(7.6%) who suffered from mild to moderate ECC was not significant when compared to the HAZ of <-0.47SD±1.03SD for 158 (92.4%) individuals who had severe ECC with an independent samples test where a Levene's test for equality of variances where F=0.064, df= (169, 13), p=0.540

In populations with high levels of nutritional deficiency, children with stunting have been shown to have an increased dental caries experience in their deciduous dentition [61,62].

4.5.4.4 Statistical test

The nutritional status did not have a statistically significant relationship with early childhood caries for the 171 children with a Spearman’s correlation: between weight for height z score and dmft r=-0.064, p=0.405; between height for age z-score and dmft r= -0.063, p=0.411; and between weight for age z score and dmft r=-0.099, p=0.198 at 95% CL. These findings do not mirror those of other studies that have shown that children with low Z scores in HAZ, WHZ and WAZ indexes had an increased risk of having dental caries.

4.5.4.5 Null Hypothesis

The association between nutritional status and dental age is accepted as the null hypothesis that there is no association between the nutritional status and the dental age is rejected.

4.5.5 Nutritional Status and Dental Age

Most studies that asses the association between dental age and nutrition use eruption instead of tooth mineralisation. Delay in the eruption and exfoliation of the deciduous teeth has been observed in malnourished children (61). A longitudinal study by Alvarez et al. showed a significant delay in the eruption of the deciduous dentition in children who had one episode of malnutrition occurring in early childhood, even though some of the teeth erupted two years after the malnutrition episode (161). Enwonwu's study involving Nigerian children showed that the eruption of primary teeth demonstrated a correlation with height and weight changes (95).

Unlike eruption which is more susceptible to environmental factors, tooth development is insulated and is, therefore, more reliable maturity indicator. A study involving Northern Sudanese children comparing the timing of tooth formation in normal and malnourished groups concluded that sustained malnutrition had a little measurable effect on tooth mineralisation (162). A study by Cameriere et al. involving Peruvian school children that used the Cameriere and Demirjian methods to estimate dental age in normal and undernourished children found no significant influence of under-nourishment on tooth mineralisation. They, however, suggested that the use of a quantitative method to assess this influence would be more accurate than the radiographic method they employed in this study (119).

However, a study by Hilgers et al. in the USA found that children who are overweight or obese had significantly accelerated dental development compared to children with normal BMI even after adjusting for age and gender ($p< 0.01$) (163). The mean dental age acceleration for obese and overweight subjects was 1.53±1.28 years and 1.51±1.22 years respectively when the Demirjian's method was used to assess dental age and (163).

4.5.5.1 Weight for height for age z score and dental age

One hundred and thirty six(79.5 %) children whose dental age was not delayed and the mean for WHAZ as <-0.2SD±1SD, se=0.09SD;(range -2.72SD to 1.93SD) while thirty five with delayed dental age had a mean WHAZ , of <-0.31SD±0.88SD, se= 0.15 SD, (range <-2.14SD to 1.68 SD).

4.5.5.1.1 Statistical test: independent samples test

A Levene's test for equality of variances indicated that there were no statistically significant differences between the length/height for age z score -WHAZ for children whose dental age was delayed and those whose dental age was not delayed where F=2.174, df= (169, 50), p=0.506 at 95% CL.

Overweight children have been shown to have more erupted teeth (higher eruption rates) than those with normal BMI [(164)]. Costacurta et al. [(76)] assessed childhood obesity about skeletal (cervical vertebra maturation) and dental maturity. The children were categorised as underweight, normal weight, pre-obese and obese according to the body fat percentage (FM %) McCarthy cut-offs classification and BMI. FM% was determined using Dual-energy X-ray Absorptiometry (DXA). The BMI classification did not show any statistical difference among the groups as for chronological, dental and skeletal age. However, according to FM% McCarthy classification, it was observed that with an increase in the FM% (i.e. from normal weight to obese children) the skeletal-dental age increased concerning the chronological age. In the study, the difference between chronological and dental-skeletal age was not statistically significant for normal underweight (p=0.46) and normal weight (p=0.33) children. However, the differences were statistically significant for the pre-obese (p=0.01) and the obese (p<0.001) children. The explanation behind these results as discussed by Costacurta et al. may be because BMI misclassifies adiposity status in the paediatric population compared to DXA. Mack et al. [(77)] found similar results in a study of orthodontic patients.

Hedayati and Khalafinejad [(165)] in a similar study (BMI, dental development by Demirjian and skeletal maturation of cervical vertebrae), the findings were slightly different. It was observed in their study that there was a correlation between dental maturity and increasing BMI percentile (p=0.002), where children who were overweight and obese had accelerated dental development [(165)]. However, this study differed from that by Costacurta et al. in that there was no significant relationship between BMI percentile and skeletal maturation.

4.5.5.2 Weight for age Z scores and dental age

One hundred and thirty six(79.5 %) children whose dental age was not delayed and the mean for WAZ as <-0.35SD±0.95 SD, se=0.08 SD;(range <-3.40SD to 2.29 SD) while thirty-five with delayed dental age had a mean WAZ, of <-0.72SD±0.86SD, se= 0.15 SD, (range <-2.79SD to 0.97 SD).

4.5.5.2.1 Statistical test

Significant differences for height for age z score -WAZ between the children whose dental age was delayed and those whose dental age was not delayed with an independent sample test with a Levene's test for equal variance where F=0.532, df= (169, 57), p= 0.041

Significant and a strong positive association was observed between the weight for age z score and dental age for the 171 children where a Spearman's correlation r=0.202, p=0.008 at 95% CL.

As earlier mentioned, low weight for age (wasting) has been associated with the delayed eruption of the deciduous dentition [161]. Delgado et al. in a study involving Guatemalan children found that heavier children had a more significant number of deciduous teeth erupted and that the timing of eruption of deciduous teeth was more closely associated with postnatal weight than with birth weight [166]. As an estimate of mean chronological age in populations living under conditions of mild to moderate malnutrition, the use of the low number of deciduous teeth erupted is relatively accurate, with variations of between 1-2 months [166].

4.5.5.3 Height for age z score and dental age

There were 136 (79.5 %) children shoes dental age was not delayed, and their mean HAZ was -0.39SD±1SD, se= 0.09SD, (range <-3.30SD to 2.21 SD); while 35 children whose dental age was delayed had a mean HAZ of <-0.86SD±1.07, se=0.18 SD, (range <-3.02SD to 1.62 SD).

4.5.5.3.1 Statistical test: independent samples test

A Levene's test for equality of variances indicated significant differences for length/height for age z score -WHAZ between the children whose dental age was delayed and those whose dental age was not delayed where $F=0.504$, $df= (169, 50)$, $p=0.016$ at 95% CL.

These findings mirror those in a longitudinal study by Alvarez that showed delayed eruption of deciduous teeth with malnutrition (62). According to this study, one malnutrition episode occurring during the first year of life is sufficient to cause a significant delay in the eruption of all deciduous teeth. This pattern was observed even though some of the teeth erupted two years after the malnutrition episode (62). It was also shown in the same survey that compared to wasting; stunting was more strongly associated with the delayed eruption of deciduous teeth. The observation is to be expected since stunting is chronic malnutrition and has a more significant impact while wasting is acute malnutrition (161). A study by Psoter et al. showed similar results in Haitian adolescents were both delayed shedding of the deciduous dentition and delayed the eruption of permanent teeth was associated with early childhood protein-energy malnutrition (EC-PEM) and current stunting in adolescence. The result demonstrated that malnutrition beginning in the earliest years and extending throughout childhood influenced the eruption and exfoliation of teeth (75).

Haddad et al. also showed that taller children have more erupted teeth than shorter children, regardless of birth weight and birth length (167). Kaur and Singh had similar findings where there was a strong, positive association between height and the number of erupted deciduous and permanent teeth (116). Flores-Mir et al., however, showed in their study of Peruvian school children aged 9.5-16.5 years that skeletal maturity stages and dental development were not associated with stunting (168). In their study, an adaptation of the Hägg and Taranger method was used to assess skeletal maturity of the middle phalanx of the third finger while the Demirjian method was used to assess dental maturity of the lower left canine.

4.5.5.4 Null Hypothesis

The association between dental age and WHZ was insignificant with a Spearman's correlation with r=-0.001, p=0.994. However, significant associations were noted between dental age and HAZ, r=0.314, p=0.000 and between dental age and WAZ r=0.202, p=0.008 at 95% CL.

Therefore, the null hypothesis that there exists no association between the dental age and nutritional status in children aged 3-5-year-old in Nairobi, Kenya is accepted when WHZ, may be used as a parameter for nutritional status as a

However, the null hypothesis is rejected when HAZ and WAZ are used as parameters for nutritional status since there was a strong positive and statistically significant relationship; Spearman's correlation p=0.00 and p=0.002 for HAZ and WAZ respectively

4.6 CONCLUSION

Most of the children had a dental age which was advanced when compared to the chronological age. The advanced dental age in respect to chronological age may be due to racial differences, and there may be a need to establish a reference dental age dataset for Kenyan children of African descent. The dental age had associations with only WAZ as underweight and HAZ as stunting in growth as nutritional status parameters. Hence children who are underweight or stunted in growth may have delayed dental maturity. The was also no relationship between dental age and ECC. Hence the severity of early childhood caries may not be a good indicator of delayed dental age. There was also no relationship between nutritional status and ECC.

4.7 RECOMMENDATIONS

The children of African descent have a dental age which is advanced beyond the chronological age. Further research has to be carried out to confirm this finding. That children in the age category of 3-4.9 years with severe malnutrition in terms of stunting (HAZ) and severe underweight (WAZ) are vulnerable to delayed dental age hence delayed eruption of the dentition. Hence when determining the dental age, stunting and severe weight loss should be taken into consideration.

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APPENDICES

APPENDIX I: Ethical Approval Letter

UNIVERSITY OF NAIROBI
COLLEGE OF HEALTH SCIENCES
P O BOX 19676 Code 00202
Telegrams: varsity
Tel:(254-020) 2726300 Ext 44355

KENYATTA NATIONAL HOSPITAL APPROVED 19 FEB 2018 KNH/UoN-ERC P.O. Box 20723-00202 NRB.

KNH-UON ERC
Email: uonknh_erc@uonbi.ac.ke
Website: http://www.erc.uonbi.ac.ke
Facebook: https://www.facebook.com/uonknh.erc
Twitter: @UONKNH_ERC https://twitter.com/UONKNH_ERC

KNH
QUALITY HEALTH CARE

KENYATTA NATIONAL HOSPITAL
P O BOX 20723 Code 00202
Tel: 726300-9
Fax: 725272
Telegrams: MEDSUP, Nairobi

Ref: KNH-ERC/A/70

19th February, 2018

Joyce Atieno Omuok
V60/87644/2016
Dept.of Paediatric Dentistry and Orthodontics
School of Dental Sciences
College of Health Sciences
University of Nairobi

Dear Joyce

RESEARCH PROPOSAL – CHRONOLOGICAL AGE, DENTAL AGE AND NUTRITIONAL STATUS AMONG 3-5 YEAR OLDS WITH EARLY CHILDHOOD CARIES IN NAIROBI, KENYA (P595/10/2017)

This is to inform you that the KNH- UoN Ethics & Research Committee (KNH- UoN ERC) has reviewed and **approved** your above revised proposal. The approval period is from 19th February 2018 – 18th February 2019.

This approval is subject to compliance with the following requirements:

a) Only approved documents (informed consents, study instruments, advertising materials etc) will be used.
b) All changes (amendments, deviations, violations etc) are submitted for review and approval by KNH-UoN ERC before implementation.
c) Death and life threatening problems and serious adverse events (SAEs) or unexpected adverse events whether related or unrelated to the study must be reported to the KNH-UoN ERC within 72 hours of notification.
d) Any changes, anticipated or otherwise that may increase the risks or affect safety or welfare of study participants and others or affect the integrity of the research must be reported to KNH- UoN ERC within 72 hours.
e) Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. (*Attach a comprehensive progress report to support the renewal*).
f) Submission of an *executive summary* report within 90 days upon completion of the study.
This information will form part of the data base that will be consulted in future when processing related research studies so as to minimize chances of study duplication and/ or plagiarism.

For more details consult the KNH- UoN ERC website **http://www.erc.uonbi.ac.ke**

Protect to discover

Yours sincerely,

PROF. M. L. CHINDIA
SECRETARY, KNH-UoN ERC

c.c. The Principal, College of Health Sciences, UoN
The Deputy Director, CS, KNH
The Chairperson, KNH-UON ERC
The Assistant Director, Health Information, KNH
The Dean,School of Dental Sciences, UoN
The Chair, Dept.of Paediatric Dentistry and Orthodontics,UoN
Supervisors: Prof. Gladys Opinya, Dr. Edith Ngatia

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APPENDIX II: NACOSTI Research Authorization Letter

NATIONAL COMMISSION FOR SCIENCE,
TECHNOLOGY AND INNOVATION

Telephone:+254-20-2213471,
2241349,3310571,2219420
Fax:+254-20-318245,318249
Email: dg@nacosti.go.ke
Website : www.nacosti.go.ke
When replying please quote

NACOSTI, Upper Kabete
Off Waiyaki Way
P.O. Box 30623-00100
NAIROBI-KENYA

Ref: No. **NACOSTI/P/18/18409/22026**

Date: **9th April, 2018**

Dr. Joyce Atieno Omuok
University of Nairobi
P.O. Box 30197-00100
NAIROBI.

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on ***"Chronological age, dental age and nutritional status in 3-5 year-olds with early childhood caries,"*** I am pleased to inform you that you have been authorized to undertake research in **Nairobi County** for the period ending **9th April, 2019.**

You are advised to report to **the County Commissioner, the County Director of Education and the County Director of Health Services, Nairobi County** before embarking on the research project.

Kindly note that, as an applicant who has been licensed under the Science, Technology and Innovation Act, 2013 to conduct research in Kenya, you shall deposit **a copy** of the final research report to the Commission within **one year** of completion. The soft copy of the same should be submitted through the Online Research Information System.

DR. STEPHEN K. KIBIRU, PhD.
FOR: DIRECTOR-GENERAL/CEO

Copy to:

The County Commissioner
Nairobi County.

The County Director of Education
Nairobi County.

APPENDIX III: Nairobi City County Research Authorization Letter

NAIROBI CITY COUNTY

Telephone 020 344194

Web: www.nairobi.go.ke

City Hall,
P. O. Box 30075-00100,
Nairobi,
KENYA.

COUNTY HEALTH SERVICES

REF: CHS/1/13/ (11) - 018

TO: DR. JOYCE ATIENO OMUOK
UNIVERSITY OF NAIROBI
P O BOX 19676
NAIROBI

DATE: 10TH APRIL, 2018

RE: RESEARCH AUTHORIZATION FOR CHRONOLOGICAL AGE, DENTAL AGE AND NUTRITIONAL STATUS AMONG 3-5-YEAR-OLD WITH EARLY CHILDHOOD CARIES IN NAIROBI, KENYA

Reference is made to a letter from the Director Human Resource Management

Ref. HRD/3/4/487/MWN/2018 dated 12TH March, 2018.

Authority is hereby granted to you to carry out research on **"Chronological Age, Dental Age and Nutritional Status Among 3-5-Year-Old with Early Childhood Caries In Nairobi, Kenya "**Please note that your research runs for one-week w.e.f from 17th April to 31st May, 2018.

During the course of your research you will be expected to adhere to the rules and regulations governing the Nairobi City County.

You will also be expected to submit a copy of your research project to the office of the undersigned.

By a copy of this letter, the SCMOH: Dagoretti North, Lady Northey, is requested to accord you the necessary assistance.

Research fee of five thousand shilling (5000) has been paid.

EUNICE MUSAU
CHIEF ADMINISTRATIVE OFFICER – (CHS)

Cc: - SCMOH – Dagoretti → Lady Northey, (State House Rd:)
SCHAO – Dagoretti → " " " "
In/Charge – Lady Northey

APPENDIX IV: Kenya Bureau of Standards Calibration Certificate

(BS/MET/2/3/798)

ORIGINAL

Kenya Bureau of Standards
P.O Box 54974–00200
NAIROBI
Tel:(+254 020) 6948000
info.metrology@kebs.org
Website: www.kebs.org

KEBS
CALIBRATION MARK

Calibration Certificate

Page 1 of 2 Pages

REQUESTED BY : **Dr. Omuok Joyce**
School of Dental Sciences, University of Nairobi
EQUIPMENT : **Electronic Weighing Scale.**
TYPE/MODEL : **5305.**
MANUFACTURER : **Made in China.**
LAB NAME : **Mass (Site).**
CALIBRATION DATE : **2018-04-13.**
CERTIFICATE No. : **BS/MET/2/3/91/798.**
CALIBRATION STICKER: **35593.**

1. **COMMENTS**
The errors are within the allowable limits as stipulated in the standards mentioned below.

2. **REFERENCE STANDARDS AND EQUIPMENTS USED**
(a) The scale was calibrated according to Kenya Standard KS OIML R76: 2006 (Specifications for non automatic weighing machines) and EURAMET CG No. 18: 2015 (Guidelines on the calibration of Non automatic weighing Instruments).
(b) Class M_1 & M_2 standard masses were used in calibrating the scale.
(c) These standards are traceable to the National Standards.

3. **CALIBRATION PROCEDURE**
Calibration Procedure No. MET/2/OP/01 (Measurement Procedure for Calibration of Balances) was followed in calibrating the scale.

Calibrated by: D. Githua Date: 2018-04-13

Checked by: D. Tonui Date: 2018-04-13

Signed: Date: 2018-04-13

For: MANAGING DIRECTOR

Calibration certificate without signature and official stamp is not valid. This certificate has been issued without any alteration and may not be reproduced other than in full except with the approval of the Managing Director KEBS.
If undelivered please return to the above address.

4. RESULTS

4A Error of Indications

NOMINAL MASS IN: (kg)	AVERAGE READING IN: (kg)	CORRECTION IN: (kg)
0	0.0	0.0
1	1.0	0.0
2	2.0	0.0
5	5.0	0.0
10	10.0	0.0
20	20.0	0.0
40	39.9	+0.1
60	59.8	+0.2
80	79.8	+0.2
100	99.8	+0.2
120	119.8	+0.2
140	139.8	+0.2
150	149.8	+0.2

4B Repeatability

The repeatability test was carried out at 80kg and found to be within 0.1 kg

4c Eccentricity test:

Corner loading was carried out with 60kg weight and the deviation was 0.0kg for all the five test points

5. UNCERTAINTY

5.1 The uncertainty in measurement is ± 0.12 kg.

5.2 The reported uncertainty of measurements was calculated and expressed in accordance with EA-4/02 publication, and was based on a standard uncertainty multiplied by a coverage factor of k=2, which, unless stated otherwise, provides a level of confidence of approximately 95 %.

--o----O----o--

APPENDIX V: Kenya Bureau of Standards Calibration Certificate

(BS/MET/2/3/91/799)

ORIGINAL

Kenya Bureau of Standards
P.O Box 54974–00200
NAIROBI
Tel:(+254 020) 6948000
info.metrology@kebs.org
Website: www.kebs.org

KEBS
CALIBRATION MARK

Calibration Certificate

Page 1 of 2 Pages

REQUESTED BY : **Dr. Omuok Joyce**
School of Dental Sciences, University of Nairobi
EQUIPMENT : **Electronic Weighing Scale.**
TYPE/MODEL : **5305.**
MANUFACTURER : **Made in China.**
LAB NAME : **Mass (Site).**
CALIBRATION DATE : **2018-04-13.**
CERTIFICATE No. : **BS/MET/2/3/91/799.**
CALIBRATION STICKER : **35570.**

1. COMMENTS

The errors are within the allowable limits as stipulated in the standards mentioned below.

2. REFERENCE STANDARDS AND EQUIPMENTS USED

(a) The scale was calibrated according to Kenya Standard KS OIML R76: 2006 (Specifications for non automatic weighing machines) and EURAMET CG No. 18: 2015 (Guidelines on the calibration of Non automatic weighing Instruments).
(b) Class M_1 & M_2 standard masses were used in calibrating the scale.
(c) These standards are traceable to the National Standards.

3. CALIBRATION PROCEDURE

Calibration Procedure No. MET/2/OP/01 (Measurement Procedure for Calibration of Balances) was followed in calibrating the scale.

Calibrated by: D. Githua Date: 2018-04-13

Checked by: D. Tonui Date: 2018-04-13

Signed: Date: 2018-04-13

For: MANAGING DIRECTOR

4. RESULTS

4A Error of Indications

NOMINAL MASS IN: (kg)	AVERAGE READING IN: (kg)	CORRECTION IN: (kg)
0	0	0
1	1	0
2	2	0
5	5	0
10	10	0
20	20	0
40	39.9	+0.1
60	60.1	-0.1
80	80.1	-0.1
100	100.1	-0.1
120	120.1	-0.1
140	140.1	-0.1
150	150.1	-0.1

4B Repeatability

The repeatability test was carried out at 80kg and found to be within 0.1 kg

4c Eccentricity test:

Corner loading was carried out with 60kg weight and the deviation was 0.0kg for all the five test points

5. UNCERTAINTY

5.1 The uncertainty in measurement is ± 0.12 kg.

5.2 The reported uncertainty of measurements was calculated and expressed in accordance with EA-4/02 publication, and was based on a standard uncertainty multiplied by a coverage factor of k=2, which, unless stated otherwise, provides a level of confidence of approximately 95 %.

--o----O----o--

APPENDIX VI: Schedule of Activities

Event	Person(s) Responsible	Time Limit
1. Proposal Writing	Principle Investigator Supervisors	December 2016 -October 2018
2. Submission to Ethical Committee and BPS UoN for approval	Principal Investigator Research, Ethics and Standards Committee Kenyatta National Hospital and the University of Nairobi.	November, 2018
3.Clearance with Local Authorities	Principal Investigator Medical Superintendent-Lady Northey Dean, UNDH	February – March, 2018
4. Data Collection	Principal Investigator Supervisors Field Assistants	April – August, 2018
5. Data Entry	Principal Investigator	September, 2018
6.Data Analysis and Report Writing	Principal Investigator	October – December, 2018
7. Thesis Writing	Principal Investigator Supervisors	January – April, 2019
8.Thesis Submission	Principal Investigator	May, 2019
9. Thesis defence	Principal Investigator	Novemeber, 2019

APPENDIX VII: Budget

Category	Costs (Kshs)	No. of Units	Total Cost (Kshs)
Proposal Development			
• Internet access • Flash Disk • Printing • Binding	• 60/hr • 3000 • 900 • 200	• 900 hrs • 1 • 15 • 15	54,000 3,000 13,500 3,000
			73,500
Personnel			
▪ 1st Assistant ▪ 2nd Assistant ▪ 3rd Assistant	• 12,000 • 12000 • 12000	1 1 1	12,000 12,000 12,000
			36,000
Training of Personnel			**10,000**

• Principal Investigator • Research assistants	• 10,000 • 10,000	1 3	20,000 30,000
			50,000
Data Collection			
• Printing of forms • Pre-testing questionnaires • Weighing scale • Plane mirrors • Examination gloves • Face masks • Disinfectant solution • Gauze • Sterilisation pouches	• 150 • 150 • 3,000 • 400/pc • 750/pkt • 400/pkt • 2800/pkt • 1500 • 2000/pkt	220 20 2 30 5 3 1 1 1	33,000 3,000 6,000 12,000 3,750 1,200 2,800 1,500 2,000 **65,250**

• Internet • Biostatistician • Thesis typing and printing • Thesis binding • Calibration (KEBS)	• 2000 • 450 • 8,700	10 10 2	30,000 40,000 15,000 4500 17,400
			106,900
Total			**341,650**

APPENDIX VIII: Consent Information Document (English)

Dear Parent/Guardian of ....,

I am Dr Omuok Joyce Atieno, a Masters of Paediatric Dentistry student at the University of Nairobi, School of Dental Sciences, Kenya.

Study background: Early Childhood Caries (ECC) if left untreated, may progress to a more severe form, which may negatively impact on dietary intake (due to pain and discomfort) with the risk of the child being underweight due to poor feeding. A reduction in a child's quality sleep that is necessary for proper emotional and physical development may occur. Inadequate sleep may affect growth hormone production, and hence growth is affected, particularly body weight and height and possibly dental development.

Broad objective: In partial fulfilment of my degree, I am working on a dissertation entitled: 'Chronological age, dental age and nutritional status among 3-5-year-olds with early childhood caries in Nairobi, Kenya.' the study aimed at determining the effect of early childhood caries on the nutritional status and dental age of 3-5-year-old children.

Procedure: The study involved a dental examination done by the Principal Investigator (Dr Omuok Joyce Atieno) on children with Early Childhood Caries. It lasted 10-15 minutes for each child. The investigation involved an assessment of the oral hygiene status, dental caries experience, nutritional status, chronological age and dental age. I asked questions relevant to the research and subsequently recorded them in a questionnaire. Then I proceeded to measure the height and weight of your child. Height shall be measured using a standard height board and the weight using a Salter weighing scale. Next, I will examine your child's mouth using sterile instruments and materials and record the findings. Finally, I will examine the child's radiograph (OPG) to determine the dental age.

No treatment will be given to the child during the study, but all participants will be treated appropriately for dental caries at the Lady Northey Dental Hospital.

Voluntariness: Participation in this study is voluntary for both you and your child.

Assent process: Your child will not be forced to be examined if they resist or are unable to open their mouth.

Confidentiality: Even though the information obtained will be made available to the Lady Northey Dental Hospital and the University of Nairobi, the child's details and the results of the study will remain confidential and used only for research purposes. Your child's identity will be concealed, and his/her name will not appear anywhere on the coded forms with the information. All documents, paper and computer records will be kept under lock and key and with password protection respectively.

Benefits: The examination is solely for academic purposes and doesn't imply that any dental treatment will be offered. The child shall be treated at the Lady Northey Dental Hospital or referred where needed.

Risks: There will be no risks involved while undertaking this procedure and no fee whatsoever was levied on those who participate.

The right of withdrawal: You may withdraw your child from participating at any time without suffering any consequences.

This letter is to kindly request you accept and allow your child to participate in the study. Read it and make sure you have understood it before signing and return the signed document to the hospital if you agree to your child's participation in this study.

For further information or inquiries; -

Dr Omuok Joyce Atieno, joyceomuok@gmail.com

Lead supervisors:

Prof. Gladys Opinya, amaniwanjala@yahoo.com

Dr Edith Ngatia, edith_muthoni@yahoo.co.uk

The Chairperson, Kenyatta Hospital/University of Nairobi Ethics and Research Committee, uonknh_erc@uonbi.ac.ke

APPENDIX IX: Consent Information Document (Swahili)

IDHINI YA UTAFITI KUTOKA KWA MZAZI/MLEZI WA MTOTO WA MIAKA MIATAU HADI MITANO ANAYEKABILIWA NA SHIDA YA MATUNDU KWENYE MENO.

Kwa mzazi/mlezi wa ……………………………………………………………

Mimi ni Daktari Omuok Joyce Atieno, mwanafunzi wa stashahada, kwenye kitengo cha meno ya watoto, Chuo Kikuu cha Nairobi, Kenya.

Kiini cha utafiti: Matatizo ya matundu kwenye meno ya watoto yasiposhughulikiwa mapema humtatiza motto kwa uchungu na hata ukosefu wa usingizi wa kutosha. Matatizo haya humfanya motto kukua pole pole ikilinganishwa na vile watoto wa umri wake wanavyokua.

Lengo la utafiti: Hii ni sehemu muhimu katika kukamilisha mradi wangu wa tatizo la matundu menoni miongoni mwa wa wtoto wa umri wa miaka mitatu hadi mitano, kwenye jiji la Nairobi, nchini Kenya. Utafiti huu pia utaweza kuonyesha madhara ya tatizo hili kwenye malazi na ulaji ya watoto hawa.

Utaratibu wa utafiti: Meno ya motto wako yatakaguliwa na Dkt Omuok Joyce ili yaonekane kama yana tundu lolote. Pia, usafi wa mdomo wake utaangaliwa. Watakaopatikana na tatizo la matundu kwenye meno yao watatibiwa kwenye hospitali ya meno ya Lady Northy kwa malipo ya chini.

Ushiriki: Hakuna atakayekulazimisha kushiriki kwenye utafiti huu. Pia, hakuna atakayemlazimisha motto wako kufungua mdomo ikiwa hataki.

Usiri: Ingawa matokeo ya utafiti huu yatatumika chuoni Nairobi na hospitali ya meno ya Lady Northey, jina la motto na matokeo ya utafiti yatasalia kuwa siri.

Manufaa: Utafiti huu utamsaidia mzazi kujua iwapo motto wake ana tatizo la tundu na kama meno ya mwanawe yanamea kwa njia inayofaa.

Hatari: Utaratibu wa utafiti huuhauna madhara yoyote kwa motto anayeshiriki. Mtoto au mzazi ana uhuru wa kujiondoa kutoka kwenye utafiti huubilakupata adhabu yoyote.

Ikiwa umeelewa (mzazi/mlezi) utaratibu wa utafiti huu na ungetaka motto wako ashiriki, tafadhali tia sahihi kwenye barua hii.

Sahihi: ……………………………………….

Kwa maelezo zaidi/maswali, tafadhali wasiliana na;

Dkt. Omuok Joyce Atieno, joyceomuok@gmail.com

Wasimamizi wakuu:

Prof. Gladys Opinya, amaniwanjala@yahoo.com

Dr Edith Ngatia, edith_muthoni@yahoo.co.uk

Mwenyekiti, Hospitali ya Kenyatta / Chuo Kikuu cha Nairobi Kamati ya Maadili na Utafiti, uonknh_erc@uonbi.ac.ke

APPENDIX X: Statement of Consent (English)

I..,

Parent/Guardian of...hereby permit Dr Omuok Joyce Atieno to conduct a dental examination on my child. She has described to me what is going to be done to my child, the risks, benefits involved and my child's rights regarding this study. I also understand that the decision to participate in this study will not alter my child's health status or treatment and my child will not be forced to participate.

I understand that the examination is solely for academic purposes and doesn't imply that any dental treatment will be offered and that my child shall be treated at the Lady Northey Dental Hospital.

I am aware that although, the information obtained will be made available to Lady Northey Dental Hospital, the University of Nairobi, Kenya, my child's details will remain concealed and study results shall remain confidential.

I agree to photographs of my child's mouth being taken, and consent to their usage in scientific publications. As a parent, I understand that by signing this form, I do not waive any of my child's legal rights but merely indicate that I have been informed about the research study in which am voluntarily agreeing my child participate.

YES	NO

Child's Name: ....

Age: ....

Parent/Guardian's Name: ....

Signature/Thumb Print: ....

Date: ....

I do at this moment confirm that I have explained the nature of the study to the patient and caregiver.

Name of Investigator: ....

Signature of Investigator: ....

Date: ....

APPENDIX XI: Statement of Consent (Swahili)

IDHINI KUTOKA KWA MZAZI/MLEZI

Mzazi/mlezi …………………………… nimemruhusu Daktari Joyce Atieno Omuok kutumia meno ya motto wangu kwenye utafiti wake. Nimesoma na kuelewa maelezo ya utafiti wake. Naelewa kuwa matokeo ya utafiti huu yatasalia kuwa siri.

Nimeidhinisha Daktari Joyce Atieno Omuok kuchukua picha za mdomo wa motto wangu na kutumika kwenye utafiti wake.

Nimekubali mtoto wangu kushiriki kwenye utafiti huu bila kulazimishwa na yeyote.

NDIO	LA

Jina la motto: …………………………………………………………..

Umri: ………………………………………………………………..

Jina la mzazi/mlezi: …………………………………………………

Sahihi: ……………………………………………………………..

Tarehe: …………………………………………………………

APPENDIX XII: Data Collection Form

ID No.____________________________________ DATE OF BIRTH: --/--/-

Name of Hospital:___________________________ DD/MM/YY

SEX: Male Female

ANTHROPOMETRY

	First Reading	Second Reading	Average
Height			
Weight			

ORAL HYGIENE STATUS: Plaque Index (Silness-Löe, 1964)

55 (M)	55 (B)	55 (D)	55 (P)	52 (M)	52 (B)	52 (D)	52 (P)	64 (M)	64 (B)	64 (D)	64 (P)
84 (M)	84 (B)	84 (D)	84 (L)	72 (M)	72 (B)	72 (D)	72 (L)	75 (M)	75 (B)	75 (D)	75 (L)

DENTAL CARIES ASSESSMENT

55	54	53	52	51	61	62	63	64	65
85	84	83	82	81	71	72	73	74	75

TOOTH STATUS	CODE FOR DECIDUOUS TEETH
Sound	A
Decayed	B
Filled with D=decay	C
Filled with no decay	D
Missing as a result of caries	E
Sealant varnish	F
Bridge abutment or special crown	G

STAGING, SCORING AND DETERMINATION OF THE DENTAL AGE OF PANORAMIC RADIOGRAPHS

Tooth	31	32	33	34	35	36	37	Total
Maturity Stage								
Maturity Score								
Estimated Age								
Chronological Age								
Gender								

APPENDIX XIII: Caregivers' Questionnaire (English)

A:SOCIAL DEMOGRAPHY

Date: __ /__ / __

Date of Birth of the child: __ / __ / __ **Unknown** ☐

Sex: Male ☐ Female ☐

Caregiver: Mother ☐ Father ☐ Aunty ☐

Uncle ☐ Grandparent ☐ Other ☐

Marital Status: Single ☐ Married ☐ Widowed ☐

Separated ☐ Divorced ☐ Other ☐

Residence:____

Number of children:____

How many people do you live with?______________________________

Level of education of caregiver:

No formal education ☐ Primary School ☐

Secondary School ☐ Technical college ☐ University ☐

Occupation of Caregiver

Professional (accountant, doctor, teacher, company executives etc.) ☐

Clerical and white collar ☐ Businessman/woman ☐

Skilled manual worker ☐

Unskilled worker ☐ Unemployed ☐

MORBIDITY:

Natal History

Mode of delivery of the child:

Spontaneous natal delivery (SVD) ☐

Caesarian section (CS) ☐ Unkown ☐

Gestation period at delivery: _______________Weeks Unkown ☐

Birth weight of the child: _______________kgs Unkown ☐

Has the child received all immunisations? Yes ☐ No ☐

Has your child suffered from any illness in the past seven days? Yes ☐ No ☐

If yes, which of these illnesses:

A diarrhoea Cough/cold ☐ Malaria ☐

Other (specify) ____

Has the child had any chronic/prolonged illnesses in the past? Yes ☐ No ☐

If yes, for what duration?____months

At what age? ____months

Trauma:

Has the child suffered from any trauma to the teeth/jaws in the past?

Yes ☐ No ☐

If yes, at which location of the mouth?

Upper right	Upper front	Upper left
Lower right	Lower front	Lower left

At what age did the trauma occur? -
_______________________________________months.

C. DIETARY HABITS

Mode of feeding at birth:

Exclusive breastfeeding ☐ Breastfeeding and bottle feeding ☐

Exclusive bottle feeding ☐

Duration of breastfeeding (in months)

____

Duration of bottlefeeding (in months)

____

What did you place in the bottle?

____

Did your child sleep with the bottle in the mouth? Yes ☐ No ☐

Did you breastfeed on demand? Yes ☐ No ☐

What does your child feed on during the following meal times?

Breakfast:____

10.00am snack:

____

Lunch

____

4.00pm snack

Dinner

APPENDIX XIV: Caregivers' Questionnaire (Swahili)

SEHEMU HII ITAJAZWA NA MZAZI/MLEZU WA MTOTO

Tarehe: __ /__ / __

Tarehe ya kuzaliwa: __ / __ / __ **Haijulikani** ☐

Jinsia: Kiume ☐ Kike ☐

Mlezi: Mama ☐ Baba ☐ Shangazi ☐

Mjomba ☐ Babu/Nyanya ☐ Wengine ☐

Hali ya ndoa: Hujaoa/hujaolewa ☐ Ndoa ☐ Mjane ☐

Kutengana ☐ Talaka ☐ Nyingine ☐

Makazi:____

Watoto wangapi?:______________________________________

Unaishi na watu wangapi?________________________________

Kiwango chako cha masomo?:

Hakuna elimu rasmi ☐ Shule ya msingi ☐

Shule ya sekondari ☐ Chuo cha ufundi ☐ Chuo kikuu ☐

Kazi?:

Mtaalam (mhasibu, daktari, mwalimu, watendaji wa kampuni nk) ☐

Kazi ya ofisi ☐ Mfanyibiashara ☐ Mtaalamu wa mwongozo wenye ujuzi ☐

Mfanya kazi asiye na ujuzi ☐ Asiyeajiriwa ☐

UGONJWA:

Historia ya mtoto:

Mtoto alizaliwa vipi?:

Kawaida: ☐ Upasuaji ☐ Haijulikani ☐

Mtoto alizaliwa baada ya miezi mingapi?: Wiki _________ Haijulikani ☐

Mtoto alizaliwa akiwa na uzito wa kilo ngapi?: Kilo ________Haijulikani ☐

Mtoto amepewa chanjo zote? Ndio ☐ La ☐

Mtoto ameugua ugonjwa wowote kwa wiki moja iliyopita? Ndio ☐ La ☐

Ikiwa jibu ni ndio, ameugua ugonjwa gani?

Kuhara ☐ Homa/ kukohoa ☐ Malaria ☐

Zingine (eleza)

____

Mtoto ameugua ugonjwa uliochukua mda mrefu?

Ndio ☐ La ☐

Ikiwa ndio, ilichukua mda gani? Miezi_______________________________________

Aliuguwa akiwa na umri gani?? Miezi ____

Kiwewe:

Mtoto amepata maumivu yanayotokana na kuumiza/kuanguka kwenye meno/ufizi?

Ndio ☐ La ☐

Ikiwa ndio, ni sehemu gani ya mdomo ilihusika?

Upande wa juu kulia	Upande wa juu mbele	Upande wa juu kushoto
Upande wa chini kulia	Upande wa chini mbele	Upande wa chini kushoto

Aliumia akiwa na umri upi?

Miezi ____

C. MALAZI/ VYAKULA

Mtoto alipozaliwa, alinynya au alipewa maziwa kwa chupa?

Kunyonya pekee ☐

Kunyonya pamoja na maziwa kwa chupa ☐

Maziwa kwa chupa pekee ☐

Mtoto alinyonya kwa mda wa miezi ngapi? _________________________

Mtoto alitumia chupa kwa mda gani? ______________________________

Mtoto aliwekewa nini kwenye chupa _______________________________

Mtoto alilala akiwa na chupa mdomoni? Ndio ☐ La ☐

Mtoto alinyonya kila alipotaka? Ndio ☐ La ☐

Mtoto wako hula nini kwa wakati zilizotajwa hapo chini?

Chakula cha asubuhi? ____

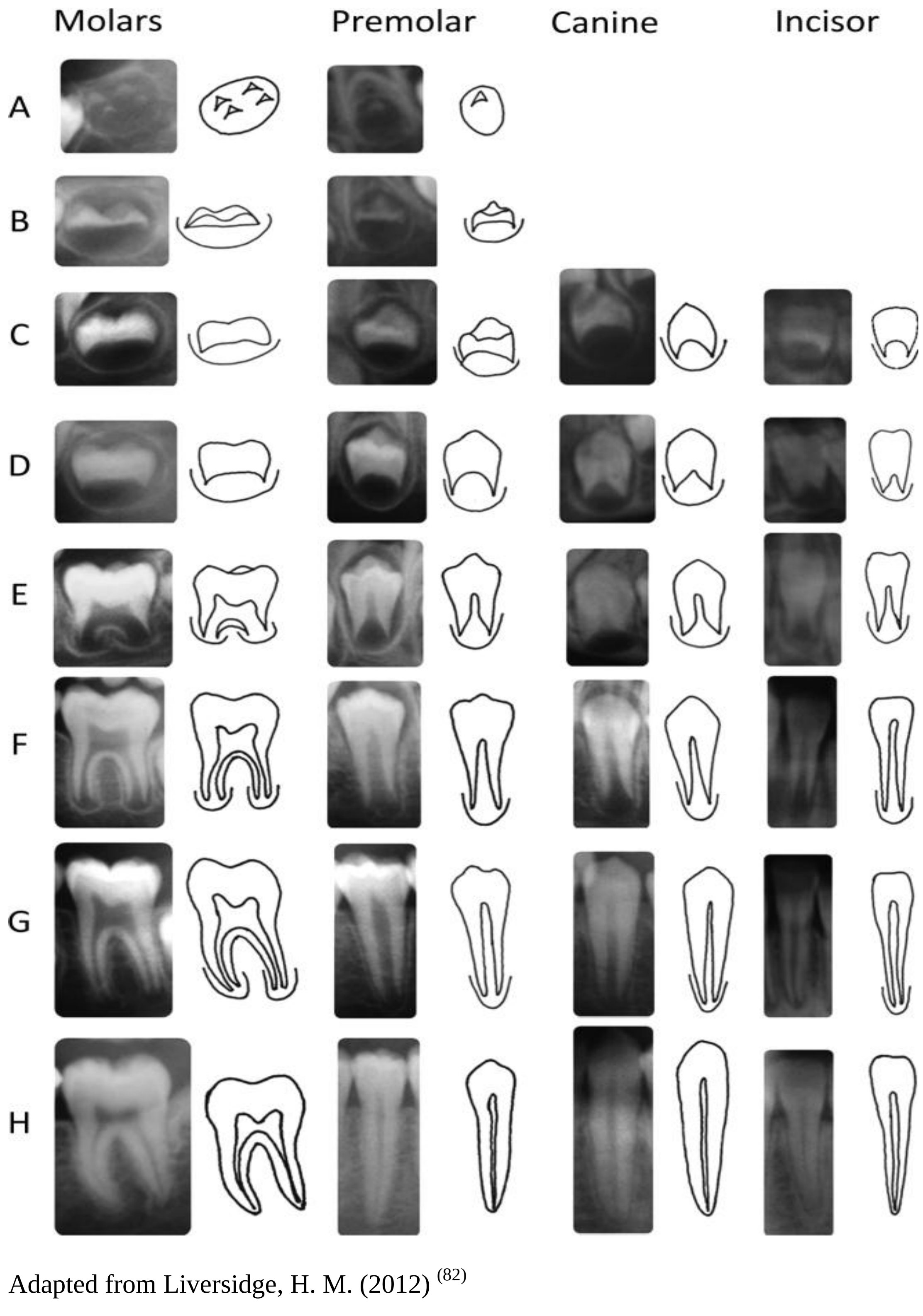
Saa nne? ____

Chakula cha mchana? ____

Saa kumi?____

Chakula cha jioni/usiku?____

APPENDIX XV: Demirjian's Tooth Maturity Chart



Adapted from Liversidge, H. M. (2012) [82]

APPENDIX XVI: Demirjian's Tooth Stage Descriptions

Stage	Descriptions
A	In both uniradicular and multiradicular teeth, a beginning of calcification is seen at the superior level of the crypt in the form of an inverted cone or cones. There is no fusion of these calcified points.
B	Fusion of the calcified points forms one or several cusps which unite to give a regularly outlined occlusal surface.
C	a. Enamel formation is complete at the occlusal surface. Its extension and convergence towards the cervical region is seen. b. The beginning of a dentinal deposit is seen. c. The outline of the pulp chamber has a curved shape at the occlusal border.
D	a. The crown formation is complete down to the cemento–enamel junction. b. The superior border of the pulp chamber in the uniradicular teeth has a definite curved form, being concave towards the cervical region. The projection of the pulp horns, if present, gives an outline shaped like an umbrella top. In molars the pulp chamber has a trapezoidal form. c. Beginning of root formation is seen in the form of a spicule.
E	*Uniradicular teeth:* a. The walls of the pulp chamber now form straight lines, whose continuity it broken by the presence of the pulp horn, which is larger than in the previous stage. b. is less than the crown height. *Molars:* a. Initial formation of the radicular bifurcation is seen in the form of either a calcified point or a semi-lunar shape. b. is still less than the crown height.
F	*Uniradicular teeth:* a. The walls of the pulp chamber now form a more or less isosceles triangle. The apex ends in a funnel shape. b. The root length is equal to or greater than the crown height. *Molars:* a. The calcified region of the bifurcation has developed further down from its semi-lunar stage to give the roots a more definite and distinct outline with funnel shaped endings. b. The root length is equal to or greater than the crown height.
G	The walls of the root canal are now parallel and its apical end is still partially open (Distal root in molars).
H	a. The apical end of the root canal is completely closed (Distal root in molars). b. The periodontal membrane has a uniform width around the root and the apex.

Reprinted from Appendix in 'A New System of Dental Age Assessment' by Demirjian, A., Goldstein, H., Tanner, J. M. (1973) *Human Biology: The International Journal of Population Genetics and Anthropology*, 45 (2). Copyright© 1973 Wayne State University Press, with the permission of Wayne State University Press. Stage E point b updated as The root lenght reaches at least 1/3 of crown height for both uniradical teeth and molars (Levesque and Demirjian 1980).

Adapted from Liversidge, S. M. (2012) [82]

APPENDIX XVII: Tooth Notation

I_1 Permanent mandibular central incisor

I_2 Permanent mandibular lateral incisor

C Permanent mandibular canine

P_1 Permanent mandibular first premolar

P_2 Permanent mandibular second premolar

M_1 Permanent mandibular first molar

M_2 Permanent mandibular second molar

APPENDIX XVIII: Demirjian's Tables (Maturity Scores)

Boys

Tooth	0	A	B	C	D	E	F	G	H
	Stages								
M_2	0·0	1·7	3·1	5·4	8·6	11·4	12·4	12·8	13·6
M_1				0·0	5·3	7·5	10·3	13·9	16·8
PM_2	0·0	1·5	2·7	5·2	8·0	10·8	12·0	12·5	13·2
PM_1		0·0	4·0	6·3	9·4	13·2	14·9	15·5	16·1
C				0·0	4·0	7·8	10·1	11·4	12·0
I_2				0·0	2·8	5·4	7·7	10·5	13·2
I_1				0·0	4·3	6·3	8·2	11·2	15·1

Girls

Tooth	0	A	B	C	D	E	F	G	H
	Stages								
M_2	0·0	1·8	3·1	5·4	9·0	11·7	12·8	13·2	13·8
M_1				0·0	3·5	5·6	8·4	12·5	15·4
PM_2	0·0	1·7	2·9	5·4	8·6	11·1	12·3	12·8	13·3
PM_1		0·0	3·1	5·2	8·8	12·6	14·3	14·9	15·5
C				0·0	3·7	7·3	10·0	11·8	12·5
I_2				0·0	2·8	5·3	8·1	11·2	13·8
I_1				0·0	4·4	6·3	8·5	12·0	15·8

Adapted from A. Demirjian and H. Goldstein (1976) [36]

APPENDIX XIX: Certificate of Originality

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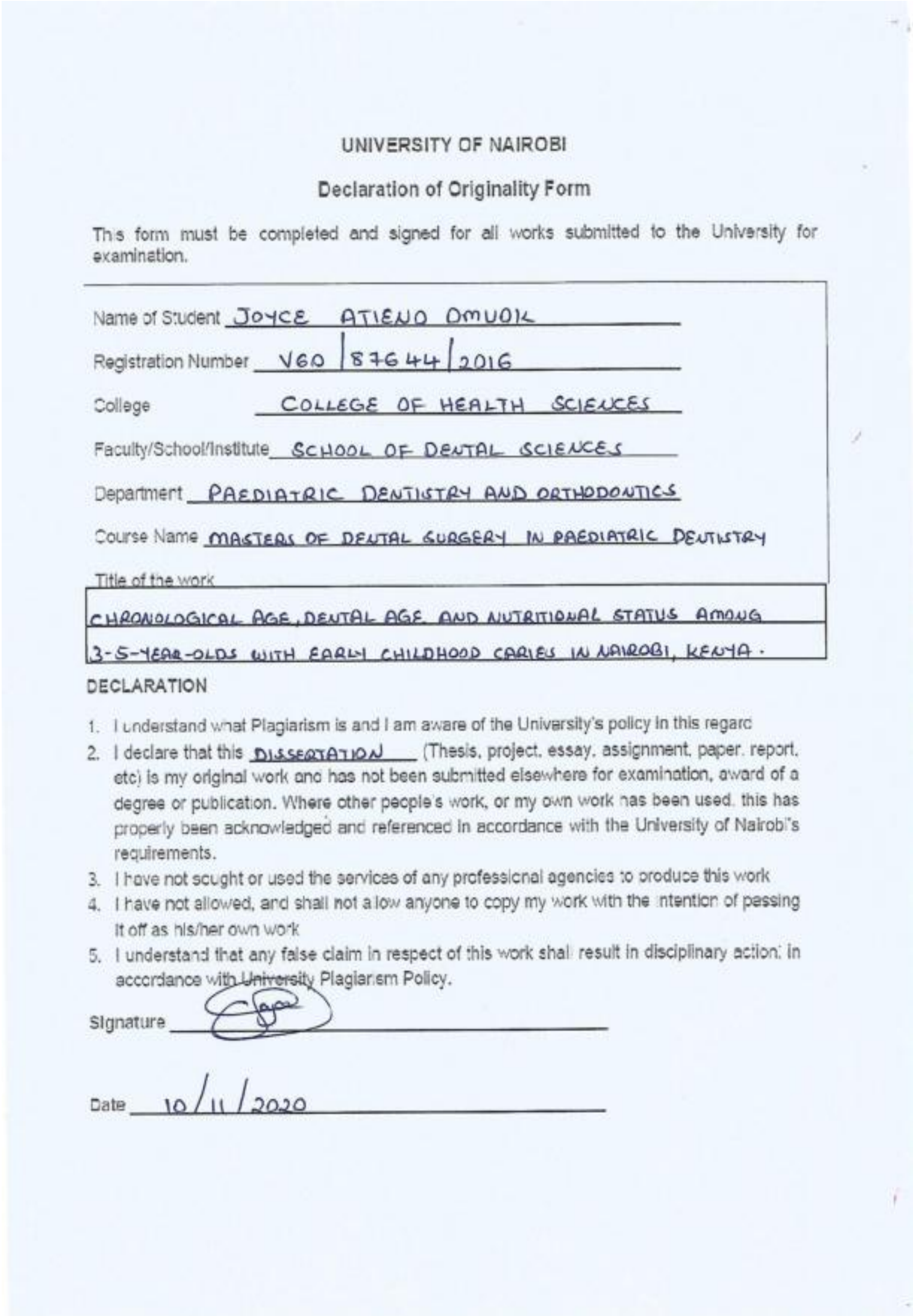
APPENDIX XX: Declaration of Originality



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Faculty/School/Institute SCHOOL OF DENTAL SCIENCES

Department PAEDIATRIC DENTISTRY AND ORTHODONTICS

Course Name MASTERS OF DENTAL SURGERY IN PAEDIATRIC DENTISTRY

Title of the work

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