A CROSS-SECTIONAL SURVEY TO DETERMINE THE AGE OF EMERGENCE OF PERMANENT TEETH OF CAUCASIAN CHILDREN OF THE COLCHESTER AREA OF THE UK

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Title

A Cross-Sectional Survey To Determine The Age Of Emergence

Of Permanent Teeth Of Caucasian Children

Of The Colchester Area Of The UK.

Key Words

Emergence, Permanent Teeth, Caucasian, Age Prediction, Forensic Age Assessment

Abstract

There is a general assumption that permanent teeth in children are emerging into the oral cavity earlier than the dates given in published scientific studies conducted many years ago. In the course of this research a rigorous experimental protocol was devised to provide reliable data collection and analysis methods and give contemporary emergence rate estimations with a strong scientific basis. In addition equations are presented to predict the chronological age of children using only the sex of the child and the number of permanent teeth present. Data was collected between April 1998 and July 2001 from 12,395 children between 4 and 15 years of age, in the Colchester area of the UK. The results show that the ages of emergence of the permanent teeth are later than previously assumed. This research also confirms previous research showing that girl's teeth emerge before boy's teeth, that there is no statistical difference in the age of emergence contra-lateral teeth in the same arch and that there is a statistical difference in the age of emergence of ipsi-lateral teeth in opposing arches.

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Chapter 1: Introduction

There is a general assumption based on research that children are growing faster and maturing earlier. The age of menarche, which is frequently used as an indicator of maturation, is generally getting lower at a rate of about four months per decade and between 1850 and 1950 it went from 17 years to 13.5 years *(Charles, 1958)*. Herman-Giddens et al *(1997)* wrote "On average, African-American girls begin puberty between eight and nine years of age and white girls by ten years of age." These changes are probably due to nutritional and socio-economic changes, because where there has not been a change in the diet or life style of a community, the age of menarche has not altered over periods of at least fifty years *(Zacharias and Wurtman, 1969)*.

Dental age correlates closely with chronological age in the developing child *(Davidson and Rodd, 2001)*. Research has shown that chronological age is more closely related to dental age than skeletal, somatic or sexual maturity indicators *(Lewis and Garn, 1960; Demirjian et al, 1985)*. This is probably because teeth develop and emerge in a protected environment and their development proceeds even to the detriment of the development of other systems. Rickets, malnutrition, genetics, human intervention etc. may delay or speed-up the development of teeth, but they do not intrinsically change their development.

Teeth are unique because once they are formed they are not continually being remodelled. However mineralised and un-mineralised soft tissues such as bones and skin are remodelled throughout life. Secondary dentine may be deposited in the pulp of teeth and caries, acid, abrasion, etc. may modify the surface of a tooth but its intrinsic structure remains unaltered. Teeth remain in the mouth until a person dies or the tooth is exfoliated or extracted.

Studies over the last century *(James and Pitts, 1912; Medical Research Council, 1925; Leslie, 1951; Lavelle, 1976)* have shown that children's teeth are emerging earlier. Nadler *(1998)* compared the age, and the teeth, of the children who attended his orthodontic practice during the 1970's with the children who attended in the 1990's. He found from assessing children's teeth that their dental maturation was 1.40 years earlier in the 1990's than in the 1970's.

The research described in this thesis was undertaken to investigate whether, as is assumed within the dental profession, and as has been shown in research investigating both sexual and dental development, a trend towards earlier maturation has continued to the present day in the UK. It is important to know whether reports of earlier development are apocryphal or real so that the timing of dental health care initiatives, dental treatment, orthodontic treatment and forensic age assessment used to predict the chronological age of children in the identification of dead children may be accurate.

Chapter two of this thesis reviews the literature related to the use of teeth in age assessment, methods of data collection, variables which should be considered in dental age assessment analysis and the protocols for standardization of data collection. This literature review contributed to the methodology of this thesis as it showed the importance of a large data set in order to reduce the effect of individual variation and bias. Whilst there will always be value in gathering information from longitudinal studies the difficulties of such data collection increases with the increasing cost of sustaining such studies and the increasing mobility of any given population. As it is still possible to collect data in a cross-sectional manner within the current constraints of budget, population mobility and bureaucracy, this research chose a cross-sectional style of data collection. The literature review also showed that a simple standardized repeatable protocol was essential both for good data collection and for a good comparative data set to be created; and it showed the importance of removing data collected from sources which might be genetically or medically compromised.

Chapter three, Materials and Methods, gives a background to Colchester, its schools; its school dental health care services; the personnel, equipment and protocols used to collect the data; data recording methods; electronic storage of the data and the statistical methods used to analyse the data.

The results of this research are given in chapter four which shows the distribution by six-month age band of the 11,770 children in the data set; the age range over which each permanent tooth emerged; the median age of the emergence of each permanent tooth of the children of the data set; differences between, boys and girls, the right and left sides of the mouth and upper and lower teeth. This chapter also offers methods to predict the chronological age of a Caucasian child by its sex and the number of permanent teeth in the mouth.

Chapter five discusses the methodology and results of this research. It investigates the sample size of a data set which would be needed to undertake valid comparisons with this research, and compares different methods of calculating median ages from a single data set. This chapter compares the ages of emergence; order of emergence; and the statistics related to the right and left sides of the mouth and the upper and lower jaws with other research; and discusses the uses of the predictive models offered.

Chapter six considers the conclusion of this research that the teeth of Caucasian children of the Colchester area of the UK are emerging later than in previous decades. It considers possible reasons for this finding and it offers recommendations for further research into this phenomenon.

Chapter 2: The Use Of Teeth In Age Assessment

2.1 Introduction

Since the 19th century there has been documentary evidence of teeth being used as indicators of age in Britain. Saunders (*1837*) addressed Members of both Houses of Parliament on teeth as a test of age, with reference to the regulation of factory labour in relation to children. He stated "If the third molar [first permanent molar] have not protruded, you can have no hesitation in affirming that the culprit has not passed his seventh year". And, "It may be relied on, however, as an almost infallible sign of the child's being seven years of age, if the whole [all four first permanent molars] have been evolved from the gum". He then presented a table of the teeth, which may be found in a child's mouth at given ages, so permitting the prediction of the age of any child, between the ages of seven and fourteen, from the number of permanent teeth in their mouth. Saunders recorded that he found, "As a general rule, the development of the teeth in girls was more regular, and a little in advance of that of boys".

In 1897, Sir John Tomes (*1897*) published a table recording the results of Cartwright's *(1857)* examination of 3,074 children and the number of teeth found in each of twelve categories of teeth, the upper and lower, incisors, canines, anterior bicuspids, posterior bicuspids, anterior molars and posterior molars, between the fifth and sixteenth birthdays. (All the incisors were grouped together and no mention is made of third permanent molars.) This information was used to illustrate the effects of various medical conditions, such as rickets and malnutrition, on the eruption of teeth.

Age assessment using teeth was obviously an issue of the day because Tomes refers to pigs at a Royal Agricultural Society show which were disqualified on the grounds that their teeth showed them to be older than the age they were entered. However the owner brought conclusive proof that they were not, but had been highly fed and cared for, and that this had had the effect of speeding up the development of the teeth.

Britain, according to James and Pitts (*1912*), was not alone in the late 19th and early 20th centuries in investigating the timing of the arrival of various teeth in the mouth. Similar types of investigation were also being undertaken in the USA (*Bean, 1914*), the Philippines (*Bean, 1914*), France (*Legros and Magitot, 1880*; *Cherot, 1898*) and Scandinavia (*Forberg, 1901*).

The first major British report investigating the incidence of dental disease in children from England and Wales included an investigation into the average age and period of eruption of each morphological variety of permanent tooth, excluding third molars *(Medical Research Council, 1925)*. During the dental examination the teeth were inspected for signs of caries (decay), hypoplasia (malformation), gingival inflammation (disease) and mal-occlusion (mal-positioning).

It was realised, at that time, that hypoplasia, the defective formation of teeth, often seen as a definite narrow band of ill-formed enamel running horizontally around teeth, indicated contemporaneous sites of tooth development. As the bands of hypoplasia were not in the same position on the crowns of teeth it was concluded that all teeth were not formed simultaneously. The information was not used to predict or confirm age but to investigate of the rate, and degree of severity, of dental decay.

In the USA, Logan and Kronfeld (*Logan and Kronfeld, 1933; Kronfeld, 1935*) reported on the development of human jaws and their surrounding structures following the sectioning of 30 cadavers between the ages of birth and fifteen years. This work was used to develop methods for the repair of cleft palates in a manner that did not damage the surrounding structures. Logan and Kronfelds' (*1933)* list describing the development and calcification of teeth have been widely used, since the mid 1930's, in age assessments and age predictions even though their data was based on a small sample of children who died early, and may therefore not have had a classical or healthy pattern of development before death.

In 1941 Schour and Massler (*1941*), also from the USA, wrote a review of the development and chronology of the human dentition with a view to facilitating everyday dental practice. (No research data was included in the review.) The review included a chart which showed the progressive development of the deciduous and permanent teeth, crowns and roots, from five months intra-utero to thirty-five years of age. This chart, periodically updated, is still used by some practitioners today even though its origins appear to be more anecdotal than factual.

During and after the Second World War there was a period of intense medical and dental data collection and analysis relating to the development of children. This meant that the development and the formation of teeth were closely studied both in isolation, and in relation to the overall development of the child.

In Britain surveys were carried out at the National Children's Home, Frodsham from September 1942 to September 1946 and this led to a paper by Stones et al (*1951*) on the times of shedding of deciduous teeth and eruption of permanent teeth. An anthropometric study *(cited in Clements et al, 1953 a,b)* was undertaken of Birmingham school children, Clements et al (*1953 a, b*) analysed the dental observations and published papers on the time and order of eruption of permanent teeth of English children.

In New Zealand, Leslie (*1951*), undertook a biometrical study of the eruption of the permanent dentition of New Zealand children, excluding the native Maori, to investigate the effect of the environment of that particular country on the dental age of its children. It was found that the New Zealand children "Exhibited an advanced dental development (as measured by the eruption pattern in the anterior segments of the jaws)". He therefore advised that "The common practice of applying, to the case of New Zealand children, information concerning the dental development of English children should no longer be considered logical and may prove quite misleading". It is interesting to note that he also listed data showing that New Zealand children were, at that time, of greater stature and weight than contemporary British children.

In the USA, the Forsyth Dental Infirmary for Children, Harvard, Boston, Massachusetts, and the medical establishments associated with it, undertook much long-term research into the development of children, including their teeth. Over a period of about fifteen years, authors like Hurme (*1948, 1949, 1957*), Gleiser (*Gleiser and Hunt, 1955*), Hunt (*Hunt and Gleiser, 1955*), Demisch and Wartmann (*1956*), Barton (*Barton and Hunt, 1962*), Gron (*1962*), Fanning (*1961, 1962*) and Moorrees (*Moorrees et al, 1963*) all wrote copiously on various aspects of dental development.

The 1960's saw an expansion in the worldwide collection and analysis of dental data relating to children. Work continued in Great Britain, at Wolverhampton (*Butler, 1962*) and Manchester (*Miller et al, 1965*) where both teams found that children's teeth were emerging earlier than they had in 1925 *(Medical Research Council, 1925).* In the USA, at the Forsyth Dental Infirmary for Children and in Ohio, Garn (*Garn et al, 1965*), Israel (*Israel et al, 1967*), Knott and Meredith (*1966*) investigated the effect of endocrinopathies on the time of emergence of teeth. They found that the development of the teeth was delayed or advanced in the same direction as the skeleton, but that the teeth developed less extreme patterns of development than the skeleton. They also investigated and compared the sequence of emergence of teeth in the upper and lower jaws and found that generally lower teeth emerged before upper teeth. Work was undertaken in Hungary (*Adler, 1963*), which found that the sequence of tooth emergence was influenced by the premature extraction of deciduous teeth, the opposite conclusion to that of Butler (*1962*). In New South Wales, Australia (*Gates 1964*) found that lower teeth emerged before upper teeth, except for premolars where the order was reversed, and that girl's teeth emerge before boy's teeth. In Ghana, Houpt et al, *(1967)* found that the teeth of the indigenous children emerged a year before their North American Caucasian contemporaries and in the Gambia the research of McGregor et al, *(1968)* showed that taller, heavier children had more teeth than shorter, lighter children of the same age.

The scope of investigations into the timing of formation and eruption of teeth broadened to encompass the effect of the oral and sociological environments (the socio-economic status started to be recorded regularly at this time) on the eruption / emergence of teeth (*Fanning, 1962; Butler, 1962*). The possible effects of physical build (*Barton and Hunt, 1962*), as estimated by somatotype, was found to be an unreliable indicator of tooth emergence in adolescence; and skeletal formation and chronological age (*Gron, 1962*) were found to be less closely associated with the emergence of teeth than the stages of root formation. Some researchers investigated the effect of racial background, and grouping, on the order and timing of the emergence of teeth, for example Israel et al *(1967)* investigated the Quechua Indians from Central Ecuador and the Pima Indians from Arizona and found that they closely resembled each other in the specific pattern of lower precedence of emergence over upper teeth. This research permitted comparisons to be made between children from different countries and the same racial background, between children of the same country and different racial backgrounds and between children with different countries and different racial backgrounds.

During the 1970's and 1980's data collection continued and new systems of dental age assessments were generated, the best known of which was that of Demirjian et al (*1973*) which estimated dental age, radiographically, by reference to seven teeth on the left side of the mandible. Others, including Gleiser and Hunt (*1955*), Nolla (*1960*), Moorrees et al

(1963), presented radiographic dental age assessment systems. Demirjian's system is the system routinely used today.

Many localized studies have been undertaken to find dates and orders of emergence for either the whole permanent dentition or groups of teeth within the permanent dentition. These ranged from aboriginal groups like Canadian Eskimos (*Mayhall et al, 1978*) and Northern Ontario Indians (*Titley, 1984*), to comparisons of different racial groups in a single country (American Negroes and Caucasians, *Garn et al, 1972*); (Kenyan Africans and Asians, *Hassanali and Odhiambo, 1982*) and different communities within a single country like Britain (*Lavelle, 1976*) and New Guinea (*Malcolm and Bue, 1970*). Refugee groups were studied in their rehabilitation centres, for example Tibetan refugees were studied in India (*Nayak and Patel, 1977*), and work continued on the African continent in Gambia (*Billewicz and McGregor, 1975*) and Nigeria (*Ajmani and Jain, 1984*).

Since 1990 there has been a continuation in the collection and recording of dental data from children, which is beginning to allow comparison of dates of tooth formation and emergence for children in different communities throughout the world. Blankenstein et al (*1990 a, b*) found that the onset of eruption in South African Black children was later than most African studies but similar to Kenyan African and North American Black children. They also found that the teeth of South African Indian children erupted three and one half, to seven months later than their Black South African peers; Davidson and Rodd *(2001)* found that Somali children in the UK were significantly more dentally advanced than their Caucasian peers.

When the age of tooth emergence of communities of different children have been compared with Demirjian's standards *(Demirjian et al, 1973)* some have found to be comparable *(Farah et al, 1999)* and others have not *(Liversidge et al, 1999)*. Other studies have found that within a single piece of research the times of emergence for individual teeth do not follow the same general pattern as the whole jaw. Both Eskeli et al (*1999*) and Rajic et al (*2002*) found that some teeth emerged earlier and some later than in previous studies so that an overall pattern of earlier or later emergence of teeth could not be established.

Over the last 150 years there has been a change from investigating dental reports in isolation to using the data in comparative and cumulative fashions. This means that the data relating to emergence and formation of teeth is used with other physiological / biological maturation indicators to investigate and / or predict development and age. Teeth and bones may be used together to shed more light on the age of a child or skeleton (*Hunt and Gleiser, 1955*). Some papers compare different age assessment systems (*Sierra, 1987; Lewis, 1991*) and others investigate whether standards generated by a single system are currently accurate for a given population e.g. Demirjian's system has been assessed for Hong Kong, Chinese children (*Davis and Hagg, 1994*), London Bangladeshi and Caucasian children (*Liversidge et al, 1999*) and Sheffield Somali and Caucasian children (*Davidson and Rodd, 2001*).

Since the 1950's the medico-legal or forensic implications of using dental data have been given greater prominence. In 1955, Hunt and Gleiser investigated the use of skeletons and their teeth to determine the sex and age of a dead child. In December 1956 a symposium was held in New York entitled "The human dentition in forensic medicine". Hurme (*1957*) presented a paper on the time and sequence of tooth eruption as an indicator of age. More recently the forensic value of using age assessment in relationship to forensic topics, e.g. in relation to the casualties of the Desert Storm Campaign (*Morse et al, 1994*) and in mass disasters such as aircraft crashes have been published *(Clark, 1986).* Forensic age estimation has been the motivation for investigating the dental maturity of the children of Western Australia (*Farah et al, 1999*), in 18^{th} and 19^{th} century London (*Liversidge, 1999*) and the current research.

2.2 Some Definitions Used In Dental Methods of Age Assessment Analysis

Three main terms have been used in dental age assessment and analysis, 'eruption', 'emergence' and 'dental age'. In the earliest studies concerning the presence of teeth in the mouth, the terms eruption and emergence were used interchangeably, with a preponderance of the use of the term 'eruption'. More recently the term dental age has been used in association with tooth formation studies and age assessment systems.

Today the term 'eruption' means all movements of the tooth from its inception to its final position at its extraction or at the death of an individual. This includes the movement of the tooth germ intra-osseously, sub-gingivally, in the mouth from its first presence until it reaches the occlusal plane, and its movement within the occlusal plane during life. The term 'emergence' relates to the time that the tooth pierces the gingivae (gums), when it is first present in the mouth. It does not relate to all the other movements of the tooth. 'Dental age' is an age calculated by investigation or measurement. It is a maturation indicator, which may be used in comparison with other physiological age maturation indicators e.g. skeletal age and secondary sex character age. It may be used to indicate chronological age or may be used in comparison with it.

Table 2.1 shows the term eruption has historically been the most frequently used term relating to the presence of teeth in the mouth. It also shows that historically standardization of the terms used in relation to the presence or absence of teeth in the mouth has not been agreed or universally applied. In some instances the terms have not been defined at all. Leslie *(1951)* defined a tooth as having erupted "when the tooth had pierced the gum" and as late as 1990 Blankenstein (Blankenstein et al, 1990 a) defined eruption as "when any part of the tooth was visible". Despite this Demirjian (*Demirjian et al, 1973*) more than fifteen years earlier than Blankenstein, had stated, "Emergence which is erroneously called eruption, represents only one stage in the continuous process of dental eruption, or migration to reach the occlusal level". It is perhaps since his work has been published, that the definitions of eruption and emergence have been more clearly defined, though even now they still have not been universally applied. *(Eskeli et al, 1999; Rajic et al, 2002)*

As the presence or absence of the teeth in the mouth is not usually relevant to purely radiographic studies of the development and chronology of teeth, the terms eruption and emergence are not considered, though the term alveolar emergence may be used when a tooth appears above the alveolar crest of bone. It is not always possible to distinguish if the tooth is present in the mouth from a radiograph. In radiographic studies the term dental age is frequently used, though as can be seen from Table 2.1, this term is rarely defined.

Table 2.1 The Terms Used to Investigate Age in the Reviewed Papers

Author	*Year of Publication*	*Terms Used in Paper*	*Definitions*
Tomes J / Cartwright S	1897	eruption	Not defined
Ainsworth (MRC)	1925	eruption	Eruption classification, Group 1 : teeth not showing, Group 2 : teeth commencing to erupt, I.e. with tip of cusp visible, Group 3 : teeth less than completely erupted, Group 4 : teeth fully erupted and / or in occlusion
Logan WHG and Kronfeld R	1935	eruption	Not defined
Schour I, Massler M	1941	eruption	Not defined
Hurme VO	1948	eruption, emergence	A bibliographical study, gives other's definitions but not his own
Stones HH, et al	1951	eruption	Not defined
Leslie GH	1951	eruption	A tooth was considered erupted when any portion of the crown had pierced the muco-periosteu
Clements et al	1953 a + b	erupted	The tooth having pierced the gum

Author	Year of Publication	Terms Used in Paper	Definitions
Gleiser I, Hunt EE	1955	eruption, alveolar emergence, clinical emergence	Not defined though clinical emergence is referred to as, "a fleeting event whose exact time of occurrence is often impossible to determine."
Hunt EE, Gleiser I	1955	eruption, emergence	Not defined
Demisch A, Wartman P	1956	emergence, eruption	Not defined
Hurme VO	1957	eruption, emergence	Not defined
Hays RL et al	1958	erupted	If any portion of the crown had penetrated the oral mucosa
Butler DJ	1960	erupted	The presence of any part of the crown through the mucosa
Nanda RS	1960	erupted	When any part of its crown was visible in the oral cavity
Gron A-M	1962	emergence	A term used for a tooth that had just pierced the gingiva but was not more than 3mm above the gingival level, estimated from the tip of the cusp or from the incisal margin
Carr LM	1962	eruption	A tooth was regarded as having erupted if any portion of its crown was visible

Author	*Year of Publication*	*Terms Used in Paper*	*Definitions*
Fanning EA	1962	eruption, clinical emergence	Not defined
Adler P	1963	eruption	Not defined
Moorrees CFA et al	1963	emergence, eruption	Emergence is only a specific phase of short duration in the continuous process of eruption
Gates RE	1964	eruption	When any portion of the crown projected through the gums
Miller J et al	1965	erupted	When any part of the crown was visible
Knott VB et al	1966	eruption	The point at which the alveolar mucosa is pierced and exposure of the crown of a tooth approximately 1mm in diameter
Houpt MI et al	1967	eruption	Not defined
McGregor IA et al	1968	presence of teeth	A tooth was present if any part of it had broken through the gum

Author	*Year of Publication*	*Terms Used in Paper*	*Definitions*
Malcolm LA, Bue B	1970	eruption	A tooth was considered to be erupted if any portion of its crown was visible through the gum
Garn SM et al	1972	emergence	Age at piercing the gingiva
Demirjian A et al	1973	gingival emergence, eruption, dental age	Gingival emergence, which is erroneously called eruption, represents only one stage in the continuous process of dental eruption, or migration to reach the occlusal level. Dental age based on developmental stages achieved and given a score
Shumaker DB	1974	eruption, emergence	A tooth was considered erupted when it reached the plane of occlusion, emergence was not defined
Billewicz WZ and McGregor IA	1975	eruption, emergence	Any tooth which had at least partly emerged through the gum was counted as present
Lavelle CLB	1976	emergence, gingival eruption,	If any part of the tooth had pierced the oral mucosa , the tooth was considered present
Nayak SK, Patel S	1977	eruption	A tooth was considered to have erupted only when a portion of the tooth, however small, had penetrated the gingiva
Mayhall JT et al	1978	emergence, eruption	Emergence refers to the moment that any portion of the tooth crown pierces the gingiva and is visible in the oral cavity. Eruption refers to the movement of a tooth towards its final occlusal position.
Demirjian A, Levesque G-L	1980	emergence	Emergence is a very short period, determined by the time of appearance of a tooth in the mouth

Author	*Year of Publication*	*Terms Used in Paper*	*Definitions*
Hassanali J, Odhiambo JW	1982	eruption	A tooth was considered as having erupted if the crown was visible through the gingivae
Titley KC	1984	emergence	The moment when any part of the tooth crown pierces the gingiva
Ajmani ML, Jain SP	1984	eruption	Not defined
Demirjian A	1986	clinical emergence, alveolar emergence, dental age	(Clinical) emergence is the piercing of the gum, alveolar emergence is the piercing of the alveloar bone, eruption is the dynamic movement of the tooth, both before and after emergence, dental age based on radiographic developmental and maturity scores
Sierra AM	1987	dental age	Not defined
Nonaka K, Miura T	1990	gingival emergence, gingival eruption	Not defined
Kumar CL, Sridhar MS	1990	eruption	If any part of a tooth had pierced the gum (gingival eruption)
Blanenstein R et al	1990 a+b	eruption	If any part of the tooth was visible.
Lewis AB	1991	dental age	Dental age assessed with Bolton Standards of Dental Developmental Growth

Author	*Year of Publication*	*Terms Used in Paper*	*Definitions*
Smith BH	1991	eruption, emergence	Emergence marks the first appearance of the tooth through the gingiva
Elmes AJ, Dykes E	1997	emerged	If any part of the tooth had pierced the gingiva
Gillett RM	1997	emergence	The emergence of a tooth through the gums; 0=no tooth present, 1=crown of the tooth emerging through the gum, 2=crown of the emerging tooth less than half way, 3=crown of the tooth more than half way but not in occlusion,4=fully emerged and in occlusion
Nadler GL	1998	emergence, eruption	Gingival emergence of the teeth represents only one stage in the process of dental eruption to reach the occlusal table
Kochhar R, Richardson A	1998	eruption, gingival emergence	Not defined
Maki K et al	1999	dental age	Not defined, but assigned according to Kullman's method
Liversidge HM, Molleson TI	1999	dental age	Not defined
Eskeli R et al	1999	emergence, eruption	Grades of eruption, Grade 0 = tooth not visible in the mouth, Grade 1(clinical eruption) = at least one cusp visible, Grade 2 = entire occlusal surface / mesiodistal width of tooth visible, Grade 3 = tooth in occlusion or at the occlusal level

Author	*Year of Publication*	*Terms Used in Paper*	*Definitions*
Rajic Z et al	2000	eruption	Initial eruption was determined by the time at which 50% of the children had a particular tooth in the oral cavity
Davidson LE, Rodd HD	2001	dental age	Not defined

During the collection of the data for the different surveys there was no standardization of decision as to whether permanent teeth, which had been extracted, should be recorded as present or absent. Leslie (*1951*) included the data relating to extracted teeth and recorded the teeth as having been present. Clements et al *(1953 a, b)* called all unerupted and extracted teeth absent, and they were recorded as 'not present.' Nanda (*1960*) did not use any records from the children who had had any teeth extracted. Miller et al (*1965*) made no special note of teeth, which might have been congenitally absent. Thus all four of these papers have used different criteria in order to classify their data. It is therefore very important to determine which terms are being used and what is being defined so that results may be accurately assessed and compared.

2.3 Data Collection For Age Assessment Analysis

2.3.1 Introduction

The two main methods used for data collection for age assessment analysis are visual and radiographic. Histological and chemical methods may also be used. Caution must be applied when data are compared, since different collection and analysis criteria may mean that comparisons may be invalid.

2.3.2 Visual Collection Methods

Visual collection methods usually depend on an examination of a child's mouth, though they may be based on the examination of dental casts (*Nanda, 1960*). The dental examination may occur in a hospital (*Moorrees et al, 1963*), through the remit of a school dental inspection (*Butler, 1962*; *Elmes and Dykes, 1997*), at a university dental school (*Miller et al, 1965*) or in the community (*Nonaka et al, 1990*).

The most basic visual dental examinations occur in good daylight (*Billewicz and McGregor, 1975*). Standards of visibility improve through good natural light (*Blankenstein et al, 1990 a and b*), to angle poise lamps (*Miller et al, 1965*) and specialist dental lights (*Elmes and Dykes, 1997*). Dental mirrors are normally used (*Kumar and Sriddhar, 1990*), but may be supplemented with dental probes (*Elmes and Dykes, 1997*).

Visual collection methods have mostly been employed in cross-sectional surveys and less frequently have been used in longitudinal studies (*Stones et al, 1951; Fanning, 1961; Vanobbergen et al, 2000*). Normally a 'present' or 'absent' recording is made, and sometimes total numbers of teeth are recorded. Two exceptions to this were the Medical Research Council (*1925*) report where Ainsworth, the sole examiner, recorded four stages of the visibility of the crown of a tooth

(1 = not showing, 2 = just commencing to erupt, 3 = less than completely erupted and 4 = fully erupted and/or in occlusion) and Gron (1962) who limited emergence to the first 3mm of a cusp or incisal margin of a tooth being present in the mouth.

2.3.3 Radiological Collection Methods

Radiographic methods employed to collect data about children's teeth depended largely on the equipment available at the time, the equipment employed by a particular institution and the evolution of technology. Initially this was limited to producing radiographic plates perpendicular to the object being X-rayed. This might have been a serial section of a cadaver (*Logan and Kronfeld, 1933; Kronfeld, 1935*), the lateral side of the jaw (*Gleiser and Hunt, 1955)* or the lateral side of the skull (*Fanning, 1961*). By 1963 lateral oblique radiographs were used to record lower and upper upper teeth (*Moorrees et al, 1963*) and, by 1973 Demirjian et al (*1973*) were using orthopantomographs. Rotational tomography is routinely used today. Radiographs of individual or small groups of teeth were originally taken using short-cone techniques (*Fanning, 1961*), but are now normally taken using a long cone technique to reduce distortion and subject a smaller region of the body to the radiographic dose (*Morse et al, 1994*).

Radiographic studies have been used to acquire both cross-sectional *(Demirjian et al, 1973*) and longitudinal data, for example, Gleiser and Hunt (*1955*) used a series of over twenty-five radiographs to study their subjects from birth till ten years of age.

2.3.4 Histological and Chemical Collection Methods

Histological slides of children's teeth have not frequently been used during forensic age assessments, though Logan and Kronfeld (*Logan and Kronfeld, 1933; Kronfeld, 1935*) decalcified serial sections of the jaws of cadavers and stained the remaining soft tissues with Haematoxylin and Eosin stain, in order to examine and record the development of teeth in relation to the other structures of the jaws. Their work showed that calcification of teeth (seen as a void in the slides) began before mineralisation was visible on radiographs.

Histological slides of teeth are used more frequently in the assessment the age of adult's teeth. Gustafson (*1950*) pioneered a system for age assessment of adults using the attrition, periodontosis, secondary dentine development, cementum apposition, root resorption and root transparency. Various authors have modified and refined his scheme, but it remains the standard histological method for age assessment.

Chemical collection methods, for age assessments, mainly depend on the measurement of D-aspartic acid in dental collagen (*Gillard et al, 1990*). D-aspartic acid accumulates over time during life in metabolically stable proteins, including those found in dental enamel and dentine. A measurement of its level gives a method for determining age at death. A sample of tooth is demineralised and is then dissolved in acetic acid, before being applied to an anion-exchange column. The eluate collected contains both D-aspartic acid and L- aspartic acid, which are separated chromatographically and the percentages of each, in a given sample, can then be found. The age at death, or when the tooth was extracted, can then be read off a graph listing the percentage of D-Aspartic Acid against age in years. The cost of the equipment required to undertake these age assessments usually mean that they are limited to hospital or university laboratories.

2.3.5 Summary of Collection Methods

The choice of data collection method for chronologies of tooth formation and age assessments has been largely pragmatic. Visual collection methods have been predominantly used in cross-sectional data collection investigations which are not dependent on radiographs for analysis, and longitudinal investigations using dental study models of children's teeth. Radiographs have been used in longitudinal studies and cross-sectional studies requiring radiographs for the analysis leading to age determination and chronology production. Histological and chemical data collection methods have not been routinely used because they demand so much finance, time and equipment. Their use is generally limited to universities and hospitals. At this time a "best method" of data collection for use with all chronologies of tooth formation and age assessment systems has not been agreed.

2.4 Sample Sizes and Data Collection Strategies Which May Be Used In Dental Age Assessment Analysis

Table 2.2 summarises the data collection strategies - cross-sectional, longitudinal or bibliographic – and sample sizes that have been used in studies of dental age assessments.

Table 2.2 Styles and Sample Sizes Used to Study Dental Age

Author	*Publication Date*	*Style C-S, Longitudinal, Bibliographic*	*Child Sample Size*	*Radiographic Sample Size*	*Ages Studied*
Tomes J / Cartwright S	1897	C-S	3074	0	Not given
Ainsworth (MRC)	1925	C-S	4000	0	Not given
Logan WHG and Kronfeld R	1935	C-S	30+	0	Birth - 15
Schour I, Massler M	1941	Summary	0	0	Pre-natal - 21
Hurme VO	1948	Bibliographic	93,000	0	5 -14
Stones HH, et al	1951	Longitudinal	329	0	2 - 14
Leslie GH	1951	C-S	2,762	0	5 -13
Clements et al	1953 a	C-S	2,792	0	5 -13
Clements et al	1953 b	C-S	3,489	0	5-14
Gleiser I, Hunt EE	1955	Longitudinal	50	24 each, ie 1200	Birth - 10
Hunt EE, Gleiser I	1955	C-S	93	93	2 - 8
Demisch A, Wartman P	1956	C-S	151	302	8 -16

Author	*Publication Date*	*Style C-S, Longitudinal, Bibliographic*	*Child Sample Size*	*Radiographic Sample Size*	*Ages Studied*
Hurme VO	1957	Bibliographic	100,000	0	4 - 16
Nanda RS	1960	Longitudinal	2,500 approximately	Not given	Birth - 15
Butler DJ	1960	C-S	1,943	0	5 - 12
Fanning EA	1961	Longitudinal	99	Not given, possibly 7,000	Birth - 11.5
Barton WH, Hunt HH	1962	C-S	71	0	11 1/2 - 18
Fanning EA	1962	Longitudinal	8	Not given, possibly 176	4 - 10.5
Carr LM	1962	C-S and Longitudinal	(C-S)3,952 (Long)3,463 Teeth	0	5 -13yrs 11 mnths
Gron A-M	1962	C-S	874	2,622	Not given
Moorrees CFA et al	1963	Longitudinal	480	Not given	Birth - 25
Adler P	1963	C-S	30,250	0	6 - 13yrs 11mnths
Gates RE	1964	C-S	5,660	0	6 - 15
Garn SM	1965	Longitudinal	63	Not given, at least 126	Birth - 17
Miller J et al	1965	C-S and Longitudinal	(C-S)694, (Long)2,000	0	3 - 15

Author	*Publication Date*	*Style C-S, Longitudinal, Bibliographic*	*Child Sample Size*	*Radiographic Sample Size*	*Ages Studied*
Knott VB et al	1966	Longitudinal	50	Not given	Not given
Houpt MI et al	1967	C-S	715	0	4 -18
McGregor IA et al	1968	C-S	3051	0	2 - 37 mnths
Malcolm LA, Bue B	1970	C-S	Not given	0	4 - 20
Sanin C, Savara BS	1971	C-S	101	0	Not given
Garn SM et al	1972	C-S	1951	0	Not given
Demirjian A et al	1973	C-S	2928	2928	2 - 20
Shumaker DB	1974	Longitudinal	23	Multiples of 23 - not given	Not given
Billewicz WZ and McGregor IA	1975	C-S	3971	0	4.5 - 14
Lavelle CLB	1976	C-S	4000	0	5 - 14
Nayak SK, Patel S	1977	C-S	369	0	5 - 23
Mayhall JT et al	1978	C-S	368	0	Birth - 22
Demirjian A, Levesque G-L	1980	C-S	0	5,437	2.5 - 19

Author	*Publication Date*	*Style C-S, Longitudinal, Bibliographic*	*Child Sample Size*	*Radiographic Sample Size*	*Ages Studied*
Hassanali J, Odhiambo JW	1982	C-S	2847	0	4 - 14
Ajmani ML, Jain SP	1984	C-S	1668	0	6 -23
Titley KC	1984	C-S	1191	0	5.5 - 17.4
Sierra AM	1987	C-S	153	306	8 - 12
Kumar CL, Sridhar MS	1990	C-S	1008	0	5 - 14
Nokaka K, Miura T	1990	C-S	817	0	5 - 6
Blanenstein R et al	1990 a	C-S	1024	0	3.87 - 9.63
Blanenstein R et al	1990 b	C-S	1036	0	3.83 - 9.92
Smith BH	1991	Bibliographic	0	0	
Lewis AB	1991	C-S	694	990	4 - 16
Davis PJ, Hagg U	1994	C-S	0	204	5 - 7
Elmes AJ, Dykes E	1997	C-S	505	0	4.49 - 8.75
Gillett RM	1997	C-S	721	0	5.5 -14
Nadler GL	1998	C-S	300	300	8.5 -14.5

Author	*Publication Date*	*Style C-S, Longitudinal, Bibliographic*	*Child Sample Size*	*Radiographic Sample Size*	*Ages Studied*
Simpson SW, Kunos CA	1998	C-S and Longitudinal	303	500 approx	3 mnths - 18
Kochhar R, Richardson A	1998	Longitudinal	276	0	5 - 15
Maki K et al	1999	C-S	650	650	5 - 12
Liversidge HM et al a	1999	C-S	521	521	4 - 9
Liversidge HM et al b	1999	C-S	76	100	Birth - 19
Farah CS et al	1999	C-S	1450	1450	4 - 16
Eskeli R et al	1999	C-S	1577	0	5 -16
LiversidgeHM	2000	C-S	106	106	Birth - 5.40
Rajic Z et al	2000	C-S	2768	0	5 - 16
Davidson LE, Rodd HD	2001	C-S	162	106	Birth - 15

Table 2.2 shows that the majority (73% – 77%) of the studies have been of a cross-sectional nature. This is because it is much easier to gather data in a 'one-shot' manner rather than in a regular pattern, over many years. The costs in time, money, storage of data and stamina of

the examiners and commitment of the volunteers are much less when one-off examinations are undertaken, as opposed to examinations over a significant period of time.

Of the sixty-two papers listed in Table 2.2, forty-five were cross-sectional studies, ten were longitudinal, three were both cross-sectional and longitudinal, three were bibliographic and one was a summary of other papers. The cross-sectional examinations were evenly spread over the period 1897 to 2001, but most of the longitudinal examinations were undertaken and published before 1967, within fifteen years of the Second World War. Large bibliographic studies were undertaken by Hurme (*1948*) and Smith (*1991*); Hurme *(1948)* undertook a synthesis of papers, published between 1857 and 1942; and Smith (*1991*) investigated the styles of data collection and analysis, rather than individual results.

All but one of the cross-sectional studies were of 6,000 or fewer children. Many of the cross-sectional studies looked at fewer than 3,000 children. Only Adler (*1963*), in Hungary, studied more children, his study included 30,250 children. The longitudinal studies, by their very nature, looked at smaller numbers of children, mostly under five hundred children, although Nanda (*1960*) looked at about 2,500 children being followed through the Child Research Programme of the Colorado School of Medicine, Denver, Colorado. The studies of Carr (*1962*), Miller et al (*1965*) and Simpson and Kunos (*1998*) looked at both cross-sectional and longitudinal data within the same research project.

Twenty-four of the studies listed in Table 2.2 involved the use of radiographs, and of these thirteen were longitudinal and eleven were cross-sectional studies. A much greater proportion of longitudinal studies included radiographs than was the case with cross-sectional investigations. This was undoubtedly because radiographs provide a stable, long-term record of a particular stage in a child's development. The other records taken at the time of the radiograph give the age of a child, so that analyses could be undertaken which allowed development and formation landmarks and timings to be generated. The numbers of radiographs studied ranged between 93 *(Hunt and Gleiser, 1955)* and about 7,000 *(Fanning, 1961)*.

The ages of the children being investigated were not always given. All of the studies, except Schour and Massler (*1941*) start at or after birth, many start at five, some cover a short, specific period e.g. five to six (*Nonaka et al, 1990*) because they investigated a specific event that occurs during this time period, and none continued beyond the age of 25.

2.5 Variables Which Should be Considered In Dental Age Assessment Analysis

2.5.1 Introduction

Over the past two centuries several biological criteria have been investigated to find their effects on the timing of dental age. These include the sex of the child, nutritional status, extraction of deciduous predecessors, the side of the mouth (right or left) that a tooth emerges into, the medical status, hormones and season of birth.

2.5.2 Sex of the child

Almost all papers investigating dental age assessments, comparisons and predictions have investigated the data relating to boys and girls separately. This was not done where there were very small samples e.g. in Liversidge's (*1999; 2000)* work related to 18th and 19th century cadavers from Christ Church, Spitalfields. Schour and Massler (*1941*) did not separate girls and boys in their charts.

Without exception, in the published literature, when boys and girls teeth were analysed separately, girls' teeth were found to develop earlier than their male counterparts as was originally reported by Saunders in 1837.

2.5.3 Nutritional Status

Tomes *(1897)* commented on the delay in teething caused by rickets (vitamin D deficiency) and the continued delay caused by malnutrition. Malcolm and Bue (*1970*) looked at the eruption times of New Guinean children and found that where their diet was better, i.e. in Lae Town, their teeth emerged earlier.

2.5.4 Extraction of Deciduous Predecessors

Stones et al (*1951*) comment that the time of eruption of a permanent tooth depends to a certain extent on the time when its deciduous predecessor was lost. They did not give any reasons for this comment in their paper and the evidence would appear to be purely anecdotal.

Leslie (*1951*) investigated the effect of premature loss, through extraction, of the deciduous teeth upon the age of eruption of the permanent successors and found that the premature loss of deciduous molars was not associated with a common degree of replacement by permanent successors, but varied considerably with the degree of prematurity of the extraction. He found that the greater the time between the extraction of the deciduous tooth and the normally anticipated time of emergence of the permanent successor, the greater the possibility of delayed eruption.

Butler (*1962*) investigated the eruption of teeth and the association between early loss of deciduous teeth and the eruption of their permanent successors. She found that the early loss of deciduous teeth did not have a significant effect on the eruption of permanent teeth.

Fanning (*1962*) investigated the effect of extracting deciduous molars on the formation and eruption of their successors, the permanent premolars. She found that there was no change in the rate of root formation of the premolars after the extractions, but an immediate eruptive spurt occurred. Premolar eruption was accelerated in the presence of long-standing necrosis, especially if there was an associated loss of surrounding bone. A similarly early clinical emergence occurred if the extraction coincided with the final growth spurt of the root.

Mayhall et al (*1978*) did not find that the premature extraction of deciduous teeth advanced their successors, in Canadian Eskimos.

This research indicates that the timing of the loss of deciduous teeth does not have a direct cause and effect influence on the time of emergence of permanent teeth, but that the time of emergence of permanent teeth is under multi-factorial control and influence.

2.5.5 The Side of the Mouth (Right or Left) Into Which a Tooth Emerges

In all the studies which compared the emergence of contra-lateral pairs of teeth, for example, the upper right and left first premolars, there has been general agreement that there is no significant difference in the time and order of emergence of each of the paired teeth.

2.5.6 Medical Status

The medical status of those examined may also influence the data collected. Tomes (*1897)* commented on the effect of rickets, delaying the eruption of teeth and Logan and Kronfeld *(Logan and Kronfeld, 1933; Kronfeld, 1935*) gathered their data by dissecting 30 cadavers, though the reasons for the deaths of the children were not given. Whilst it is possible that all the children had all been fit prior to an acute infection which lead to death, it is also possible that they suffered from a debilitating disease which lead to their death, and which could have easily affected their dental development before examination. This would automatically bias any results.

2.5.7 Hormonal Effects

Garn and his co-workers (*Garn et al, 1965*) investigated the role of hormones in modifying or mediating the course of dental development. They investigated various endocrine and non-endocrine developmental retardations and precocities, including extremes of maturation timing, congenital hypothyroids and athyrotics, hypopituitary and panhypopituitary dwarfs, sexual precocities and those suffering from Turner's Syndrome (XO chromosome). They found that in the non-endocrine developmental delays of congenital hypothyroidism and hypopituitarism, the teeth were delayed but less than the postcranial skeleton. In the constitutional and endocrine sexual precocities, dental advancement was noted with skeletal advancement, but the dental advancement was small. In Turner's Syndrome the dental development tended to be ahead of age-matched unaffected children.

2.5.8 Date of Birth

Nonaka et al (*1990*) investigated the changes in the eruption order of the first permanent teeth to emerge into the mouth, the first permanent molars and the central incisors, of Japanese children. Despite the normal pattern (63%) of central incisors preceding first permanent molars, they found that the likelihood of the molars preceding the incisors was significantly increased if the child was born in October or November rather than at other times of the year. They concluded that the causes responsible for the change must have been environmental, acting at the prenatal or perinatal stage of life, rather than genetic or socio-economic.

2.6 Protocols for Standardization of Data Collection

When data are collected over a period of time it is important to have consistent standards of collection in order to have standardized data. For example in radiographic data collections it is normal to examine the radiographs blind and then to re-examine a proportion of them again, a period of time later.

Davidson and Rodds' (2001) paper states that there was only one examiner, Davidson. She examined the radiographs at the beginning of the research period and re-examined 20 of the 162 radiographs four weeks later. There was no significant difference between the initial and the repeat mean estimations of dental age and 96%, 136 out of 140 teeth re-scored were identical.

When more than one examiner is used in a study of radiographs, training for standardization of examination technique is usually given by a single person, in order to formalise the examination procedures and standards to be set by all the examiners. Following the examinations of the radiographs, a proportion of the radiographs are re-examined and the results compared with the original records. In their paper looking at whether Demirjian's standards are applicable to British children, Liversidge et al (*1999*) used more than one examiner. Inter-examiner error was calculated by re-scoring 50 radiographs, some time (period not stated) after the original scorings were made. The difference in dental ages between the two readings was tested for significance using a paired t-test and any disagreements were reassessed for bias by counting the number of over- and under-stage assessments. The percentage agreement on 350 teeth was 87%, 22 were one stage ahead and 25 were one stage behind. This means that all of the assessments which did not agree with the original records, were within one stage of the original record

2.7 Conclusion

This literature review shows that at present there is no standardization of methodology relating to data collection and analysis for the construction of chronologies of tooth formation and emergence, nor is there standardization of methods of generation of tables for age assessment and prediction of age based on children's permanent teeth.

Earlier research had problems with the reliability and reproducibility of data collection methods and protocols, analysis methods and protocols, ambiguity of assessment, particularly of proportions of teeth, and validity of conclusions drawn. It is important to devise experimental protocols which address these problems so that robust chronologies can be produced and true data comparisons can be made. The importance of the choice of the population, the data collection methodology, the numbers of experimental subjects, the data collection protocols and methods, the statistical analysis and validity of conclusions must be rigorously considered to give a protocol for future use in this area of research.

Chapter 3: Materials and Methods

3.1 Introduction

All systems investigating the age of a living child are based on the principle of a large number of 'normal' individuals of known age being examined and their data recorded. Tables are produced which summarise the data, and median or mean ages are presented. When dental age is investigated some methods which may be employed (See section 2.3) are visual, radiographic, histological or chemical. Research data collection strategies may be cross-sectional, longitudinal or bibliographic and a summary of some of the strategies used may be seen in Table 2.2. This table shows that most studies have been of a cross-sectional nature, probably because it is much easier to gather data in a 'one-shot' manner rather than in a regular pattern, over many years. The costs in time, money, storage of data, stamina of the examiners and the commitment of the volunteers are much less when one-off examinations are undertaken, as opposed to examinations over a significant period of time. For these reasons a cross-sectional study was undertaken so as to maximise the chance of comparing results.

The literature review showed the value of having a data set as large as possible and data collection related to children is most conveniently undertaken when they are found in large numbers. Children in the UK are legally obliged to receive education and are therefore found in schools in large numbers. Schools are therefore good venues to collect data relating to children.

A pilot study undertaken in 1996 *(Elmes and Dykes, 1997)* investigating the order of emergence of permanent central incisors and permanent first molars of children in the Colchester area of the U.K. established a good rapport between the Researcher and the Community Dental Services of the Colchester area. This rapport offered the Researcher an opportunity to visit schools in the Colchester area and the opportunity to collect data when the Community Dental Officers visited the schools.

Colchester is a town of 142,515 people *(RG, 1991)* situated about 80 kilometres north-east of London having more in common with urban South-East England than with rural East Anglia. In addition to being a site of historical interest (first Roman capital of England), artistic interest (the doorway to Constable and Gainsborough country) and a thriving town, it is also a dormitory town for London.

The 1991 Census listed the population of Colchester as being 97.7% Caucasian and 2.3% Non-Caucasian. Colchester therefore had a predominantly Caucasian population. Its non-Caucasian population was about half the size of the non-Caucasian population of Ipswich, the nearest large centre of population to Colchester. (The 1991 Census listed the population of Ipswich as being 95.5% Caucasian and 4.5% Non-Caucasian.) As Colchester was predominantly Caucasian, and access to children through the schools was possible, it was chosen as the target area to investigate the age of emergence of the permanent teeth of Caucasian children.

3.2 Community Dental Services in the Essex Rivers Health Authority

The Community Dental Services of the Essex Rivers Health Authority have a legal responsibility to screen the dental health of all the children of the Colchester area (Health Service Guidelines HSG(97)4 Annex B, see Appendix 1). They have to visit all the locally maintained primary schools within the area of the Essex Rivers Health Authority once a year, and also undertake a British Association for the Study of Community Dentistry (BASCD) survey of the dental status of three hundred, twelve and fourteen year old pupils every four years

3.3 Essex Rivers Health Authority and Essex Education Authority

Essex Rivers Health Authority does not coincide with a single administrative area of the Essex Education Authority, as health and education are administered separately in Essex. Essex Rivers Health Authority covers all of the Colchester and Tendring Education Areas and the part of the Halstead section of the Braintree Education Area. (The remainder of the Braintree Education Area is covered by Mid-Essex Health Authority.) The target area included the children of the Essex Rivers Health Authority. This coincided, with one exception – Steeple Bumpstead, with the CO post coded areas. Colchester is the main town of the area and approximately in the middle geographically.

3.4 Primary and Secondary Schools in the Essex Rivers Health Authority Area

Within the Essex Rivers Health Authority Area, and during the 2001 –2002 academic year, most children attended locally maintained schools. There were one hundred and twenty three locally maintained primary schools and seventeen locally maintained secondary schools in the area. Additionally, there were four privately maintained primary schools and two privately maintained secondary schools in the area.

Table 3.1 shows the distribution of children at locally maintained primary and secondary schools in the Essex Rivers Health Authority Area, 2001 – 2002. *(Data from the Data Management Dept. of Essex County Council, Data Management Learning Services, E1 County Hall, PO Box47, Chelmsford. CM2 6WN and www.essexcc.gov.uk. 05/12/01)*

Table 3.1 The Distribution of Children at Locally Maintained Schools in the Essex Rivers Health Authority Area, 2001 – 2002.

Area	Number of Primary School Children	Number of Secondary School Children	Total Number of Children
Colchester	12,839	9,207	22,046
Tendring	10,621	6,580	17,201
Halstead / Braintree	2,791	718	3,509
Whole Area	26,251	16,505	42,756

Table 3.2 shows the distribution of children at privately maintained primary and secondary schools in the Essex Rivers Health Authority Area, 2001 – 2002. (Data collected by the researcher from the school secretaries of each school by telephone, because this data is not published. 05/12/01.)

Table 3.2 The Distribution of Children at Privately Maintained Schools in the Essex Rivers Health Authority Area, 2001 – 2002.

Area	Number of Primary School Children	Number of Secondary School Children	Total Number of Children
Whole Area	906	378	1,284

Table 3.3 shows that within the Essex Rivers Health Authority Area during the 2001 –2002 academic year, the total number of children attending school was 44,040.

Table 3.3 The Distribution of All the Children at Locally and Privately Maintained Schools in the Essex Rivers Health Authority Area, 2001 – 2002.

Area	Total Number of Primary School Children	Total Number of Secondary School Children	Total Number of Children
Whole Area	27,157	16,883	44,040

3.5 Sample Selection - The Community Dental Officer

The Community Dental Officer did not see the total school population of the study area in any given academic year, but a sub-sample of it. Working under Health Service Guidelines HSG(97)4 Annex B *(Appendix1)* and the Essex Rivers Health Authority Area code of ethics *(Appendix 2)*, he had certain criteria by which he chose the schools and children which he visited, and for whom he undertook dental examinations. These were

1. All the locally maintained primary schools were automatically visited so that pupils could have regular dental inspections.
2. The Community Dental Officer contacted the locally maintained secondary schools asking for permission to inspect a proportion of their twelve and fourteen year old pupils, every four years. This was usually given, but not always.
3. The Community Dental Officer had no right of access, or legal remit, regarding the privately maintained schools, and he therefore did not visit them.

Once the Community Dental Officer was granted permission to undertake dental inspections in a school he had a set protocol to decide which pupils had a dental inspection. These were

1. Parents / Guardians of each pupil were written to in advance of a dental inspection and asked to respond only if they did not want their child /children to have a dental inspection *(Copies of letters may be seen in Appendix 2)*. The children of those who responded were exempt from the dental inspections. Following this, the following criteria were used

2. At locally maintained primary schools with fewer than one hundred on the roll, all the children had a dental inspection.
3. At locally maintained primary schools with more than one hundred on the roll and a low rate of dental decay (fewer than 25% of pupils requiring dental treatment at any one visit) all the children, except those in years 2 and 5 had a dental inspection. All pupils have at least three dental inspections during their time at a school (assuming they pass through the whole school). The pupils in years 2 and 5, aged seven and ten years respectively, were excluded because of time constraints and Health Service Guidelines. Years 1 and 6 had a dental examination, as this meant that every child entering or leaving the school had a dental examination. Dental examinations of years 3 and 4 meant that each child had at least one, if not two, further dental examinations during their time at primary school.
4. At locally maintained primary schools with more than one hundred on the roll and a high rate of dental decay (more than 25% of pupils requiring dental treatment at any one visit) all the children had a dental inspection, this related to 25 schools (20.4%) of the schools visited during the data collection period. During the data collection period this Reisine and Psoter *(2001)* state that, "There is strong evidence for an inverse relationship between socio-economic status and the prevalence of caries." This suggests that there may have been an over representation of lower class children and a reduced representation of middle and upper class children in the data set. As the socio-economic status of the children examined was not recorded during this research it was not possible to investigate these effects, this was a limitation of the sampling method and may have lead to bias. In order to address this possible bias and have a

more representative experimental population, data were collected in the present study from the children attending the primary and secondary Privately Maintained Schools of the Essex Rivers Health Authority Area (Table 3.2).

5. At locally maintained secondary schools a sample group of three hundred, twelve year olds and three hundred, fourteen year olds had a dental inspection every four years. This was about thirty to thirty-five pupil from each secondary school. These dental examinations were undertaken as part of an on going BASCD Survey.

3.6 Sample Selection - The Researcher

One of the disadvantages of collecting the data with the Community Dental Officer was that it was not evenly distributed over all the academic year groups. Few children at locally maintained primary schools had a dental examination in academic years 2 and 5, equivalent to children aged seven and ten, and there were particularly low levels of data collection in years 7 and 8, covering the children aged eleven to fourteen.

Once these irregularities were identified, it was confirmed that sufficient data was collected for statistical analysis for academic years 2 and 5, although less than for the other academic years between 1 and 6. It was however decided that additional data was desirable to supplement that collected in association with the Community Dental Officer, in order to ensure a better representation of children in years 7 and 8, aged eleven to fourteen. Further data collection was undertaken for these age groups.

As has been stated in section 3.5, the Community Dental Officer was unable to examine whole year groups in locally maintained secondary schools and was unable to visit any of the privately maintained schools. The researcher, a registered dental surgeon of the United Kingdom (GDC No 50574), therefore made contact with all the secondary schools, both locally maintained and privately maintained, to ask permission to undertake a dental inspection of all the pupils in years 7 and 8. These two academic years included children who were eleven, twelve, thirteen and fourteen. (Although the children were pupils in only two academic years their ages spanned four years as academic and calendar years do not coincide.)

Five schools acceded to the request and seven schools declined, mainly for administrative reasons. The schools which both acceded and declined were both of comprehensive and selective entry status, and both locally and privately maintained. With ethical approval (Approval Number NM2261) *(Appendix 3)*, and the same in-school protocol *(Appendix 2)* as the Community Dental Officer, dental inspections were undertaken at those secondary schools which gave permission.

3.7 Data Collection

3.7.1 Personnel Collecting the Data

Two teams of people collected the data. The researcher was a member of both teams. The first team comprised the Researcher, the Community Dental Officer, and his Dental Nurse and the second comprised the Researcher and her Dental Nurse.

3.7.1.1 Team One Data Collection

When the first team collected data, the Community Dental Officer undertook all the dental examinations; his Dental Nurse recorded the data for the Essex Rivers Health Authority and BASCD and the Researcher recorded the data for the research. This team undertook all the dental examinations of the children attending locally maintained primary schools, and those of the 12 years olds and 14 year olds in the BASCD studies.

3.7.1.2 Team Two Data Collection

When team two collected data the Researcher undertook all the dental examinations and her Dental Nurse recorded the data. This team undertook the dental examinations of the children of Years 7 and 8, aged eleven to fourteen, attending the locally maintained and privately maintained secondary schools, which permitted the research dental examinations.

3.7.2 Standardization of Data Collection Methods

3.7.2.1 Team One

The Community Dental Officer had been trained and assessed for standardization of examination through BASCD, but the Researcher had not. To investigate whether there was a consistency of procedures undertaken by the two dentists during the dental examinations of the research, a pilot study was undertaken to assess the consistency of procedures undertaken during dental examinations. During the first three days of data collection, the first and every subsequent fiftieth child was examined, by both dentists. Each child was examined separately, and then jointly, and the data from both examiners, from both examinations, was compared.

At the end of three days, five hundred and fifty children had had a dental examination and twelve joint examinations had been undertaken. On each and every occasion identical data had been collected. This pilot study had shown that the two examiners were collecting the data in a consistent fashion so the joint examinations were discontinued. Subsequently, whenever there was any question as to the presence or absence of a tooth, both dentists examined the child's mouth, collected the data and agreed a joint interpretation of the data. This was then recorded. This process continued throughout the data collection period.

3.7.2.2 Team Two

To assess the accuracy of the data collection protocol of team two a second pilot study was undertaken between the Researcher and her Dental Nurse. At the beginning of the initial session, and subsequently every fifteen minutes, the Dental Nurse called out the contents of a dental record chart and the Researcher compared them with the teeth present in the mouth. At the end of the first day one hundred and eighty dental examinations and twelve comparisons of teeth and dental records had been performed. On each and every occasion the data was identical. This pilot study had shown that the examiner and the data recorder were working in a consistent fashion, so the joint comparisons were discontinued.

3.7.3 Period of Data Collection

Between 3rd April 1998 and 11th July 2001 ninety-seven schools were visited, some more than once. The schools varied in size from forty-three to nine hundred pupils, and the time taken to undertake all the dental examinations for a single school varied from between one and a half to six hours. The maximum rate for collecting the data was four hundred dental examinations in a single morning. (This may have affected the accuracy of this data collection, but time constraints precluded investigation of this.) On some days only one school was visited and on others three small ones were visited. A total of ninety-six days, more than nineteen working weeks, were spent collecting the data during the three-year period. Both teams were working during the whole period, though the work tended to be episodic, because of the constraints placed by schools and school holidays.

3.7.4 Venues for Data Collection

Within the ninety-seven schools the venues for the dental inspections were very variable, ranging from head teacher's offices, to stages, libraries, IT suites, classrooms, sports halls and storerooms. The convenience of the settings varied significantly from venue to venue, but the equipment and lighting were kept constant.

3.7.5 Equipment Used During Data Collection

The same equipment was used to collect all the data regardless of which team was working, or the venue. This equipment comprised

- A reclining plastic garden / beach chair, to allow good vision of the mouth
- A dental (Daray) angle poise lamp, for good illumination of the mouth
- A fresh autoclaved dental mirror for each child
- A fresh autoclaved dental probe when required

- The dentists wore dental examination gloves
- The dentists wore protective eye wear

3.7.6 Child Movements During Dental Data Collection

At the primary schools the whole class arrived together, escorted by their teacher and classroom assistants. Each child took his/her turn in the examination chair before being escorted back to the classroom.

The pupils from the first two academic years of secondary school, years 7 and 8, aged eleven, twelve, thirteen and fourteen were examined during formal classroom time. They arrived in class groups and returned, unescorted, to their classes.

The 12 and 14 year olds who had dental examinations for their BASCD age-group survey, did so in their "own time" mainly during break-times of the school day. They had to make their own way unescorted to and from the inspection site.

3.7.7 The Written Data Collected for Each Child Before Dental Examination

3.7.7.1 Team One

For each child the following data was recorded, hand-written, on his/her individual or class sheet before the dental examination was undertaken

- school
- date of the dental examination
- name

- date of birth
- sex
- race

3.7.7.2 Team Two

As the secondary schools, which permitted examination of the children's teeth were unable to furnish the Researcher with Class Sheets before the day of the dental examinations no preparation of record sheets could be made in advance. The same data as for Team One was therefore collected on the class sheets themselves.

3.7.8 Data Collection – Visual Examination

3.7.8.1 Team One

A thorough visual examination of the mouth, covering both soft and hard tissues, was undertaken using a clean, autoclaved, mirror for each child. The Community Dental Officer verbally recorded the names of the teeth present in the mouth using the Palmer- Zsigmondy notation. *(An explanation of dental notation may be found in Appendix 4.)* If it was not clear whether a tooth had emerged, the respective area of the gum was examined using an autoclaved dental probe. The findings were then called out, and were manually recorded by the Researcher, using the Palmer- Zsigmondy notation.

3.7.8.2 Team Two

When the Researcher was undertaking the dental examination a similar procedure was followed. The teeth present in the mouth were listed and the Dental Nurse recorded them manually using the Palmer-Zigmondy notation.

3.7.9 Verbal Examination of the Children During Dental Data Collection

When a child had a gap between its teeth, and where there was any possibility that a tooth could have emerged, but was not currently present, the child was asked about the history of the site. Their answers were recorded on their individual paper record cards or class sheets.

3.7.10 Validation of Data Collection

1. Team One. During the first pilot study of this research, the two examining dentists standardized and validated each other's dental examinations. Following this, if at any time the researcher was unclear as to the findings of the Community Dental Officer, she asked questions to clarify the facts before recording the data.
2. Team Two. During the second pilot study of this research, the Researcher and her Dental Nurse standardized their method of data collection and recording. If at any time the Researcher's Dental Nurse was unclear as to which teeth were present she asked for verbal clarification before recording the data.
3. When the Researcher was recording the dental data the qualified Dental Nurse who habitually worked with the Community Dental Officer, was sitting beside her. She was able to see and visually check the hand written records as they were being written. On three occasions, during the whole data collection period, an error was made and she corrected the Researcher. As this happened, the Community Dental Officer stopped and clarified the correct information before continuing.

3.8 Dental Records

3.8.1 Dental Data Recording Protocols

All the data collected at the time of the dental examinations was recorded manually.

3.8.1.1 Team One

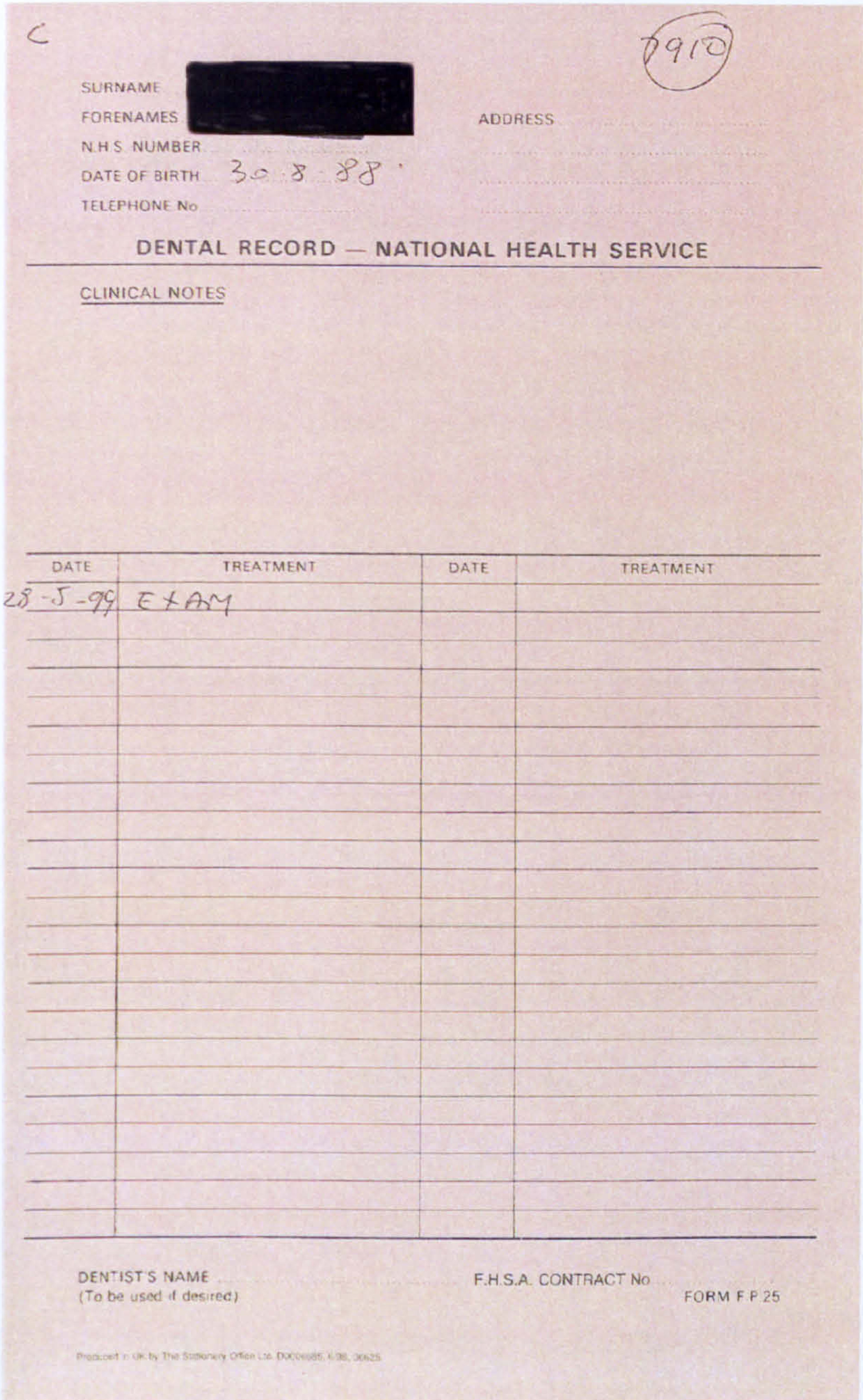
When the Researcher was working with the Community Dental Officer his Dental Nurse recorded the data he required on school class sheets and simultaneously the Researcher recorded the teeth present onto individual paper record sheets. All the information relating to the history of permanent teeth which may have been present at some time but which were absent at the dental examination was also recorded. This gave a guide as to which teeth had been lost through decay, orthodontics or trauma. A record was also kept of all dilacerated and geminated teeth. *(Definitions of these terms may be found in Appendix 5)* It was noted if any child was a twin, identical or non-identical.

3.8.1.2 Team Two

When the researcher was working with her Dental Nurse she called out the teeth which were present and her Nurse in turn wrote the dental record of each child onto a class sheet. As with Team One, a record was made of teeth had been lost through decay, orthodontics or trauma; dilacerated and geminated teeth; and twin siblings.

3.8.2 Format of Dental Records

The dental data for the children at primary schools was recorded on modified NHS record card continuation sheets, though the addresses and National Insurance Numbers of the children were not recorded (See Figure 3.1). The individual forms were collected into bundles for each school and labelled with the school and date of the dental examinations.



C

0910

SURNAME [redacted]
FORENAMES
N.H.S. NUMBER
DATE OF BIRTH 30.8.88
TELEPHONE No

ADDRESS

DENTAL RECORD — NATIONAL HEALTH SERVICE

CLINICAL NOTES

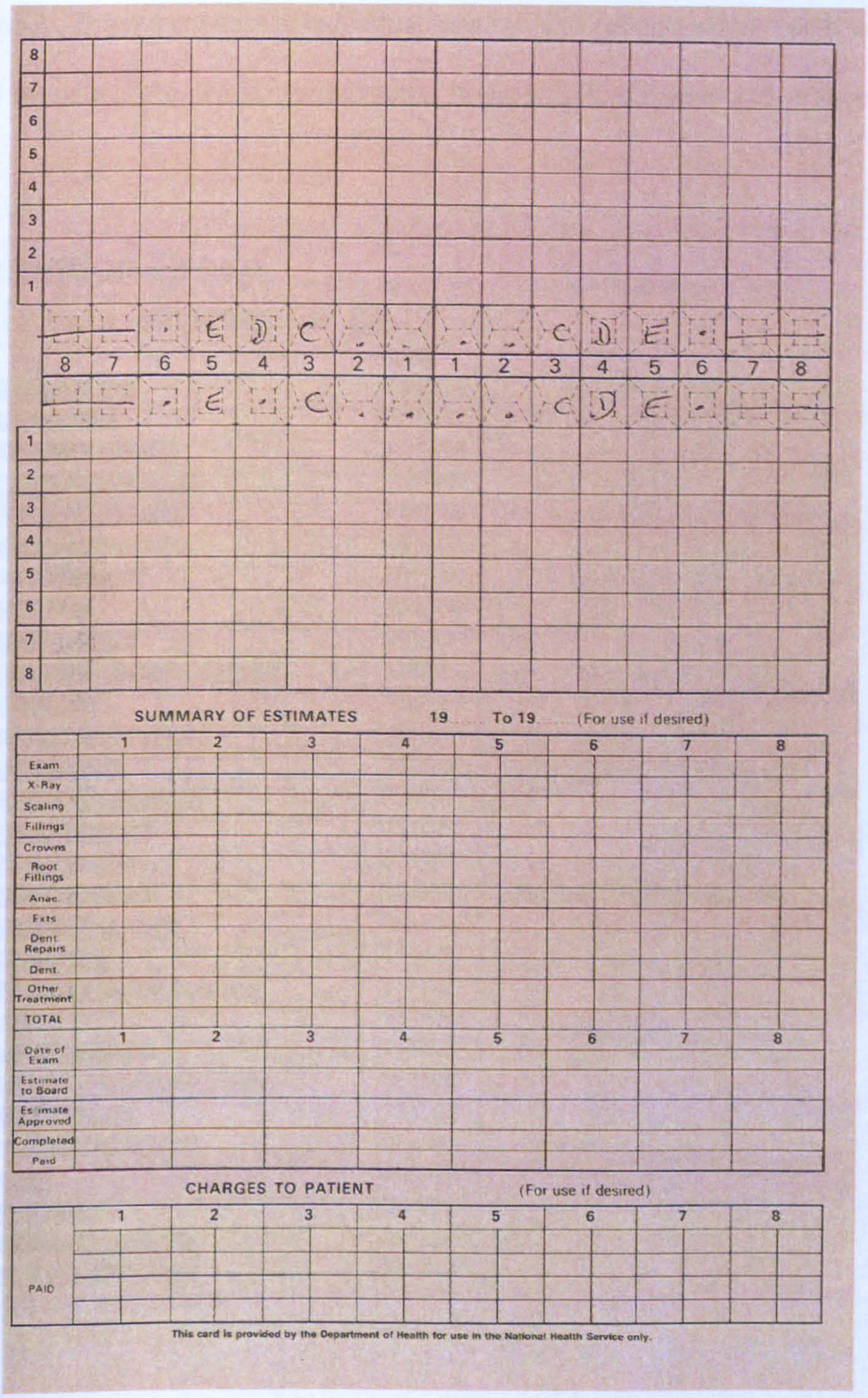
DATE	TREATMENT	DATE	TREATMENT
28-5-99	EXAM		

DENTIST'S NAME
(To be used if desired)

F.H.S.A. CONTRACT No

FORM F.P.25

Figure 3.1 Team One Record Card (Front)


8 7 6 5 4 3 2 1 1 2 3 4 5 6 7 8

E D C C D E

E C C D E

SUMMARY OF ESTIMATES 19...... To 19...... (For use if desired)

	1	2	3	4	5	6	7	8
Exam								
X-Ray								
Scaling								
Fillings								
Crowns								
Root Fillings								
Anae.								
Exts								
Dent. Repairs								
Dent.								
Other Treatment								
TOTAL								
	1	2	3	4	5	6	7	8
Date of Exam								
Estimate to Board								
Estimate Approved								
Completed								
Paid								

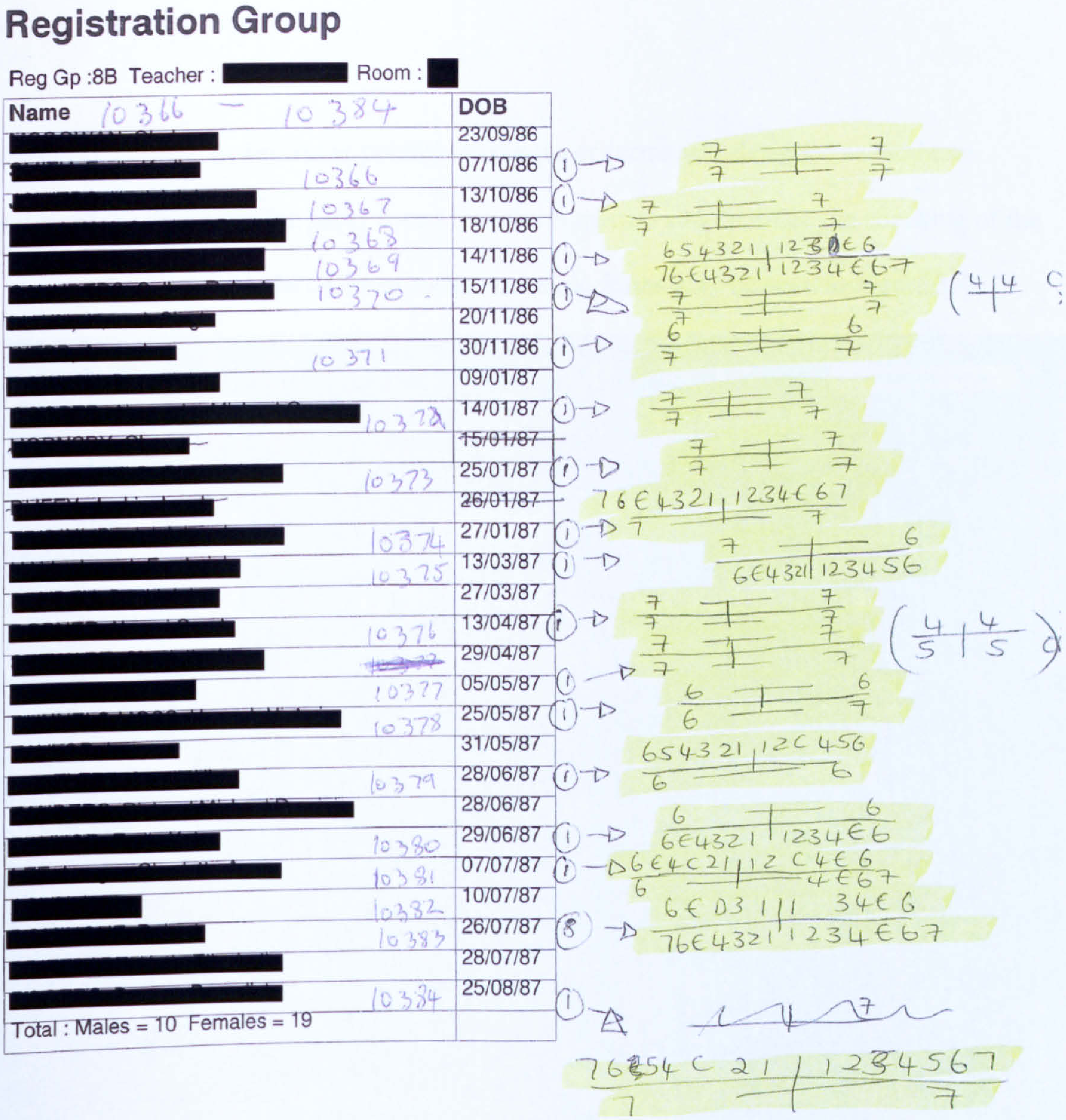
CHARGES TO PATIENT (For use if desired)

	1	2	3	4	5	6	7	8
PAID								

This card is provided by the Department of Health for use in the National Health Service only.

Figure 3.2 Team One Record Card (Back)

The data from the secondary schools was entered directly on the information sheets supplied by the school. These were kept in individual files for each school, marked with the school name and the date of the dental examinations. A sheet used to collect data is shown in Figure 3.3.



Registration Group

Reg Gp :8B Teacher : [redacted] Room : [redacted]

Name 10366 — 10384	DOB
[redacted]	23/09/86
[redacted] 10366	07/10/86
[redacted] 10367	13/10/86
[redacted] 10368	18/10/86
[redacted] 10369	14/11/86
[redacted] 10370	15/11/86
[redacted]	20/11/86
[redacted] 10371	30/11/86
[redacted]	09/01/87
[redacted] 10372	14/01/87
[redacted]	~~15/01/87~~
[redacted] 10373	25/01/87
[redacted]	~~26/01/87~~
[redacted] 10374	27/01/87
[redacted] 10375	13/03/87
[redacted]	27/03/87
[redacted] 10376	13/04/87
[redacted]	29/04/87
[redacted] 10377	05/05/87
[redacted] 10378	25/05/87
[redacted]	31/05/87
[redacted] 10379	28/06/87
[redacted]	28/06/87
[redacted] 10380	29/06/87
[redacted] 10381	07/07/87
[redacted] 10382	10/07/87
[redacted] 10383	26/07/87
[redacted]	28/07/87
[redacted] 10384	25/08/87
Total : Males = 10 Females = 19	

Figure 3.3 Example of a Record Sheet Used by Team Two

3.9 Electronic Recording and Storage of Data

The data was initially recorded onto paper forms but to facilitate storage and analysis the data was transferred to an IBM compatible computer (Packard Bell Platinum with Pentium II processor) and was stored in an electronic format using a commercially available database package, Microsoft Access.

An electronic form, as similar as possible to the paper forms was designed to facilitate transfer of the data from the paper forms into the computer and facilitate the checking of the accuracy of the data transfer. One of these electronic forms may be seen in Figure 3.4.

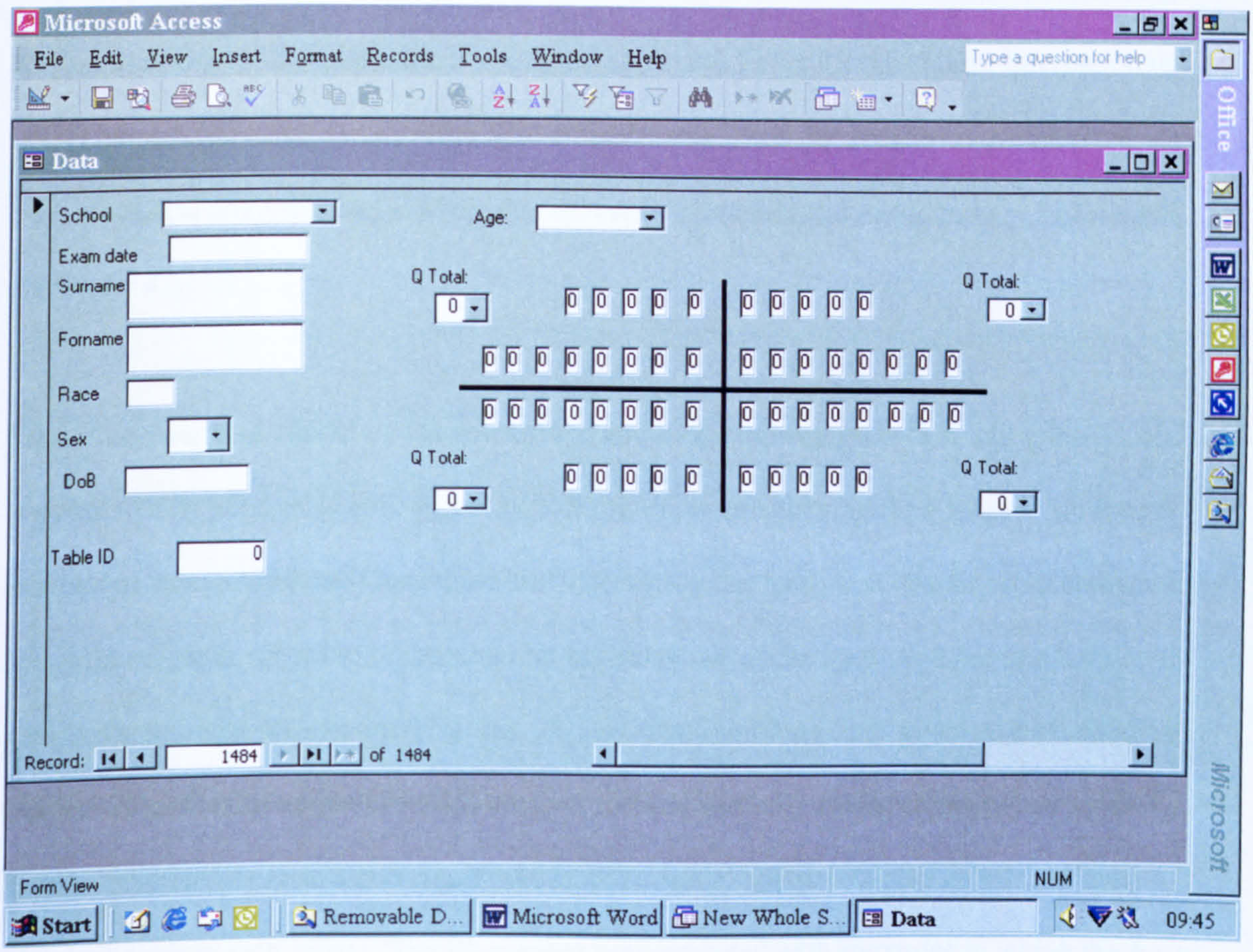


Figure 3.4 Electronic Record Form

As the data from the paper form for each child was entered into its MS Access form it was given its unique identifying number, using the auto numbering facility of the program. This allowed the data relating to each child to become anonymous.

Additional calculated fields on the MS access form were the age at the time of examination of the child and quadrant total boxes. These allowed a straight comparison of ages and numbers of teeth to be made. (Quadrant total fields were produced by adding together all the teeth in a single quadrant of the mouth, if deciduous tooth and its permanent successor were present only the permanent tooth was recorded.) During the transfer of the data, the notation of the teeth was changed from the Palmer – Zsigmondy to the Federation Dentaire Internationale (FDI) notation of teeth, as this numerical notation was more convenient to use in association with statistical analysis. *(An explanation of this format of dental notation may be found in Appendix 4.)*

Data entry was undertaken by the researcher, and took eighteen months to complete. Data was entered in batches of 100, as it was difficult to remain accurate and focused for longer periods of time. After each batch, the entry in the Access form was visually checked against the original paper record to make sure that the entry was correct and that the quadrant totals corresponded with the expected figures. At this time the ID number given to each child by the MS Access auto number facility was recorded on the original paper record card. This both completed the record and signified that the original and the Access forms had been checked against each other. The ID number corresponded with the order in which the forms were entered. All the original paper forms were stored in ID number, under school and date references. From this point onwards the data could become anonymous.

At the end of data entry there were 12,395 forms and two tables, one with all the data relating to each child and one relating to the schools visited.

The data relating to missing, supplemental, geminated and fused teeth were recorded in a Microsoft Excel program and were presented in Appendix 6. This data sub-set related to 219 children, 1.77% of those examined, and it was not included in the analysis of this research.

As the proportion of the Non-Caucasian children was very small, relative to the proportion of Caucasian children, it was decided that analyses should only be undertaken for the Caucasian children. The data relating to the four hundred and six Non-Caucasian children was not used in the analysis of this research but may be used for further research.

The removal of the data relating to 219 children with dental anomalies and 406 children who were not of Caucasian origin from the original sample of 12,395 children, left a final data set of 11,770 Caucasian children on whom the analyses of this research were undertaken. This was 26.7% of the children in the Essex Rivers Health Authority Area, during the academic year 2001 – 2002.

3.10 Data Entry Validation

1. The data was entered into the Microsoft Access forms in batches of approximately 100. On a separate occasion, after each batch, the paper and Access forms were compared.

For each child the

- Name
- School
- Date of examination
- Date of birth
- Gender
- Racial group
- ID number
- Decimal age
- Tooth present / absent fields and
- Quadrant totals

were compared for accuracy of match.

2. By comparing the quadrant total boxes to the actual number of teeth on the paper form it was possible to undertake a second check on the tooth entry fields. When it was found that the lower right quadrant total box (Q4) was consistently wrong, the text box for this quadrant was investigated. It was found that an incorrect FDI tooth number was in the listing, 34 instead of 44. A correction solved the problem.

3. Once the data was entered into the Access program an independent assessor compared approximately 3,000 data entry cards, randomly removed from the storage boxes with the original paper record charts. No errors were found confirming the validity of the protocol.

3.11 Export of Data to SPSS Data Base and Validation of the Transcription

To facilitate data handling and analysis, the data was transferred electronically from Microsoft Access to the Statistical Package for Social Sciences (SPSS) program, Version 10 for MS Windows.

As this offered an opportunity for transcription error, two hundred specific records were examined separately in both programs, to check that they were identical and a further fifty records were randomly selected for examination in both programs. In each instance the records were identical in both programs.

3.12 Anonymity of Data

Once the data had been converted to the SPSS Data Base and the transcription had been validated the children and their schools were given anonymity by removing their names. Subsequent analysis was undertaken using ID numbers alone.

3.13 New Fields Introduced Into the SPSS Data Base

To facilitate analysis the data for school, sex and race were converted to numeric variables. The schools were numbered from 1 to 97 assigned in the order that the schools were visited and the sex of each child was coded as 1 for boys and 2 for girls.

Variables were computed for the total number of permanent teeth, the total number of deciduous teeth and the total number of teeth for each child. Six-month age bands were introduced where the name of the age band was the measure of central tendency of the time span, so that the six-month age-band 8.5 years equals 8.25-8.74 years. There were 23 six-month age bands that ranged between 4 years and 15 years. These permitted comparisons between children of different ages and between the two sexes; and were used in the production of predictive models.

3.14 Statistical Analysis

3.14.1 Distribution of Data

Analysis of the numbers of children in each six-month age band showed that they were not normally distributed around the mean age of the sample of children. There was a tri-modal distribution of the data. Further analysis showed that the data in each of the three periods, four to seven years, seven to ten years and ten to thirteen years was normally distributed but that it was not normally distributed as a whole. This was because the sample selection, as described in Sections 3.5 and 3.6, was not limited to a specific number of children of any given age but was controlled by the total number of children having a dental examination during any given session.

Because of the nature of the samples taken, the median, E_{50} (emergence [as defined in Section 2.2 of this paper] the presence of any part of a specific tooth in the mouth, of 50% of the population), was the chosen measure of central tendency; this was the method used by James and Pitts *(1912)*, the Medical Research Council *(1925)*, Leslie *(1951)* and Lavelle *(1976)* during their research.

3.14.2 Medians

The median age of emergence was calculated for each tooth individually for all the children, and boys and girls separately. For each tooth, all the children (or gender grouped children) were placed in six-month age bands and the percentage presence of the specific tooth was found in each of the six-month age bands individually. Actual life tables were constructed which listed the percentage presence of each tooth in each age band. The median was found by extrapolation from these tables using equation 3.1, after finding such i that $P_i<50\%$ and $P_{i+1}>50\%$

Equation 3. 1 Equation to find the Median Age of Emergence of Each Permanent Tooth

$\alpha * P_i + (1-\alpha)(P_{i+1}) = 50\ \%$ of the population had a specific tooth present

Where α was found from this equation and was used to calculate the median age

P_i denotes the known proportion below 50% on the ith age group

(P_{i+1}) denotes the known proportion 50% in the $(i+1)$th age group

The figures from the life tables for each tooth *(Appendix 8)*, grouped by quadrant, for all the children, and gender related groups were used to graphically illustrate the pattern of emergence for each tooth *(Appendix 9)*.

3.15 Active Age Range of Emergence

The active age range of emergence of each tooth was defined as being between the age of the youngest child in the sample to have the nominated tooth and the oldest child in the sample not to have the nominated tooth.

3.16 Order of Emergence

The order in which each tooth in each quadrant emerged was found from the tables of median age of emergence. Tables were produced for all the children, and then boys and girls separately.

3.17 Contra-Lateral Pairs of Teeth

In order to discern whether there was a significant difference in the emergence time of a specific tooth and its opposite paired tooth in the same arch e.g. 15 and 25, or 33 and 43, a Mann-Whitney U Test was performed *(Clegg, 1990)*.

In addition to the whole data set being investigated, separate tests were conducted according to gender.

3.18 Ipsi-Lateral Pairs of Teeth

In order to discern whether there was a significant difference in the emergence time of a specific tooth and its paired tooth in the opposing arch e.g. 15 and 45, or 23 and 33, a Mann-Whitney U Test was performed.

In addition to the whole data set being investigated, separate tests were conducted according to gender.

3.19 Summary

A simple, robust, reproducible and reliable protocol for a standardized data collection, and statistical analysis has been produced, tested and utilised to give a data set of 11,770 Caucasian children from the Colchester area of the UK. This data set can be used to generate a chronology of tooth emergence, tables for use in age assessment investigations and the capacity to predict the age of children based on the number of their permanent teeth and sex.

This data set was based on dental examinations, undertaken between 3rd April 1998 and 11th July 2001, on twelve thousand, three hundred and ninety-five children attending schools in the Essex Rivers Health Authority Area. The records of two hundred and nineteen children, of whom 105 were boys (48%) and 114 (52%) girls, which equated to 1.77% of the total sample of children who had had teeth removed for trauma, decay or orthodontics and the records of the children who were suffering from major systemic illness or genetically inherited disorders were not included in the data set; neither were the records of the four hundred and six Non-Caucasian children (3.26% of the total sample), 210 boys (1.69%) and 195 girls (1.57%).

The data was collected by a standardized dental examination in a cross-sectional manner. Each dental examination investigated the presence or absence of each of twenty-eight permanent teeth in the mouth of each child. The children were placed in six-month age bands by decimal age and actual life tables recording the percentage of children having each tooth for each age band were generated. The median age of emergence was found when fifty percent of the children in a given age band had the specific tooth.

Chapter 4: Results

4.1 Data Set

The data set for this research comprises 11,770 children, 6151 boys (52.3%) and 5619 girls (47.7%). Between them they had a total of 130,436 permanent teeth. The age ranges for the children were 4.10 to 15.01 years for boys and 4.14 to 14.99 years for girls.

The distribution of the children by age and sex can be seen in Figure 4.1. (The reasons for this distribution are covered in Section 3.14.1.)

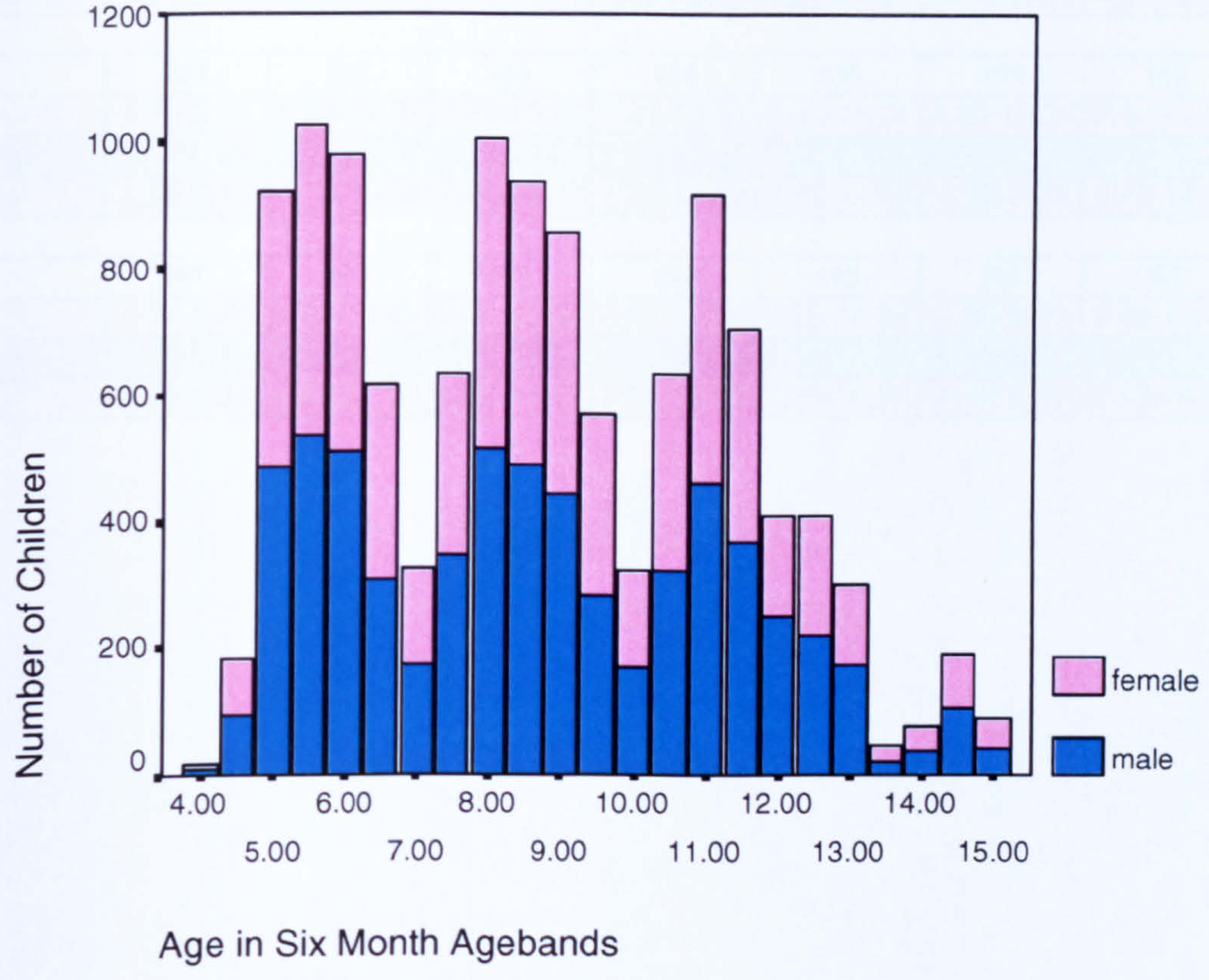


Figure 4.1 The Frequency of Children in Each Six-Month Age Band by Gender

4.2 Age Ranges of Emergence of the Permanent Teeth

The specific age range during which each of the permanent teeth of all the children, and gender related groups, emerged is shown in Table 4.1.

Table 4.1 Age Ranges of Emergence in Years for Each Permanent Tooth

	t11	t12	t13	t14	t15	t16	t17
All	5.53-10.34	5.74-11.60	7.28-14.97	7.07-13.45	7.28-14.94	4,77-9.82	9.49-14.97
Boys	5.54-10.34	7.14-11.60	8.98-14.97	7.07-13.31	7.72-14.64	4.77-9.82	9.64-14.97
Girls	5.53-9.20	5.74-11.27	7.28-14.74	7.28-13.45	7.28-14.94	4.80-8.91	9.49-14.94
	t21	t22	t23	t24	t25	t26	t27
All	5.05-10.34	6.44-11.79	7.73-14.97	7.07-13.45	7.28-15.01	4.77-9.04	9.84-14.84
Boys	5.05-10.34	6.84-11.79	7.96-14.97	7.07-13.28	7.72-15.02	4.77-8.61	9.94-14.53
Girls	5.39-9.20	6.44-11.27	7.73-14.40	7.28-13.45	7.28-14.61	4.80-9.04	9.84-14.84
	t31	t32	t33	t34	t35	t36	t37
All	4.73-9.37	5.53-11.27	7.28-13.33	7.28-13.31	7.96-15.01	4.80-10.37	9.42-14.84
Boys	4.73-9.37	5.84-11.27	8.26-13.33	7.94-13.31	8.26-15.01	4.91-10.37	9.57-14.49
Girls	4.96-8.54	5.53-10.51	7.28-12.70	7.28-12.87	7.96-14.96	4.80-8.70	9.42-14.84
	t41	t42	t43	t44	t45	t46	t47
All	4.92-8.76	5.53-11.49	7.28-13.33	7.28-13.33	7.28-14.99	4.80-8.85	9.43-14.91
Boys	4.92-8.76	5.81-11.49	8.39-13.33	7.90-13.33	8.32-14.97	4.90-8.61	9.57-14.91
Girls	4.96-8.54	5.53-10.34	7.28-12.87	7.28-12.87	7.28-14.99	4.80-8.85	9.43-14.84

4.3 Median Dates of Emergence of the Permanent Teeth

The median age of emergence for the permanent teeth of all the children, and the boys and girls separately, calculated by the method shown in Section 3.14.2, is shown in Table 4.2. The number of children contributing to each of the median ages can be seen in Appendix 7. The largest sub-set of the data for a specific tooth was 8959 for tooth 41 for all the children, and the smallest sub-set of the data was 601 boys for tooth 17.

Table 4.2 Median Dates of Emergence in Years (Six-Month Age Bands) for Each Permanent Tooth

	t11	t12	t13	t14	t15	t16	t17
All	7.13	8.23	11.50	10.81	11.73	6.42	12.53
Boys	7.71	8.98	11.63	11.13	11.92	6.50	12.50
Girls	7.02	8.00	11.14	10.66	11.55	6.32	12.52
	t21	t22	t23	t24	t25	t26	t27
All	7.14	8.22	11.44	10.84	11.76	6.42	12.42
Boys	7.23	8.43	11.66	11.03	11.86	6.54	12.40
Girls	7.03	8.02	11.14	10.70	11.60	6.30	12.00
	t31	t32	t33	t34	t35	t36	t37
All	6.27	7.39	10.17	10.98	11.78	6.30	11.75
Boys	6.38	7.52	10.79	10.96	11.90	6.40	11.85
Girls	6.15	7.16	9.94	10.68	11.64	6.18	11.61
	t41	t42	t43	t44	t45	t46	t47
All	6.23	7.38	10.43	10.73	11.75	6.34	11.79
Boys	6.34	7.49	10.78	10.95	11.84	6.46	11.88
Girls	6.31	7.45	9.96	10.55	11.51	6.23	11.67

4.4 Order of Emergence of the Permanent Teeth

The order of emergence for each tooth (by median emergence date) is listed, for all the children, and boys and girls separately, in Table 4.3. (The first tooth to emerge in each quadrant is found at the left end of each line and the last tooth to emerge in each quadrant to the right end of each line.)

Table 4.3 Order of Emergence of Each Permanent Tooth

All Q1	t16	t11	t12	t14	t13	t15	t17
Boys Q1	t16	t11	t12	t14	t13	t15	t17
Girls Q1	t16	t11	t12	t14	t13	t15	t17
All Q2	t26	t21	t22	t24	t23	t25	t27
Boys Q2	t26	t21	t22	t24	t23	t25	t27
Girls Q2	t26	t21	t22	t24	t23	t25	t27
All Q3	t31	t36	t32	t33	t34	t37	t35
Boys Q3	t31	t36	t32	t33	t34	t37	t35
Girls Q3	t31	t36	t32	t33	t34	t37	t35
All Q4	t41	t46	t42	t43	t44	t45	t47
Boys Q4	t41	t46	t42	t43	t44	t45	t47
Girls Q4	t46	t41	t42	t43	t44	t45	t47

Although there are some differences in the orders of emergence in the lower quadrants of teeth these differences are not statistically significant. (A discussion of the groups of teeth that emerge concurrently may be found in Section 5.6.)

4.5 Comparison of the Median Age of Emergence Between Contra-Lateral Pairs of Teeth Within the Same Arch

A Mann-Whitney U Test at $\alpha = 0.003$ level, Bonferroni Correction due to fourteen comparisons, showed that there was no significant difference between the median ages of emergence of each tooth within the fourteen pairs of teeth, irrespective of gender.

4.6 Comparison of the Median Age of Emergence Between Ipsi-Lateral Pairs of Teeth Within Opposing Arches

A Mann-Whitney U Test showed that there were some significant differences between the median ages of emergence of some of the teeth within the fourteen pairs of teeth investigated.

Table 4.4 Significant Differences in Ipsi-Lateral Teeth for All Children, Boys and Girls

Tooth Pair	All	Boys	Girls
t11 and t41	$p = 0.002$	$p < 0.003$	$p < 0.003$
t12 and t42	$p = 0.002$	$p = 0.004$	$p < 0.003$
t13 and t43	$p = 0.005$	$p < 0.003$	$p < 0.003$
t14 and t44	$p = 0.001$	$p < 0.001$	$p < 0.003$
t15 and t45	$p < 0.003$	$p < 0.003$	$p < 0.003$
t16 and t46	$p < 0.003$	$p < 0.003$	$p < 0.003$
t17 and t47	$p < 0.003$	$p < 0.003$	$p < 0.003$
t21 and t31	$p < 0.001$	$p = 0.001$	$p < 0.003$
t22 and t32	$p < 0.003$	$p < 0.003$	$p < 0.003$
t23 and t33	$p < 0.003$	$p = 0.001$	$p < 0.003$
t24 and t34	$p < 0.001$	$p < 0.001$	$p < 0.003$
t25and t35	$p < 0.003$	$p < 0.003$	$p < 0.003$
t26 and t36	$p < 0.003$	$p < 0.003$	$p < 0.003$
t27 and t37	$p < 0.003$	$p < 0.003$	$p < 0.003$

4.7 Frequency of Emergence of Permanent Teeth

Life tables showing the percentage of children, boys and girls, having each tooth in each six-month age band can be seen in Appendix 8. From the actual life tables, graphs were produced to show the percentage of the population showing emergence of each tooth, in each quadrant between four and fifteen years of age. The pattern of the graphs was similar for all the children and the gender related groups of children. Examples of a upper arch quadrant

(Figure 4.2) and a lower arch quadrant (Figure 4.3) can be found below. Graphs for all four quadrants for all the children and gender related groups may be seen in Appendix 9.

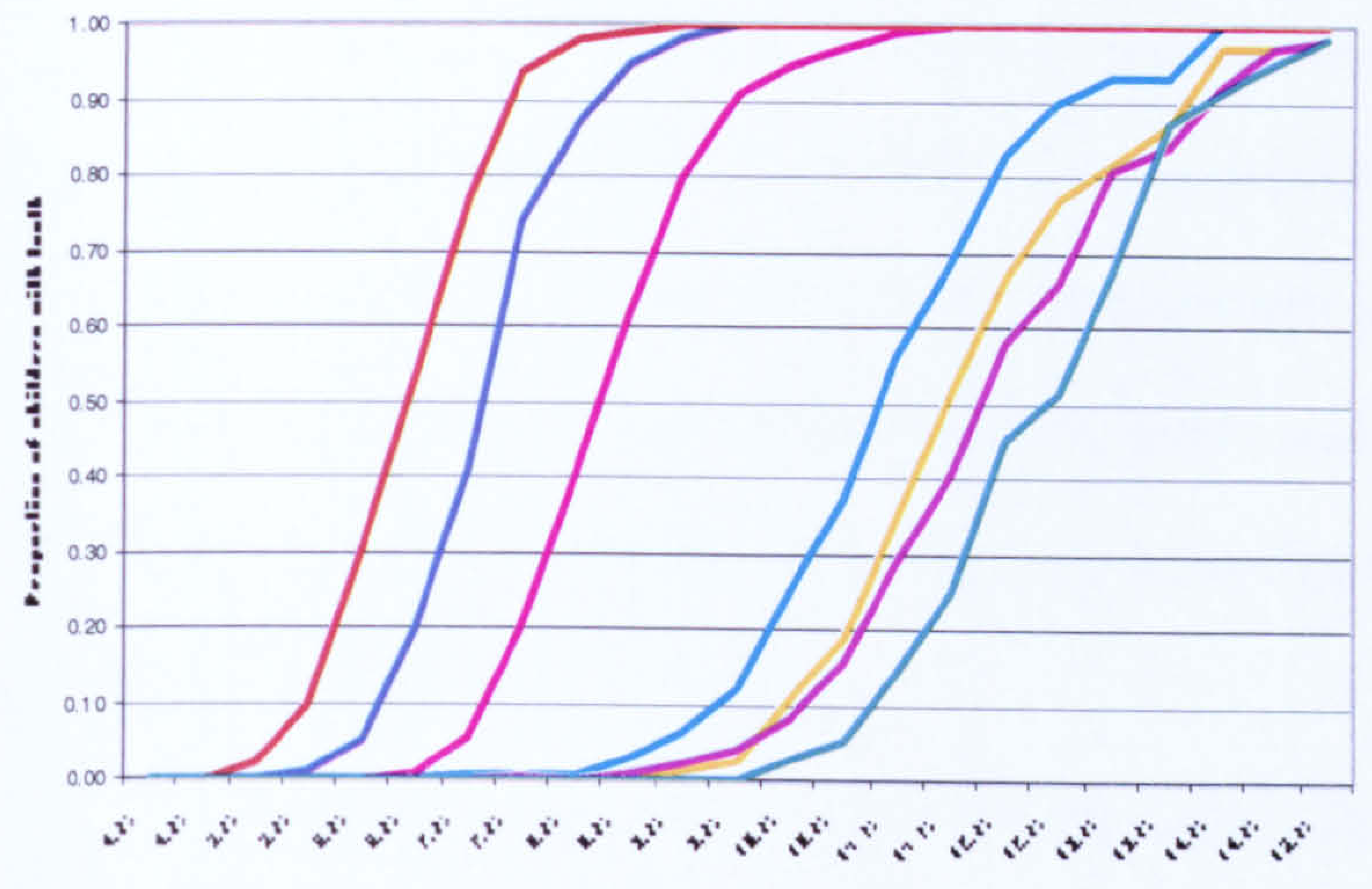


Figure 4.2 Graphical Representation of the Life Tables for

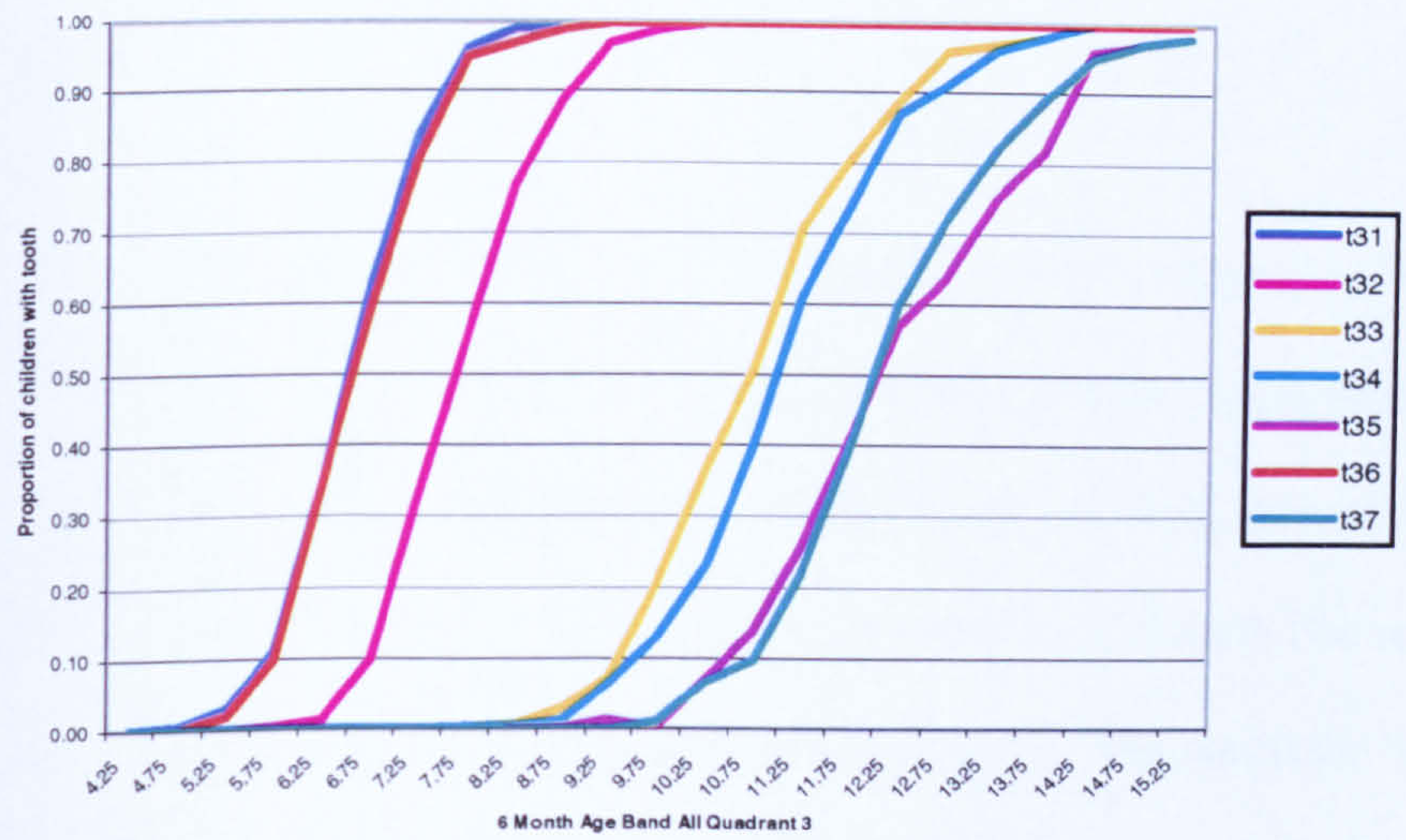


Figure 4.3 Graphical Representation of the Life Tables for Six Month Age Bands All Children Quadrant 3

4.8 Validation of the Accuracy of the Results

1. When the range of emergence for each tooth was found the records for the three children above and below each of the extreme values for attainment or non-attainment were checked for accuracy on the paper records. In the extremely rare cases that inaccuracies in data entry, or records, were found, the electronic records were amended. All of the teeth were completely checked at least seven times. Sixty-two extreme outliers were found. (An extreme outlier was defined as any data point three times greater than the interquartile range.)
2. An independent expert was used at each stage to verify validity of concept and outcome.

4.9 Predictions

4.9.1 Age as a Function of the Number of Permanent Teeth and Gender, Using a Regression Model For the Whole Mouth.

A regression model was created to predict the age of school children within the five to fifteen years of age cohort. To predict age as a function of the number of permanent teeth and the gender of the child a linear regression was performed on the data. It was found that these two predictors could explain 86.5% of the variation of the whole model. The whole model was found to be significant ($F(1,11767) = 263.499$, $p < 0.001$). The predictor 'number of teeth' accounted for 86.2 % of the explained variation $t(1) = 274.810$, $p < 0.001$. The predictor 'gender' accounted for 0.3% of the whole variation and was found to be significant (t (1)=16.233 p<0.001). The coefficients from the linear regression give us the following predictive equation:

Equation 4.1 To Predict the Age of a Child From the Number of Its Permanent Teeth and Its Gender

$Y = a + b_1 x_1 + b_2 x_2$

Age = 5.670 + 0.279 * 'number of permanent teeth' + (- 0.284 * 'gender[1]')

Age of a boy (years) = 5.670 + (0.279 * 'number of permanent teeth') + (- 0.284 * 0)

= 5.670 + (0.279 * 'number of permanent teeth')

Age of a girl (years) = 5.670 + (0.279 * 'number of permanent teeth') + (– 0.284 * 1)

= 5.670 + (0.279 * 'number of permanent teeth') – 0.284

The equations for boys and girls may be represented graphically and can be seen in Figure 4.4.

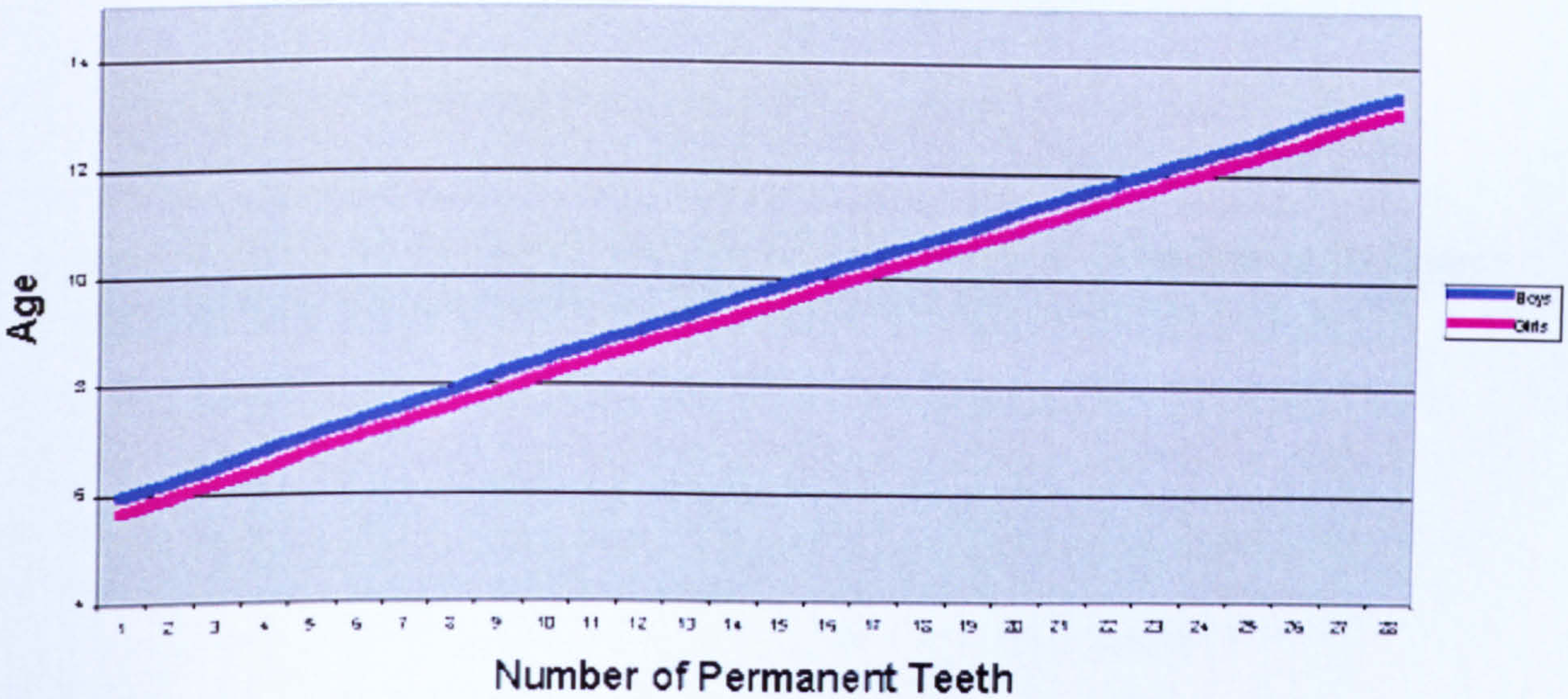


Figure 4.4 The Relationship Between Age in Years, Sex and Number of Permanent Teeth in Boy's and Girl's Mouths

[1] Where gender equals 0 for boys and 1 for girls

4.9.2 Age as a Function of the Number of Permanent Teeth and Gender, Using a Regression Model For the Upper or Lower Arch Alone.

From these data the most accurate model to predict the age of school children is by the number of their permanent teeth and their gender in the whole mouth, but there are forensic cases when only an upper or lower arch of teeth is intact and available for analysis In this instance a linear regression analysis shows that the two predictors, 'number of permanent teeth in the upper / lower arch' and 'gender' are valid and may be used to predict age.
It was found that 'number of permanent teeth in the upper / lower arch' and 'gender' could explain 84.5% / 84.8% of the variation of the whole model. The models were found to be significant ($F(1,11767) = 187.083$, $p < 0.001$) and ($F(1,11767) = 262.035$, $p < 0.001$). The predictor 'number of teeth' accounted for 84.3% of the explained variance $t = 253.748$, $p < 0.001$ and $t = 256.080$, $p < 0.001$. The predictor 'gender' accounted for 0.2% of the whole model and was found to be significant ($t = 13.678$, $p < 0.001$ and $t = 16.188$, $p < 0.001$).

The coefficients from the linear regression give us the following predictive equation:

Equation 4.2 To Predict the Age of a Child From the Number of its Upper or Lower Permanent Teeth and its Gender

$Y = a + b_1x_1 + b_2x_2$

For the Upper Arch

Age = 5.887 + 0.549 * 'number of permanent teeth' + (- 0.256 * 'gender[2]')

For the Lower Arch

Age = 5.581 + 0.541 * 'number of permanent teeth' + (- 0.301 * 'gender')

[2] Where gender equals 0 for boys and 1 for girls

4.9.3 Age as a Function of the Number of Permanent Teeth Presented in a Tabular Form

A tabular representation of the likelihood of a tooth being present may be seen for all children, and boys and girls separately, in Tables 4.5, 4.6 and 4.7. These three tables list the percentage of children having each tooth at <10%, 10% – 49%, 50% – 90% and >90% during any six month age band between four and fifteen years of age. (25% and 75% attainment rates could be found from the data but this would not be of practical use in the field, as the key issue to forensic odontologists is whether on a balance of probabilities a child has attained a specific age or not. This is shown when the percentage of children having each specific tooth reaches 50%). When a tooth is in the blue band of the figure it is very unlikely to be present in a child's mouth and if it is the grey band of the figure it is very likely to be present in a child's mouth at any given age. When the a tooth moves from the pink to the purple band, <50% to >50%, it moves from having less than a 50% probability of being present in the mouth to having more than a 50% probability of being present in the mouth at this age. In practice this means that there is a greater probability of the tooth being present in the mouth than it being absent from the mouth at the given age and so a prediction of the age of the child may be made.

If a ruler is laid across the table at any chosen age it will show the likelihood of each tooth being present in the mouth, so if the ruler is placed to show the nine years age band, for all children, it can be seen that there is a greater than 90% likelihood of teeth t11, t16, t21, t26, t31, t32, t36, t41, t42 and t46 being present; between 50% and 90% likelihood of teeth t12 and t22 being present; and less than 10% likelihood of teeth t13, t14, t15, t17, t23, t24, t25, t27, t33, t34, t35, t37, t43,t44, t45, and t47 being present. This data can then be compared with the actual situation in a child's mouth and a decision made as to the probable age of the given individual. This information may be used to help in an age assessment used in a forensic identification of a dead child and in an age assessment used for immigration purposes, e.g. if a Caucasian refugee or asylum seeker came from Eastern Europe where their data had been destroyed by war or fire.

Table 4.5 The Percentage of Children With Emerged Permanent Teeth (t11 – t47) for Each Six-Month Age Band (4 – 15)

	t11	t12	t13	t14	t15	t16	t17	t21	t22	t23	t24	t25	t26	t27	t31	t32	t33	t34	t35	t36	t37	t41	t42	t43	t44	t45	t46	t47
4	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
4.5	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
5	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
5.5	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	11	<10	<10	<10	<10	10	<10	11	<10	<10	<10	<10	10	<10
6	<10	<10	<10	<10	<10	31	<10	<10	<10	<10	<10	<10	31	<10	35	<10	<10	<10	<10	35	<10	37	<10	<10	<10	<10	32	<10
6.5	20	<10	<10	<10	<10	54	<10	20	<10	<10	<10	<10	54	<10	63	10	<10	<10	<10	60	<10	65	12	<10	<10	<10	58	<10
7	42	<10	<10	<10	<10	75	<10	41	<10	<10	<10	<10	77	<10	84	33	<10	<10	<10	81	<10	86	31	<10	<10	<10	81	<10
7.5	74	19	<10	<10	<10	>90	<10	74	20	<10	<10	<10	>90	<10	>90	55	<10	<10	<10	>90	<10	>90	56	<10	<10	<10	>90	<10
8	88	41	<10	<10	<10	>90	<10	87	41	<10	<10	<10	>90	<10	>90	77	<10	<10	<10	>90	<10	>90	76	<10	<10	<10	>90	<10
8.5	>90	60	<10	<10	<10	>90	<10	>90	62	<10	<10	<10	>90	<10	>90	89	<10	<10	<10	>90	<10	>90	89	<10	<10	<10	>90	<10
9	>90	78	<10	<10	<10	>90	<10	>90	80	<10	<10	<10	>90	<10	>90	>90	<10	<10	<10	>90	<10	>90	>90	<10	<10	<10	>90	<10
9.5	>90	>90	<10	12	<10	>90	<10	>90	>90	<10	12	<10	>90	<10	>90	>90	21	13	<10	>90	<10	>90	>90	19	13	<10	>90	<10
10	>90	>90	11	28	<10	>90	<10	>90	>90	11	25	<10	>90	<10	>90	>90	37	23	<10	>90	<10	>90	>90	38	23	<10	>90	<10
10.5	>90	>90	17	38	16	>90	<10	>90	>90	19	37	16	>90	<10	>90	>90	51	40	14	>90	<10	>90	>90	52	41	15	>90	<10
11	>90	>90	36	57	31	>90	14	>90	>90	35	56	29	>90	14	>90	>90	71	61	26	>90	22	>90	>90	71	61	27	>90	22
11.5	>90	>90	50	69	43	>90	24	>90	>90	52	69	41	>90	25	>90	>90	81	74	41	>90	40	>90	>90	80	74	41	>90	39
12	>90	>90	69	81	58	>90	41	>90	>90	67	83	58	>90	45	>90	>90	89	87	57	>90	60	>90	>90	88	87	59	>90	58
12.5	>90	>90	77	89	66	>90	49	>90	>90	77	>90	66	>90	51	>90	>90	>90	>90	64	>90	72	>90	>90	>90	>90	69	>90	66
13	>90	>90	82	>90	83	>90	66	>90	>90	82	>90	81	>90	67	>90	>90	>90	>90	75	>90	82	>90	>90	>90	>90	77	>90	80
13.5	>90	>90	87	>90	82	>90	84	>90	>90	87	>90	84	>90	87	>90	>90	>90	>90	82	>90	80	>90	>90	>90	>90	78	>90	84
14	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90
14.5	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90
15	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90

Key
< 10%
% - 49%
% - 90%
> 90%

Table 4. 6 The Percentage of Boys With Emerged Permanent Teeth (t11 – t47) For Each Six-Month Age Band (4 – 15)

	t11	t12	t13	t14	t15	t16	t17	t21	t22	t23	t24	t25	t26	t27	t31	t32	t33	t34	t35	t36	t37	t41	t42	t43	t44	t45	t46	t47
4	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
4.5	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
5	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
5.5	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	11	<10	<10	<10	<10	10	<10	11	<10	<10	<10	<10	10	<10
6	<10	<10	<10	<10	<10	31	<10	<10	<10	<10	<10	<10	31	<10	35	<10	<10	<10	<10	35	<10	37	<10	<10	<10	<10	32	<10
6.5	20	<10	<10	<10	<10	54	<10	20	<10	<10	<10	<10	54	<10	63	10	<10	<10	<10	60	<10	65	12	<10	<10	<10	58	<10
7	42	<10	<10	<10	<10	75	<10	41	<10	<10	<10	<10	77	<10	84	33	<10	<10	<10	81	<10	86	31	<10	<10	<10	81	<10
7.5	74	19	<10	<10	<10	>90	<10	74	20	<10	<10	<10	>90	<10	>90	55	<10	<10	<10	>90	<10	>90	56	<10	<10	<10	>90	<10
8	88	41	<10	<10	<10	>90	<10	87	41	<10	<10	<10	>90	<10	>90	77	<10	<10	<10	>90	<10	>90	76	<10	<10	<10	>90	<10
8.5	>90	60	<10	<10	<10	>90	<10	>90	62	<10	<10	<10	>90	<10	>90	89	<10	<10	<10	>90	<10	>90	89	<10	<10	<10	>90	<10
9	>90	78	<10	<10	<10	>90	<10	>90	80	<10	<10	<10	>90	<10	>90	>90	<10	<10	<10	>90	<10	>90	>90	<10	<10	<10	>90	<10
9.5	>90	>90	<10	12	<10	>90	<10	>90	>90	<10	12	<10	>90	<10	>90	>90	21	13	<10	>90	<10	>90	>90	19	13	<10	>90	<10
10	>90	>90	11	28	<10	>90	<10	>90	>90	11	25	<10	>90	<10	>90	>90	37	23	<10	>90	<10	>90	>90	38	23	<10	>90	<10
10.5	>90	>90	17	38	16	>90	<10	>90	>90	19	37	16	>90	<10	>90	>90	51	40	14	>90	<10	>90	>90	52	41	15	>90	<10
11	>90	>90	36	57	31	>90	14	>90	>90	35	56	29	>90	14	>90	>90	71	61	26	>90	22	>90	>90	71	61	27	>90	22
11.5	>90	>90	50	69	43	>90	24	>90	>90	52	69	41	>90	25	>90	>90	81	74	41	>90	40	>90	>90	80	74	41	>90	39
12	>90	>90	69	81	58	>90	41	>90	>90	67	83	58	>90	45	>90	>90	89	87	57	>90	60	>90	>90	88	87	59	>90	58
12.5	>90	>90	77	89	66	>90	49	>90	>90	77	>90	66	>90	51	>90	>90	>90	>90	64	>90	72	>90	>90	>90	>90	69	>90	66
13	>90	>90	82	>90	83	>90	66	>90	>90	82	>90	81	>90	67	>90	>90	>90	>90	75	>90	82	>90	>90	>90	>90	77	>90	80
13.5	>90	>90	87	>90	82	>90	84	>90	>90	87	>90	84	>90	87	>90	>90	>90	>90	82	>90	80	>90	>90	>90	>90	78	>90	84
14	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90
14.5	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90
15	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90	>90

Key
< 10%
% - 49%
% - 90%
> 90%

Chapter 5: Discussion

5.1 Data Collection

The collection of data for statistical analysis is fraught with opportunities for inaccuracy due to poor methodology, indiscipline of collection practices, poor standardization of collection protocols, differing interpretations of 'standards' and 'stages of development' in the interpretation of radiographs and study models, and the lack of standardization of the relevant terminology. It is essential to have consistent and standardized methods for data collection before a valid statistical analysis and comparison can be undertaken. Too often comparisons are made between two sets of figures which have been generated using different methods of collection and statistical analysis, and are not addressing the same issue. These comparisons, for example between means and medians, are not valid and should not be used.

Longitudinal studies have the great advantage that they give information relating to the same children over a period of years, but they are vulnerable to changes in personnel including those taking the radiographs and impressions for dental study models, changing radiographic techniques, standardization of the reading of the developmental stages attained by a given tooth whether viewed radiographically or on dental study models, and to the evolution of understanding and interpretation which over the years may subtly and imperceptibly modify data collection.

Longitudinal studies have depended largely on radiographs and descriptions of the formation stages attained by the teeth shown on them, the systems of Moorrees et al *(1963)* and

Demirjian et al *(1973)* or modifications of them are used most frequently. The systems and standards of Kronfeld *(1935)*, Hume *(1949)*, Nolla *(1960)* have also been used. Each system may use up to fourteen stages of development of each tooth to describe its status, so there is ample opportunity to misread a stage and record a developmental stage inaccurately. Researchers using these systems are often aware of the problem and undertake regular standardizations of their perception of the dental formation stages, and re-examination of the radiographs in order that the data collected may be as reproducible as possible; but this is an ongoing weakness of this system of data collection.

When longitudinal data is collected from dental study models *(Kochhar and Richardson, 1998)* it is important to view the whole model diligently and not just to view the areas of the model where teeth are expected to emerge or be present otherwise data will be missed. Small irregularities of the model may be perceived as the very early stage of the emergence of a tooth and so give a biased, early date for the emergence of the tooth.

For these reasons a simple cross-sectional system of data collection which does not depend on the interpretation of the evidence to undertake collection or analysis of a data set and is technique independent, offers a preferable alternative to a longitudinal study into the timing of the emergence of permanent teeth. Over a relatively short period of time for data collection it can be ensured that there are no changes in personnel, equipment and attitude; and standardization of examination technique can be maintained. Cross-sectional data collection permits the accumulation of larger sets of data within current constraints of finance, sample mobility and stamina than would be possible in longitudinal data collection protocols.

A dental examination in good light and clear visibility into the mouth is both simple and reproducible. A simple present or absent decision relating to each tooth is easily made. These two facts make the system of data collection used in this research valid, reproducible, reliable and robust. It offers a method of data collection which others can undertake to increase the comparable sources of data relating to the age of emergence of the permanent teeth of children. This system could be used to investigate the age of emergence of other racial groups in the UK and other racial groups around the world. Such research would permit valid comparisons to be made between data sets, and hierarchical tables of the ages of emergence of permanent teeth could be constructed between different racial groups in different parts of the world.

5.2 Sample Size

This research analysed the data related to the permanent teeth of 11,770 children which was a very large data set in comparison to the data sets of related research (Table 2.2 lists previously published data sets). Only literary research data sets, based on the cumulative data from several papers, and the research data set of 30,250 children from north-eastern Hungary created by Adler *(1963)* were larger. The size of this data set was sufficiently large to permit robust statistical analysis and remove the risk of ambiguity.

Within the data set of this research, sub-sets were created for each tooth for all the children, and gender related groups, the largest sub-set of 8,959 children was related to tooth 41 and the smallest sub-set of 601 boys was related to tooth 17. This means that even for the smallest sub-set of this research there was a large volume of data available for analysis *(Appendix 10)*.

Within published research, the sample sizes of cross-sectional investigations into the age of the emergence of permanent teeth, ranged from 25 *(Logan and Kronfeld, 1933)* to 30,250 *(Adler, 1963)*, between these extremes Gates *(1964)* created a data set of 5,660; Medical Research Council *(1925)*, Billewicz and McGregor *(1975)* and Lavelle *(1976)* had data sets of about 4,000 children, and other data sets contained as few as 100 children *(Hunt and Gleiser, 1955: Sanin and Savara, 1971: Liversidge, 2000)*. The larger the data set the more robust the analysis and the greater the confidence in the results.

The data sets for longitudinal studies were smaller because of the difficulty of recruiting and maintaining children in such a study. These data sets tended to be <100 *(Fanning, 1961, 1962: Shumaker, 1974)* with a few studies with data sets in the low hundreds *(Stones et al, 1951: Moorress et al, 1963)* and only one larger data set of approximately 2,500 from Nanda *(1960)*.

The literary reviews investigating the data from several papers, considered data from up to 100,00 children but as a single standardized format for data collection and analysis was not utilised in the constituent papers, it was not possible, or appropriate, to use these papers in a comparative manner with this research or even with each other.

5.2.1 The Sample Size Required to Replicate This Research for Different Groups of Children

It is important to know the age of emergence of the permanent teeth of the children of the different racial groups found in the UK, and in their indigenous communities around the world, so that the best possible age assessments may be undertaken for identification purposes in forensic dentistry.

The permanent teeth of children of the different racial groups do not emerge simultaneously so for valid comparisons to be made other statistically comparable data sets using the same methods of data collection and analysis as this research need to be produced. In order to keep the size of such data sets to a minimum for financial and ethical reasons this research data set was investigated to find the minimum size of data set which could give statistically comparable results. Random samples from between 3,000 and 25 children from the existing data set were examined using a linear regression model.

Table 5.1 Linear Regression Data Investigating the Sample Size Required to Replicate this Research

Sample number	R Square	Sig. Of Whole Model	Sig. of Constant	Sig. of Gender	Sig. Of Totperm.
3000	0.867	<0.001	<0.001	<0.001	<0.001
1000	0.871	<0.001	<0.001	<0.001	<0.001
500	0.867	<0.001	<0.001	<0.001	<0.001
250	0.853	<0.001	<0.001	0.038	<0.001
200	0.874	<0.001	<0.001	0.001	<0.001
150	0.884	<0.001	<0.001	0.059	<0.001
100	0.853	<0.001	<0.001	0.292	<0.001
50	0.896	<0.001	<0.001	0.383	<0.001
25	0.917	<0.001	<0.001	0.638	<0.001

Table 5.1 shows that the whole model and the constant of the equation remained significant to 25 children, as did the factor 'the number of permanent teeth' but gender stopped being a significant factor below 200 children. This shows that a minimum 200 children would be a valid data set on which to replicate this research. Ideally the 200 children would comprise 100 boys and 100 girls and they would be evenly spread, over six month age bands, between four and fifteen years of age.

5.3 Gender Distribution

Within this research the genders were distributed 52.2% male and 47.8% female, this compares with 51.2% males and 48.8% females in the Colchester area and 51.3% males and 48.7% females in the national statistics for England and Wales *(RG 1991)*. These differences were not statistically significant at the 5% level and any fluctuation between this data set and the town and national averages may be caused by random error.

The number of children examined each day was dictated by those present at each school on the sampling day, by the parents / guardians who withheld permission for a dental examination and the data side-lined for the children who were not Caucasian or had had teeth removed for trauma, decay or orthodontics, or who were suffering from major systemic illnesses or genetically inherited disorders, rather than all the children in the Colchester area between the ages of four and fifteen.

There may also have been additional, arbitrary reasons for the distribution of children within the data set. These may include such reasons as boys being less diligent in cleaning their teeth than girls and therefore having a greater incidence of dental decay and cavities. As in the Essex Rivers Health Authority a high incidence of dental disease triggers the Community Dental Services to undertake more dental inspections, schools with a greater percentage of boys may have had more dental inspections than schools with a greater percentage of girls.

Where data sets related to boys and girls are analysed separately most studies are dependent on factors beyond the control of those collecting the data to give the final size of the data set, for example the number of children resident in a Children's Home during a specific period *(Stones et al, 1951)*, or the number of children attending school on a given day *(Clements et al, 1953 a and b)*, or the number of children attending a dental department for dental treatment *(Davidson and Rodd, 2001)* have all contributed to the size of a data set in the past. It was only when a decision was made prior to research starting that the numbers of boys and girls should be perfectly matched could this target be achieved. Miller *(Miller et al, 1965)* chose to investigate a thousand boys and a thousand girls so their sample was distributed 50% : 50%, boys : girls.

The phenomenon of differing numbers of boys and girls in a data set is not just limited to the UK but is it found through out the world; control of the proportions of boys and girls in a data set has, by the nature of collection opportunities been limited.

5.4 The Age Ranges of Emergence of Permanent Teeth

During the analysis of this data set, the active age range of emergence for each tooth was defined as being between the age of the youngest child to have the nominated tooth and the oldest child not to have the nominated tooth. The smallest age range of emergence was 3.58 years, for teeth 31 and 41 for girls, and the largest 7.71 years for tooth 45 for the girls and all the children. This is more than half a lifetime for a fifteen year old and illustrates the large variation found in the human species.

Table 4.1 shows that the first molars (16, 26, 36 and 46) and central incisors (11, 21, 31 and 41), the teeth which appear first in all the quadrants of the mouth, tend to have the shortest time range for emergence, between three and a half and five and a half years. Teeth, which appear in the mouth later in a series (lateral incisors, second premolars and second molars) tend to have a longer time range for emergence.

In all instances the second premolar teeth, 15, 25, 35 and 45, had the longest time ranges for emergence, of between six and three-quarter to seven and three-quarter years. The time ranges of emergence for, both the upper and the lower, second premolars was fairly similar. The canines, 13, 23, 33 and 43, had the third longest time ranges for their emergence, between five and seven and three-quarters years, but in this instance the lower canines emerged between one and two years earlier than upper canines.

Few papers investigating the teeth of Caucasian children of the UK have given the range of time during which permanent teeth emerge. The paper of Kochhar and Richardson *(1998)* published ranges of emergence for the permanent teeth of Caucasian children from Northern Ireland aged between the ages of four and a half and fifteen years. (They did not comment on whether any children were specifically excluded from the data set because of extractions or medical or genetic conditions.) The age ranges of emergence which are published are similar to this research; some teeth have shorter age ranges and others have longer, some start earlier and some finish later, but there is no specific pattern suggesting that the range of time during which a tooth emerges is significantly earlier or later than the other research.

Butler *(1962)* cited the work of Logan and Kronfeld, modified by McCall and Schour and compared the age range for emergence of her data set with this data, but only the 10% to 90% range was quoted, rather than the whole range, and the age of the children in her data set was between five and thirteen years, as opposed to four to fifteen years in this research; this means that her ranges appear to be both shorter and earlier because of sampling methodology rather than in response to a true comparison of ranges. When the sampling age of any research terminates before the age at which the active age of emergence of some of the teeth, there is an inevitable bias towards an earlier range of emergence for the teeth which emerge after the sampling period stops.

Research on Caucasians of European origin, but now disseminated around the world, shows several patterns of timing for the emergence of teeth. Papers have been written following research in the USA *(Hurme, 1949; Gron, 1962)*, New Zealand *(Leslie, 1951)* and Australia *(Gates, 1964)*. Hurme quotes the age of emergence of a tooth when 68.26% of a population has that particular tooth in their mouths. These ages appear to be later than the ranges of this research but comparison between the two pieces of research would not be appropriate, as different types of data would be compared. The age ranges quoted by Leslie fit fairly evenly within this research but he quotes 12.5% and 87.5% trimmed age ranges, so this too is not a valid comparison. There is a good degree of overlap of many ranges of emergence which are published, but between them there is so much variation it is difficult to see how valid comparisons could be made.

Comparable age ranges of emergence for Non-Caucasian, Non-British studies have not been published, so no comparisons are possible

5.5 The Age of Emergence of Permanent Teeth

The age of emergence of a tooth in the mouth may be given as a median or a mean age depending on the distribution of the children in the data set and the method employed to calculate the age. Even when a single style of central tendency is chosen to express the data there may be variations in the ages of emergence calculated if different parameters are used during the calculations.

5.5.1 Comparison of Methods for Calculating Medians

The median age of emergence of the permanent teeth in this data set were calculated for each tooth in three ways so as to compare the age of emergence of each tooth using different methods. The methods chosen were

I. Undertaking a median calculation using SPSS based on the tooth specific active age ranges of emergence found by the method described in Section 3.15 of this research.

II. The same calculations after the removal of 1% and 2.5% of the tooth specific sample sizes from the top and bottom ages of each tooth specific age range, so investigating the effect of removing extreme outliers at both ends of the age range of emergence.

III. The method described in Section 3.14.2 when the children were placed in six-month age bands and life tables were constructed from which the medians were found by extrapolation

Table 5.2 gives the median ages calculated by each of the above methods.

Table 5. 2 The Age of Emergence of the Upper Right Quadrant Teeth and Lower Right Quadrant Teeth Using Methods I, II and III

	t11	t12	t13	t14	t15	t16	t17
Method I	8.52	9.76	12.08	11.49	12.12	8.20	12.58
Method II 1% trimmed	7.77	8.63	11.55	10.99	11.56	6.43	12.10
Method II 2.5% trimmed	7.51	8.42	11.40	11.21	11.48	6.28	12.04
Method III	7.13	8.23	11.50	10.81	11.73	6.42	12.53
	t41	t42	t43	t44	t45	t46	t47
Method I	7.80	9.17	11.38	11.47	12.20	7.88	12.33
Method II 1% trimmed	6.26	8.02	10.98	11.08	11.69	6.52	11.85
Method II 2.5% trimmed	6.17	7.81	10.84	10.98	11.53	6.29	11.72
Method III	6.23	7.38	10.43	10.73	11.75	6.34	11.79

Using Method 1 the results suggest tooth emergence up to two years later than found in previous research. As it could be predicted that all the older children, within the given age range, would have the specific tooth, it is likely that the medians were biased towards a higher median age of emergence.

Using Method II some of the median ages were reduced by a year and one half, but the results were still higher than those found in previous research relating to children in the UK. The arbitrary nature of the trimming process suggests that this procedure was not an appropriate method of analysis for this type of data.

Method III generally gave the youngest median age of emergence for each specific tooth, though sometimes the 2.5% trimmed at both ends of the age range of the tooth, gave a lower age. Method III was chosen as the method for this research following professional statistical advice. Fortunately, the method is simple to apply, thus making the reproduction of this work, and application of the statistical methodology to other data sets for comparison purposes, very straightforward.

The time interval between the median age emergence of a single tooth found using the three different methods for a specific tooth varied between 0.61 years for tooth 47 and 1.92 years for tooth 16. *(The differences in years for each tooth by each method can be viewed in Appendix 10.)*

This investigation showed that different methods of analysis changed the results / median age of emergence of a tooth and it confirmed the importance of only comparing results which have been analysed using the same methodology.

5.5.2 The Significance of Gender on Median Dates of Emergence

From Table 4.1 it can be seen that the median age of emergence of girls' teeth is always earlier than the median age of emergence of the same tooth for boys. A Mann Whitney U test was performed to compare the difference between the median ages of emergence of boys and the girls. It was found that in nearly all instances the difference between boys and girls age of emergence for each tooth was significant ($p<0.01$). This was not however the case for t11, t16, t33, t42, t46 where there was no significant difference and t21, t36 & t43 where the significance was $p<0.05$.

Table 5.3 The Significance of Gender on Median Dates of Emergence of Each Permanent Tooth

	t11	t12**	t13**	t14**	t15**	t16	t17**
Boys	7.71	8.98	11.63	11.13	11.92	6.50	12.50
Girls	7.02	8.00	11.14	10.66	11.55	6.32	12.52
	t21*	t22**	t23**	t24**	t25**	t26**	t27**
Boys	7.23	8.43	11.66	11.03	11.86	6.54	12.40
Girls	7.03	8.02	11.14	10.70	11.60	6.30	12.00
	t31**	t32*	t33	t34**	t35**	t36*	t37**
Boys	6.38	7.52	10.79	10.96	11.90	6.40	11.85
Girls	6.15	7.16	9.94	10.68	11.64	6.18	11.61
	t41**	t42	t43*	t44**	t45**	t46	t47**
Boys	6.34	7.49	10.78	10.95	11.84	6.46	11.88
Girls	6.31	7.45	9.96	10.55	11.51	6.23	11.67

* = P < 0.05
** = P < 0.01

5.5.3 Comparisons of the Median Age of Emergence From This Research With Other Comparable Papers.

Papers by James and Pitts *(1912)*, the Medical Research Council *(1925)*, Leslie *(1951)* from New Zealand and Lavelle *(1976)* have used the same methodology as this research to produce the median age of emergence for each permanent tooth. It was therefore possible to compare the ages of emergence of this research with these papers.

Because of the large size of the data there were extremely small confidence limits for each of the ages of emergence of the teeth. Since the data were grouped in six-month intervals, the median was calculated with a precision of three months either side of its median age of emergence, this gave a six-month age band for use in comparisons with the other papers. (A summary of the data from the four papers, the median ages of emergence from this research and the ranges created for comparison can be seen in Appendix 11.)

The age of emergence of each of the teeth of each of the four papers was compared with the range of emergence found by the above method, if an emergence age fell within the range it was considered to be the 'Same' as this research, if it fell outside the range it was considered to be 'Earlier' or 'Later'. Of the 196 comparisons that were made 110 (56%) were the 'Same', 69 (35%) were 'Later' and 17 (9%) were 'Earlier. This illustrated by Figure 5.1 and the comparative tables can be seen in Appendix 11.

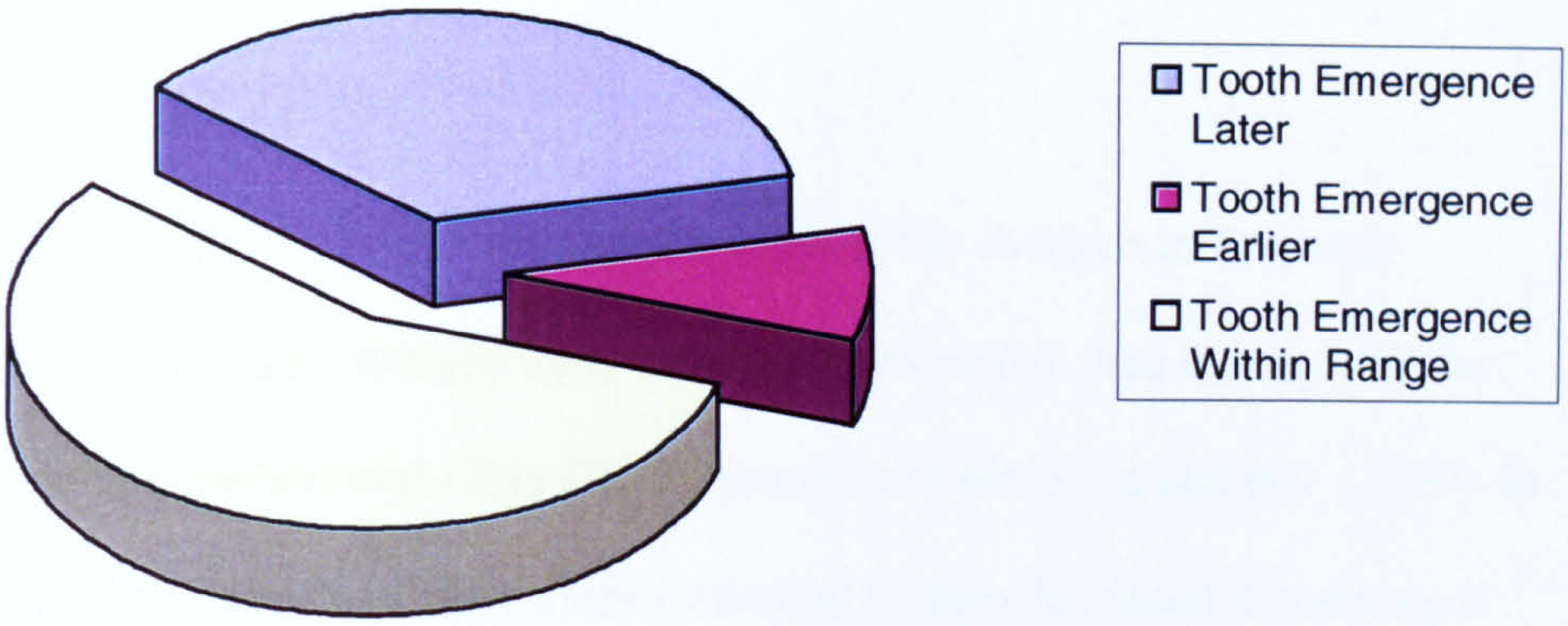


Figure 5.1 The Percentage Difference Between This Research and The Four Comparable Papers.

This comparison shows that the teeth of children in the Colchester Area of the UK are emerging somewhat later than they were in the UK in 1912, 1925 and 1976 and at about the same time as in New Zealand in 1952. As teeth are considered to be good indicators of the maturity of children this disagrees with the commonly held view that children are maturing earlier than they used to mature.

The view that children are maturing earlier may be dependent on views formed some years ago, when possibly children were maturing earlier; or it may be that children are more precocious but not maturing earlier; or it may be that society permits / encourages children to express themselves in dress and behaviour in an 'adult' manner and so they are perceived as being older than their chronological age. It is not possible to quantify how much children are perceived as 'maturing earlier' but this research does not support the view that they are maturing earlier, instead it finds that they are maturing later.

Research by Clements et al *(1953b)* showed that the teeth of the children in Registrar-General's Social Classes I and II emerged up to seven months earlier than the teeth of the children in Registrar-General's Social Class III; the research of Malcolm and Bue *(1970)* in New Guinea showed that the teeth of the children who had a better balanced diet emerged earlier than children with a poorly balanced diet; and the research of Billewicz and McGregor *(1975)* in The Gambia showed that of the children within a single age band those with more teeth tended to be heavier and taller. They concluded that, "This seems to suggest that long term under nutrition may have some influence on the eruption of permanent teeth." These papers suggest that diet is an important factor in the time of emergence of children's teeth and that the better balanced the diet the earlier their teeth emerge. As the age of emergence of children's teeth in Colchester area, sampled between 1998 and 2001, was increased in comparison with earlier samples it is possible that their diet is not as good as in previous generations. There is scope for further research into the relationship between the times of emergence of the permanent teeth of children and their diets.

5.6 The Order of Emergence of Permanent Teeth

The order in which permanent teeth are found to emerge from this research can be seen in Table 4.4 where the order of emergence of most of the teeth is identical in both upper quadrants of teeth, and both lower quadrants of teeth. There are however some differences in the order of emergence of lower first molars and incisors, and lower second premolars and second molars. As a Mann Whitney U Test has shown that there is no significant difference between the ages of emergence of contra-laterally paired teeth these differences in the order of emergence are not significant. This confirmed previous research *(Elmes and Dykes, 1997)*, which showed that there was no statistical difference in the times of emergence of all first permanent molars and lower central incisors.

A review of British papers considering the order of emergence of permanent teeth including the Medical Research Council *(1925)*, Clements et al *(1953a)*, Butler *(1962)*, Miller et al *(1965)*, Lavelle *(1976)* and Kochhar and Richardson *(1998)* has shown that groups of permanent teeth emerge together, with slightly different patterns in the upper and lower arches of teeth.

In the upper arch first molars, central incisors and lateral incisors emerge in one group over a two-year period; and canines, first premolars, second premolars and second molars emerge over another two-year period. In all instances the upper second molar is listed as the final tooth to emerge. An illustration of this pattern can be seen in Figure 4.2.

In the lower arch first molars and central incisors emerge at almost identical times followed by the lateral incisors about a year later. Canines and first premolars emerge almost simultaneously starting at about eight years of age and continuing until about thirteen years; second premolars and second molars emerge almost simultaneously about aged nine and take about six years to emerge. Sometimes the second premolar and sometimes the second molar is the last tooth to emerge in the lower arch. An illustration of this pattern can be seen in Figure 4.3.

Kochhar and Richardson *(1998)* listed the frequency of orders of 'eruption' in their sample and showed nineteen patterns of emergence in the upper arch, with 16% (the largest group) having the same order of emergence as this research, and sixteen patterns of emergence in the lower arch, with 13% (the largest group) having the same order of emergence as quadrant four of this research. Two bodies of research undertaken within a five-year period have found, that within the large variability of the human race, the same predominant pattern of emergence of the permanent teeth of the Caucasian children of the UK.

5.7 The Age of Emergence Between Contra-Lateral Pairs of Teeth

Mann Whitney U tests showed that there was no significant difference between the emergence times of contra-lateral pairs of teeth, e.g. upper first premolars (14 and 24) or lower central incisors (31 and 41), in this research data set. Clements et al *(1953 a and b)*, Stones et al *(1951)* and Kochhar and Richardson *(1998)* found the same result from their research. Other papers do not list a finding in this aspect of their analysis.

5.8 The Age of Emergence Between Ipsi-Lateral Pairs of Teeth

When a Mann Whitney U Test was run to compare the age of emergence of comparable teeth on the same side of the mouth but in upper and lower arches e.g. upper right and lower right first premolars or upper left and lower left canines, no significant difference was found (assuming that there is no significant difference between contra-lateral teeth of the same arch, see Section 5.7) between the upper and lower lateral incisors, second premolars and first and second molars. A significant difference was found between upper and lower central incisors, canines and first premolars.

There was no significant difference between the ages of emergence for any pair of teeth for the girls.

5.9 Predictive Models

In the sphere of forensic dentistry it is sometimes helpful or necessary to be able to predict the age of a child; this might be because the child has died in a mass disaster, or because a prediction of a child's age may assist in its identification; or a family may be seeking asylum and the age of their may dependents may need to be confirmed.

In the past determination of a child's age or the prediction of its age has been based on previously generated standard, like those of James and Pitts *(1912)*, Kronfeld *(1935)*, Schour and Massler *(1941)*, Hurme *(1949)*, Nolla *(1960)*, Moorrees *(Moorrees et al, 1963)*, and Demirjian *(Demirjian et al, 1973)*. Some research investigated the number of permanent teeth in a child's mouth in relation to their chronological age including Saunders *(1837)*, James and Pitts *(1912)* and Filipsson *(1975)*.

Today it is important to have current data on which to base current age assessments and age predictions. This data should be robust, reliable and valid. This research offers three methods for predicting the age of a child based on the number of permanent teeth that they have and their sex.

- Equations for predicting the age of a child using the number of permanent teeth in the whole mouth and the gender of the child, or using only one jaw and the gender of the child (Section 4.9.2)

- A graph with sex specific lines which relates the number of permanent teeth of a child to its age
- Tables for all children combined, or boys and girls separately, which can be read to give the probability of specific teeth being present at any half year age between four and fifteen. The closest match between the unknown child's data and the data within an age band gives an indication of the age of the child to within six months (Section 4.9.3)

Any one of these methods can be used independently, but a combination of methods can also be used.

5.10 Summary

This research was initiated to investigate the commonly held view that children were maturing earlier. Teeth are good indicators of age and therefore the age at which today's children's teeth emerged was investigated so that they could be compared with the ages of emergence of comparable teeth in previous papers. This permitted a comparison of the development of children today with the children who had lived over the last century.

This research has shown that instead of maturing earlier, children in the Colchester area of the UK are maturing later than twenty-five ago. The reasons for this are not immediately clear, but it is possible that socio-economic background and diet may have contributed to the changes. There may also be an associated later psychological maturation which may be associated with staying longer in the family home.

Future research should be encouraged into the relationship between the socio-economic background of children, their diet and the times of emergence of their teeth with a view to investigating their interrelationships. This work gives the sizes of data sets needed for such work.

Chapter 6: Conclusions and Recommendations

Through the statistical analysis of a data set relating to the permanent teeth of 11,770 Caucasian children from the Colchester area of the UK this research has refuted the proposition that children's teeth are emerging earlier. The permanent teeth of these children are emerging later than those of British children from the 1950's and 1970's.

As teeth are good indicators of the maturation of children this research also indicates that these same children may be maturing later than the cohorts of children investigated in the 1950's and 1970's.

Research has shown that the permanent teeth of children emerge earlier when children have a good balanced diet and good socio-economic surroundings for their upbringing. It has also shown that a poor diet and poor socio-economic backgrounds lead to the retardation of the emergence of teeth. Colchester is not an urban priority area; the overall standard of living would be considered as being good and the children who had dental examinations came from all the backgrounds found in the Colchester area. This suggests that the socio-economic background of the children did not unduly delay the age of the emergence of their teeth.

Research in the USA has shown that between 1994 and 1996 fewer than 28% of children between the ages of 2 and 18 years had a good diet and up to 23% had a bad diet. (www.childstats.gov/ac1999/econ4b.asp) (Data collected 08/12/03) Diet may be an important factor in the delayed development of children in comparison to earlier cohorts and the relationship between the times of emergence of permanent teeth and the diet of children should be investigated.

This research confirms previous research showing that girl's teeth emerge before boy's teeth, that there is no statistical difference in the age of emergence of contra-lateral teeth in the same arch; and that there is a statistical difference in the age of emergence between some ipsi-lateral teeth in opposing arches.

During this research a regression model was created to predict the age of school children between the ages of four and fifteen, based on the number of permanent teeth in their mouth and their gender. Through a linear regression it was found that the predictors, "number of permanent teeth" and "gender" could explain 86.5% of the variation of the whole model. The whole model was found to be significant ($F(1,11767) = 263.499$, $p < 0.001$). The predictor 'number of teeth' accounted for 86.2 % of the explained variation $t(1) = 274.810$, $p < 0.001$. The predictor 'gender' accounted for 0.3% of the whole variation and was found to be significant

Age = 5.670 + 0.279 * N - 0.284 * 'Gender'

Where N = Number of Permanent Teeth

Gender = 0 (For Boys)

= 1 (For Girls)

($t(1) = 16.233$ $p < 0.001$)

The coefficients from the linear regression give us the following predictive equation, as shown in equation 4.1:

$Y = a + b_1x_1 + b_2 x_2$

Age = 5.670 + 0.279 * 'number of permanent teeth' + (- 0.284 * 'gender')

This means that if the number of permanent teeth in a child's mouth are summed and multiplied by a factor of 0.279, a correction is made for girls by subtracting 0.284 years and the total added to 5.670 years, the age of a Caucasian child can be predicted. This model will give a simple and good prediction of the child's age in 87% of cases. This has the potential to be very helpful in age assessments associated with the identification of children who have died in Mass Disasters and age assessments of Caucasian children without documentation.

This research offers a simple and repeatable protocol to collect comparable data (Section 3.7); it also shows that 200 children is the minimum sample size required to replicate this research. (Section 5.2) Ideally this research would be repeated with different samples of 200 Caucasian children (100 boys and 100 girls with each hundred evenly distributed through the age band four to fifteen years) so that it could be seen if Colchester is unusual in its results or whether the trends in the UK are changing generally.

Research has shown that the teeth of different racial groups emerge at different times, for example Blankenstein et al *(1990 a and b)* found that the permanent teeth of South African Indian children emerged 3.5 to 7 months later than the permanent teeth of South African

Black children. To avoid the problems associated with previous comparative studies which failed to use standardized protocols, future work should use the research protocol designed and applied as part of this thesis to investigate the times of emergence of the permanent teeth of the different racial groups in the UK so as to establish an order of emergence between the different racial groups. The protocol was carefully designed to ensure that this would be easy to accomplish. These groups might include Scottish, Welsh and Irish children as well British Chinese, Afro-Caribbean, Somali, Bengali, Indian and Pakistani children and this would facilitate accurate age assessments to made to help in the identification of children originating in the UK who die in mass disasters. The results may also indicate areas of deprivation within certain communities.

Ideally the same research would be repeated in countries around the world so that an order of emergence between the different racial groups worldwide could be established. This would not only help with the forensic identification of children but it would also facilitate the prediction of the chronological age of children who move to a new country without legal documentation.

A further investigation could be undertaken to compare the ages of emergence of the same racial group in Britain and in their indigenous homeland, e.g. the Somali community in Britain and in Somalia. Any differences should be investigated to find the influence of diet and socio-economic on the ages of emergence of the teeth of the two communities. This research could be further expanded to include a single community in more than two countries e.g. the Chinese community in London, Hong Kong and China. If the children were having the same style of diet e.g. Cantonese, in all three communities it might reduce the influence of diet on the results and give a greater indication as to the racial component influencing the age of emergence of permanent teeth.

Further investigations using the same protocol should also be undertaken to investigate the relationship between children attending Privately and Locally Maintained schools, and healthy and medically compromised children, those with genetic or somatic disorders. This research would permit an investigation into the effects of school /educational environment and the disease processes on the development of children.

The research could also be expanded to investigate the development of abused and neglected children. If their actual chronological age is known, their dental development can be predicted and the difference between the expected and actual dental development may give an indication as to the degree of neglect which they have suffered. It may be an indicator of poor diet, care and/or socio-economic influences on the child. More research would be required to investigate the possible relationships between these children and their circumstances before any firm conclusions could be drawn, but some useful indicators may be found.

This research provides a reliable, robust, easily reproduced standardized method of age assessment which can easily be used by all forensic odontologists, and a predictive formula which can used by many in the prediction of the age of children.

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Appendix 1

NHS Primary Care Dental Services – Appendix B

Health Service
Guidelines

NHS

HSG(97)4

Date 14 March 1997

Primary Care Dental Services

Executive summary

This circular:

- Reinforces existing policy on the Community Dental Services.
- Gives details about applications for approval (under Section 56 of the 1977 NHS Act) of schemes to tackle difficulties in the local availability of dentistry, as an alternative to salaried dentists.

Background

The independent General Dental Practitioner should remain the preferred provider of routine primary oral health care, In most parts of the country General Dental Services (GDS) are accessible to all who wish to make use of them. There are, however, local pockets where there are shortages of dentists offering NHS services. The problem is often strongly localised. One of the functions of the Community Dental Service (CDS) is to provide a safety net service for patients who have approached their Health Authority (HA) for help in finding an NHS dentist, and for whom the HA is unable to find them a GDS dentist. The role of health authorities is shown in Annex A and the CDS in Annex B.

Where both the GDS and the CDS are temporarily facing significant difficulties in meeting demand for primary care dental services, there are a number of short-term measures the HA may wish to consider to bridge the gap until either GDS or CDS provision can be increased or adjusted appropriately. Guidance on these options is contained in this circular in Annexes C and D. The options in C and D are by nature temporary and not an alternative to the provision of the community dental service safety net. Information about applications is given at Annex E.

The White Paper "Choice and Opportunity" set out the Government's long term intention to permit piloting of new local arrangements for the delivery of primary care dental services through local arrangements between health authorities and service providers. The schemes outlined in the White Paper are intended to encourage local flexibility so that services can be delivered in a way which is better attuned to local needs and circumstances. Such arrangements will eventually be a local alternative to existing national arrangements for the provision of general dental services.

Addressees

For action:

HA Chief Executives
NHS Trust Chief Executives
Regional Office Dental Advisors

Annex B

Community Dental Service

Health Authorities should ensure that services for those experiencing difficulty in obtaining treatment in the General Dental Services continue to be available through the Community Dental Service. This function is additional to that provided to patients who not otherwise seek care within the GDS. Developing an integrated NHS dental service will depend on effective partnerships across the boundary of primary and secondary care.

Role of the Community Dental Service

B1) In 1989 the Department of Health issued guidance in circular HC(89)2, together with an accompanying letter from the Chief Dental Officer (PL/CDO(89)2i), to Health Authorities about the important roles and functions of the Community Dental Service. This guidance remains valid but is updated in B2 below.

B2) Health authorities should plan local dental services and monitor the dental health of all age groups in the population as part of their dental public health responsibilities. In addition, health authorities should contract for the CDS to undertake the following objectives:

- o the provision of dental health promotion programmes.
- o the provision of facilities for a *full* range of treatment to patients for whom there is evidence that they would not otherwise seek treatment from the general dental services, eg. patients with special needs.
- o The provision of facilities for a *full* range of treatment to patients who have experienced difficulty in obtaining treatment in the GDS. (This is normally termed the safety net function.)
- o The provision of treatment which may not be generally available in the general dental service, such as anaesthetics and orthodontics.
- o Oral screening for children in state funded schools at least three times in each child's school life (this may need to be more frequent where the area has generally poor dental health) and of other client groups with particular special needs.
- o The provision of epidemiological field work, principally for use by health authorities in planning local dental services, but also when required as part of the periodic programme of national surveys of child and adult dental health sponsored by the Department of Health.

Safety Net

B3) The White Paper "Improving NHS Dentistry" recognised that HAs have, on occasion, recourse either to salaried dentists or to the CDS to provide safety net services. The aim is that over time the CDS should replace the present reliance on salaried dentists, which is a short-term solution. It is the responsibility of Health Authorities to monitor local need and availability of General Dental Services to inform decisions on the appropriate allocations of resources to the CDS with the intention of strengthening its safety net role.

Appendix 2

Local Essex Rivers Health Authority Area Code of Ethics

Permission to reproduce Essex Rivers Health Authority's ethical guidance was given by Senior Dental Officer Mr. Andrew Clayton.

CONSENT TO DENTAL INSPECTION AT SCHOOL

The Department of Health's position with regard to consent to examination and treatment is set out in the NHSME booklet *"A guide to consent for examination and treatment"* which was issued under cover of HC(90)22.

That guidance distinguishes between expressed and implied consent. It makes the point that parental consent should be obtained where a child under age 16 does not have sufficient understanding of what is proposed.

At the root of consent is the capacity to understand what the proposed examination or treatment is about. In general terms the capacity of children increases as they grow older, but there will always be exceptions in particular cases.

The underlying principle was discussed in the Gillick case *(Gillick -v- west Norfolk and Wisbech Area Health Authority and another)* when it was said:

> "... parental right yields to the child's right to make his own decisions when he reaches a sufficient understanding and intelligence to be capable of making up his own mind on the matter requiring decision."

In theory, a five year old who was considered to have sufficient understanding etc could consent in his own right. The Gillick judgement does not specify ages. There is an argument for the proposition that when children deemed to have sufficient understanding etc present themselves for examination and they do not object, that they are giving implied consent.

With children under 16 however there is a tendency towards requiring parental consent for dental examinations as being proper. Where parental consent is not given, or in the case of older children where the child is not able to give consent either, then there is no proper legal basis for a dental inspection to be performed. It is not safe to assume that consent has been given.

Section 5 of the National Health Service Act 1977, as amended by the Health and Medicines Act 1988, makes it a duty of the Secretary of State to:

> *"...provide, to such extent as he considers necessary to meet all reasonable requirements -*
>
> *(a) for the dental inspection of pupils in attendance at schools maintained by local education authorities or at grant-maintained schools;..................."*

However merely putting a duty on the Secretary of State does not endow her with the power to require pupils to submit for inspection.

Section 48(4) of the Education Act 1944, as amended by the Education Reform Act 1988, provides:

> *"(4) It shall be the duty of every local education authority or, in the case of pupils at a grant-maintained school, the duty of the governing body of the school to make arrangements for encouraging and assisting pupils to take advantage of the provision for medical and dental inspection and treatment made for them in pursuance of section 5(1) of the National Health Service Act 1977, or paragraph l(a)(i) of Schedule I to that Act.*
>
> *Provided that if the parent of any pupil gives to the authority or, as the case may be, to the governing body notice that he objects to the pupil availing himself of any of the provision so made, the pupil shall not be encouraged or assisted so to do."*

Following the principle in the above proviso, the argument that there might be situations where "negative consent" might be inferred (ie where parents have been told in advance that their children might be examined and had offered no objection) has been addressed.

There first needs to be a degree of certainty that the advance notification of the examination was received by the parent(s) concerned. In these circumstances it might well be argued that it would a hard finding by a Court, where a professional person acts in a bona-fide manner in carrying out routine inspections believing that s/he has consent, to find trespass to the person of the child.

Circular HC(89)34 described the arrangements for the indemnity scheme which has operated from 1 January 1990 when health authorities undertook direct responsibility for the acts and omissions of their medical and dental staff. Similar cover is provided by NHS Trusts. EL(90)195 explains that Trusts may spread their risks more widely than health authorities and are free to make insurance arrangements which they consider to be cost effective for most risks. But they are not allowed to insure against clinical negligence.

In the last analysis therefore, it is for employing authorities/trusts who, as well as having direct responsibility for the acts and omissions of their dental staff, share vicarious liability for those acts and omissions, to decide whether they are prepared to defend their dentists if they decide to adopt a policy of negative consent. In making their decision it will be for them to consider the extent of acceptable risk having regard to the advice of their own legal advisers.

Essex Rivers Healthcare
A National Health Service Trust
Dental Services

Dental Department, Central Clinic,East Lodge Court, High Street, COLCHESTER, Essex. CO1 1UJ

Tel:- 01206 744087

Dear Parent/Guardian,

During the current school year *a* dental survey of 12 year old children is being carried out throughout the country to gather information on dental health on behalf British Association for the Study of Community Dentistry. 12 year olds have been selected randomly and your child is one of those selected.

The information obtained from the survey will be useful for future planning of dental services so your co-operation would be greatly appreciated.

if you do not wish your child to be seen at the school for this dental inspection would you please return the lower section of this form to the school office or to me at the above address.

Yours faithfully,

Mr. G. Brown,

Community Dental Officer.

NAME ....

SCHOOL ....

I do **not** wish my child to be examined at school for the dental health survey.

Signature of Parent or Guardian ....

Essex Rivers Healthcare
NHS Trust

Dental Services

Correspondence to:-
Dental Department
Central Clinic East Lodge Court
High Street
COLCHESTER
Essex CO1 1UJ
TEL: 01206 744087

Dear Parent/Guardian

The Community Dental Officer plans to visit your child's school in the near future to inspect the teeth of some of the pupils. While children are screened we would wish you to continue your own arrangements for the regular dental care of your child.

This dental screening provides an opportunity to check your child's teeth and advise if necessary. It also provides general information and statistics which are valuable for future planning of dental services.
This is merely a screening and no treatment will be carried out on this occasion.

SENIOR DENTAL OFFICER
MR A M CLAYTON BDS,DDPH,RCS(Eng.)

WMR 525

West Mersea Dental Practice,
32A, Kingsland Road,
West Mersea,
Colchester. CO5 8RA.

6/01/00

Dear Parent / Guardian,

As part of a survey to update 50 year old records of British children's teeth, I am undertaking a survey of the teeth of the young people of years 7 and 8 in the Colchester area. The information will be used to help in future planning of dental services in this area.

I will be visiting school on Wednesday 26th January, and will examine, but not treat all the children in these years.

If you do not wish your child to be seen during the survey would you please return the lower section of this form to the school office, or to me at the above address.

Yours faithfully

A.J.Elmes
Dental Surgeon

Name ______________________________ School ________________________________

I do **not** wish my child to be examined at school for the dental health survey.

Signature of Parent or Guardian ______________________________________

Please print name in capitals ____

Appendix 3

University of Hertfordshire Ethical Approval for the Researcher

UNIVERSITY OF

HERTFORDSHIRE FACULTY

OF HEALTH & HUMAN

SCIENCES

Research Ethics Committee for Nursing, Midwifery, Social Work and Counselling

Name of Student/Staff:	**AMANDA ELMES - NURSING & PARAMEDIC SCIENCES (PHD - POSTGRADUATE RESEARCH)**
Title of Programme	**THE AGE OF EMERGENCE OF PERMANENT TEETH OF CAUCASIAN CHILDREN IN THE COLCHESTER AREA OF THE UNITED KINGDOM**

Chair's Action has now been taken to approve your amended ethics application, taking into account the amendments requested in my memo dated 13 July, 1999.

Your research study can now commence without delay.

Your application has been given Approval Number: NM2261.

If any significant changes are made to the methodology the

Committee must be informed.

The enclosed Quality Monitoring Form must be completed and returned to the Committee Administrator, Avis Cowley, (Tel: 01707 285996), Room 2F258, Wright Building, Hatfield Campus, immediately the study is finished.

Geraldine Byrne
Chair of Ethics Committee for Nursing, Midwifery, Social Work & Counselling
Nursing & Adult Health, Room LF277
Tel. No: 01707 285943

c.c. Supervisor: Dr. Eric Dykes, Department of Nursing & Paramedic Sciences

Appendix 4

Tooth Charting Conventions Used During This Research

The original paper records recording the teeth present in each child's mouth at the time of the dental examination used the Palmer – Zsigmondy System of dental notation, which was the system routinely used in the UK at the time of data collection.

Under the Palmer – Zsigmondy System of dental notation, individual teeth are identified in the mouth by giving them specific numbers (signifying permanent teeth) or letters (signifying deciduous teeth). The mouth is divided into four equal quadrants depicted in Figure 6.1 below. The horizontal line, shown in red separates the area between the upper and lower teeth and the vertical line, shown in green, between the middle two front teeth of each arch differentiates the right and left quadrants of each arch.

1	2
4	3

Figure A 4.1 Diagrammatic Representation of the Nomenclature of the Four Quadrants of the Mouth

Within each quadrant the teeth are numbered, starting from the middle and working systematically backwards. As in a typical permanent dentition, there are eight teeth in each quadrant, each quadrant has teeth numbered from one to eight, with the tooth nearest the mid-line is numbered one and the tooth at the back is numbered eight. Those in between are sequentially numbered two to seven.

In this system of notation there are four teeth numbered one etc. so in order to define the position of each individual tooth, it is necessary to state the quadrant in which it is found. The quadrants are named upper right, upper left, lower left and lower right, and relate to the actual anatomical part of the mouth where the tooth is found. This means that the upper left central incisor is called the 'upper left one', whereas the lower right central incisor is called the 'lower right one' and so on. Data from both permanent and deciduous dentitions is entered on a single line.

When the information from the paper records was transferred to an electronic database the data for the permanent and deciduous teeth was entered on different lines of the form, with the permanent teeth in the middle and the deciduous teeth outside them.

To simplify the identification of each field the quadrants were identified by their Federation Dentaire Internationale (FDI) number as shown in Figure A4.1. The deciduous quadrants follow the same pattern and are numbered 5, 6, 7 and 8. Each tooth within a quadrant is numbered from 1 to 8 (permanent teeth) and 1 to 5 (deciduous teeth), starting at the mid-line and working outwards, so the upper right first permanent molar is tooth 16, and the lower left first deciduous molar 74. (As third permanent molars / ‘wisdom teeth’ [numbered eight] are not investigated during this research no reference will be found to them in the results.)

The FDI system of tooth identification, modified by adding the letter ‘t’ In front of each tooth number was used in all analyses. A diagrammatic representation of the system is shown in Figure A4.2.

18	17	16	15	14	13	12	11	21	22	23	24	25	26	27	28
48	47	46	45	44	43	42	31	41	32	33	34	35	36	37	38

Figure A4.2 Diagrammatic Representation of Each Tooth Numbered by the FDI Convention

Appendix 5

Definition of Dental Terms

5.1 Dilacerated Teeth

Dilacerated teeth are teeth which, through a developmental aberration, appear to be almost completely divided vertically into two parts, even though they have a single root and crown. The term 'dilaceration' relates to the appearance of the crown of a tooth, not its function.

5.2 Geminated Teeth

Geminated teeth are teeth which, through a developmental aberration, appear to be two teeth joined together, though they are in fact a single tooth with a single root and crown. The combined width of the tooth is twice that which might be expected, of a single tooth. The term 'geminated' relates to the appearance of the crown of a tooth, not its function.

Appendix 6

The Children Who Had a Dental Examination But Who Were Removed From the Data Set (Table A6)

ID Number	SEX	Data
19	2	14 XLA Ortho
70	1	Charting
72	2	15 and 24 XLA Ortho
337	1	14, 24, 34 and 44 XLA Ortho
354	2	14, 24, 34 and 44 XLA Ortho
379	1	55, 65, 75 and 85 XLA Caries
397	1	36 XLA Caries
401	1	75 XLA Caries
426	1	36 XLA Caries
428	1	36 and 46 XLA
450	1	75 XLA
521	1	75 and 85 XLA Caries
666	2	82 and 83 fused
669	2	82 supernumary
672	1	75 and 85 XLA Caries
797	2	15, 25, 35 and 45 XLA Ortho
989	1	36 XLA Caries
1133	2	14, 24, 34 and 44 XLA Ortho
1153	2	12 Peg lateral, 22 ? Absent
1180	2	82 and 83 fused
1215	2	Repaired cleft lip, 22 missing
1236	2	46 XLA Caries
1273	1	34 ? Absent
1289	2	16, 26, 36 and 46 XLA Ortho
1324	1	16, 36 and 46 XLA 26 present
1361	2	14, 24, 34 and 44 XLA Ortho
1368	1	?42 missing or fused to 41
1383	2	16, 26, 36 and 46 XLA Ortho
1406	1	12 absent ? congenitally
1411	1	12 absent ? congenitally
1414	2	16 absent
1699	1	16 XLA Ortho
1753	2	32 and 43 XLA Ortho
1757	2	15 and 25 XLA Ortho
2208	2	Charting
2350	1	Odontogenesis imperfecta

ID Number	SEX	Data
2624	1	12 and 22 absent
3148	1	16 and 46 XLA Ortho/Hypoplastic
3161	2	36 and 46 XLA Ortho
3164	2	14, 24, 34 and 44 XLA Ortho
3172	1	14, 24, 34 and 44 XLA Ortho
3458	1	Developmental Syndrome
3515	2	11 absent
3724	1	14, 24, 34 and 44 XLA Ortho
3980	2	34 XLA Ortho
4008	1	26 XLA Ortho
4028	1	11 Exfoliated in accident
4259	2	16 and 46 XLA
4577	2	16, 26, 36 and 46 XLA Ortho
4619	2	Downs Syndrome
4832	1	21 absent
5069	2	14, 24, 34 and 44 XLA Ortho
5163	2	81 retained ? 41 absent
5200	1	16 XIA Trauma
5239	1	16, 26, 36 and 46 XLA Ortho
5249	1	41 absent
5253	2	14, 24 34 and 44 XLA
5343	2	21 Lost after accident
5448	2	26 XLA Hypoplastic enamel
5502	2	12 and 22 absent
5513	2	14, 24 34 and 44 XLA Ortho
6242	1	14, 24, 34 and 44 XLA Ortho
6343	2	12 absent
6366	2	12 absent
6640	2	32 and42 absent
6673	2	16, 26, 36 and 46 XLA Ortho
6686	1	46 XLA
6877	1	Downs Syndrome
6899	1	16, 26, 36 and 46 XLA Ortho
6909	2	12 absent, 22 peg lateral
6983	1	11 Lost, trauma
7017	1	No 11
7045	2	32 absent
7134	2	21 lost, trauma
7159	1	15 and 25 XLA Ortho
7249	1	36 and 46 XLA
7414	1	46 XLA Caries
7418	1	Charting
7918	1	41 congenitally absent
8337	2	82 and 83 fused
8464	2	16, 26, 36 and 46 XLA Ortho
8549	1	72 absent, 82 and 83 fused
8654	1	Charting
8661	1	16 and 26 XLA Ortho

ID Number	SEX	Data
8666	2	12 absent
8765	1	82 and 83 fused
8805	2	26 XLA Caries
8809	2	12 and 22 absent
8832	1	15, 25, 34 and 45 XLA Ortho
8833	2	16, 26, 36 and 46 XLA Ortho
8910	1	Downs Syndrome
8967	2	32 and 42 absent
9155	1	46 XLA Caries
9163	2	46 XLA Caries
9199	1	14 and 44 XLA Ortho
9353	1	46 XLA Caries
9366	1	12 and 22 absent
9380	1	31 absent, severe hypodontia
9453	1	61 and 62 retained
9544	1	15, 25, 35 and 45 XLA Ortho
9562	1	15 and 25 XLA Ortho
9567	1	15, 25, 35 and 45 XLA Ortho
9593	1	14, 24, 34 and 44 XLA Ortho
9606	1	37 and 47 XLA Ortho
9610	1	14, 24, 34 and 44 XLA Ortho
9633	1	14 and 24 XLA Ortho
9642	1	14 and 24 XLA Ortho
9655	1	14 and 24 XLA Ortho
9664	1	14 and 24 XLA Ortho
9671	1	14, 24, 34 and 44 XLA Ortho
9728	2	15 XLA Ortho
9729	1	24, 34 and 45 XLA Ortho
9755	1	12 and 22 absent
9809	2	24 XLA Ortho
9838	1	12 congenitally absent
9842	2	14, 24, 34 and 44 XLA Ortho
9843	1	14 and 24 XLA Ortho
9852	1	14, 24, 35 and 45 XLA Ortho
9857	2	23 absent
9864	2	46 XLA
9877	2	13 and 23 absent
9882	1	15, 25, 35 and 45 XLA Ortho
9894	2	25 XLA Ortho
9911	2	14 and 24 XLA Ortho
9914	1	15, 25, 35 and 45 XLA Ortho
9915	1	15, 25, 35 and 45 XLA Ortho
9917	1	14, 24, 34 and 44 XLA Ortho
9937	2	22 absent
10009	1	Charting
10023	2	16, 26, 36 and 46 XLA Ortho
10163	2	14, 24 35 and 45 XLA Ortho
10171	2	14, 24, 34 and 44 XLA Ortho

ID Number	SEX	Data
10177	2	12 and 22 absent
10184	2	14, 24 35 and 45 XLA Ortho
10195	2	14 and 24 XLA Ortho
10197	1	12 and 22 absent
10202	2	14, 24, 34 and 44 XLA Ortho
10208	2	15 and 25 XLA Ortho
10213	1	25 XLA Ortho
10216	1	14, 24 and 45 XLA Ortho
10220	2	15, 25, 35 and 45 XLA Ortho
10221	2	16, 26, 36 and 46 XLA Ortho
10237	2	14, 24, 34 and 44 XLA Ortho
10241	1	14, 24, 34 and 44 XLA Ortho
10246	1	14 and 24 XLA Ortho, 12 absent
10254	1	36 XLA Caries
10285	1	Hypodontia
10296	1	14 and 24 XLA Ortho
10323	2	15, 25, 35 and 45 XLA Ortho
10336	1	15, 25, 35 and 45 XLA Ortho
10352	2	15, 25, 35 and 45 XLA Ortho
10370	1	14 and 24 XLA Ortho
10377	2	14, 24, 35 and 45 XLA Ortho
10383	1	12 and 22 absent
10388	2	14, 15, 23, 25, 34, 35, 44, 45 XLA Ortho
10394	1	34 XLA Ortho
10398	1	15, 24, 25, 34, 35 and 45 XLA Caries
10403	2	14, 24, 34 and 44 XLA Ortho
10405	2	16 and 26 XLA Ortho
10406	2	14, 24, 34 and 44 XLA Ortho
10408	2	15, 25, 35 and 45 XLA Ortho
10417	2	12 absent
10430	1	15, 25, 35 and 45 XLA Ortho
10450	2	14 and 24 XLA Ortho
10452	1	14 and 24 XLA Ortho
10466	2	15 and 25 XLA Ortho
10469	2	14, 24, 35 and 45 XLA Ortho
10488	2	14, 24, 35 and 45 XLA Ortho
10505	2	14 and 24 XLA Ortho
10520	2	35 XLA Ortho
10527	2	15 and 25 XLA Ortho
10531	2	15, 25, 35 and 45 XLA Ortho
10573	1	42 congenitally absent
10597	2	14, 24, 34 and 44 XLA Ortho
10599	2	14, 24, 34 and 44 XLA Ortho
10619	2	12 absent
10638	1	22 absent
10706	2	12 and 22 absent
10735	2	12 absent

ID Number	SEX	Data
10763	1	12 and 22 absent
10784	2	14 and 24 absent
10801	2	22 absent
10809	1	17, 27 37 and 47 XLA Ortho
10843	2	12 absent
10886	1	12 and 22 absent
10911	2	72 and 73 fused. 32 ?absent
11078	2	46 XLA caries
11105	1	16, 26, 36 and 46 XLA
11212	1	?21 absent
11258	2	36 and 46 roots only
11364	2	? 22 absent
11391	1	? 42 absent
11533	2	26 XLA Caries
11653	1	55, 65, 75 and 85 XLA Caries
11694		Damaged Card
11720		Damaged Card
11740	2	31 and 41 absent, 71 and 81 retained
11762	1	? 12 absent
11824		Damaged Card
11837		Damaged Card
11880	2	16 and 36 XLA Caries
11904	2	14 and 24 XLA Ortho
11913	1	12 supplemental 21 missing
11925	2	46 XLA Caries
12000	2	72 and 82 absent
12004		Damaged Card
12165	2	22 absent
12171	2	32 absent
12203	2	12 absent
12205	1	22 absent
12258	1	12 and 22 absent
12262	2	12 and 22 absent
12266	2	22 absent
12280	2	15 unerupted
12284	2	22 absent
12359	2	22 absent
12364	2	32 and 42 absent
12383	1	42 absent

Appendix 7

Number of Children From Whom Median Ages Were Calculated for Each Tooth

Table A7.1 The Number of Children in the Sub-Data Set for Each Tooth *Investigated*

	t11	t12	t13	t14	t15	t16	t17
All	7817	6166	2020	2770	1833	8740	1238
Boys	4016	3081	940	1355	884	4518	601
Girls	3801	3085	1080	1415	949	4222	637
	t21	t22	t23	t24	t25	t26	t27
All	7810	6199	2024	2755	1797	8750	1265
Boys	4009	3097	939	1360	862	4507	630
Girls	3801	3102	1085	1395	935	4243	635
	t31	t32	t33	t34	t35	t36	t37
All	8920	7394	3217	2878	1701	8842	1675
Boys	4575	3767	1460	1388	813	4549	806
Girls	4345	3627	1757	1490	888	4293	869
	t41	t42	t43	t44	t45	t46	t47
All	8959	7397	3215	2892	1751	8791	1618
Boys	4604	3768	1470	1400	844	4524	786
Girls	4355	3629	1745	1492	907	4267	832

Appendix 8

Life Table for Six Month Age Bands Giving the Percentage of Children With Each Tooth Emerged In Each of the Age Bands (4 – 15) For the Teeth in Quadrant 1 (t11 – t17)

Table A8.1 All Children Quadrant 1

	t11	t12	t13	t14	t15	t16	t17
4.00	0%	0%	0%	0%	0%	0%	0%
4.50	0%	0%	0%	0%	0%	0%	0%
5.00	0%	0%	0%	0%	0%	3%	0%
5.50	1%	0%	0%	0%	0%	10%	0%
6.00	4%	0%	0%	0%	0%	31%	0%
6.50	20%	1%	0%	0%	0%	54%	0%
7.00	42%	5%	0%	0%	0%	75%	0%
7.50	74%	19%	0%	0%	0%	94%	0%
8.00	88%	41%	0%	0%	0%	97%	0%
8.50	95%	60%	0%	2%	0%	99%	0%
9.00	98%	78%	2%	7%	2%	100%	0%
9.50	100%	91%	3%	12%	4%	100%	1%
10.00	100%	96%	11%	28%	9%	100%	2%
10.50	100%	98%	17%	38%	16%	100%	7%
11.00	100%	98%	36%	57%	31%	100%	14%
11.50	100%	99%	50%	69%	43%	100%	24%
12.00	100%	100%	69%	81%	58%	100%	41%
12.50	100%	100%	77%	89%	66%	100%	49%
13.00	100%	100%	82%	94%	83%	100%	66%
13.50	100%	100%	87%	91%	82%	100%	84%
14.00	100%	100%	97%	100%	95%	100%	92%
14.50	100%	100%	98%	100%	97%	100%	92%
15.00	100%	100%	98%	100%	99%	100%	95%

Life Table for Six Month Age Bands Giving the Percentage of Children With Each Tooth Emerged In Each of the Age Bands (4 – 15) For the Teeth in Quadrant 2 (t21 – t27)

Table A8.2 All Children Quadrant 2							
	t21	t22	t23	t24	t25	t26	t27
4.00	0%	0%	0%	0%	0%	0%	0%
4.50	0%	0%	0%	0%	0%	0%	0%
5.00	0%	0%	0%	0%	0%	2%	0%
5.50	1%	0%	0%	0%	0%	10%	0%
6.00	5%	0%	0%	0%	0%	31%	0%
6.50	20%	1%	0%	0%	0%	54%	0%
7.00	41%	6%	0%	0%	0%	77%	0%
7.50	74%	20%	0%	0%	0%	94%	0%
8.00	87%	41%	0%	0%	0%	98%	0%
8.50	95%	62%	0%	3%	1%	99%	0%
9.00	98%	80%	1%	6%	2%	100%	0%
9.50	100%	91%	3%	12%	4%	100%	0%
10.00	100%	95%	11%	25%	8%	100%	3%
10.50	100%	97%	19%	37%	16%	100%	5%
11.00	100%	99%	35%	56%	29%	100%	14%
11.50	100%	100%	52%	69%	41%	100%	25%
12.00	100%	100%	67%	83%	58%	100%	45%
12.50	100%	100%	77%	90%	66%	100%	51%
13.00	100%	100%	82%	93%	81%	100%	67%
13.50	100%	100%	87%	93%	84%	100%	87%
14.00	100%	100%	97%	100%	92%	100%	91%
14.50	100%	100%	97%	100%	97%	100%	95%
15.00	100%	100%	98%	100%	98%	100%	98%

Life Table for Six Month Age Bands Giving the Percentage of Children With Each Tooth Emerged In Each of the Age Bands (4 – 15) For the Teeth in Quadrant 3 (t31 – t37)

Table A8. 3 All Children Quadrant 3							
	t31	t32	t33	t34	t35	t36	t37
4.00	0%	0%	0%	0%	0%	0%	0%
4.50	1%	0%	0%	0%	0%	0%	0%
5.00	3%	0%	0%	0%	0%	2%	0%
5.50	11%	1%	0%	0%	0%	10%	0%
6.00	35%	2%	0%	0%	0%	35%	0%
6.50	63%	10%	0%	0%	0%	60%	0%
7.00	84%	33%	0%	0%	0%	81%	0%
7.50	96%	55%	0%	0%	0%	95%	0%
8.00	99%	77%	1%	0%	0%	97%	0%
8.50	99%	89%	3%	1%	0%	99%	0%
9.00	100%	97%	8%	6%	1%	100%	0%
9.50	100%	99%	21%	13%	0%	100%	1%
10.00	100%	100%	37%	23%	7%	100%	7%
10.50	100%	100%	51%	40%	14%	100%	10%
11.00	100%	100%	71%	61%	26%	100%	22%
11.50	100%	100%	81%	74%	41%	100%	40%
12.00	100%	100%	89%	87%	57%	100%	60%
12.50	100%	100%	96%	91%	64%	100%	72%
13.00	100%	100%	97%	96%	75%	100%	82%
13.50	100%	100%	96%	98%	82%	100%	80%
14.00	100%	100%	100%	100%	96%	100%	95%
14.50	100%	100%	100%	100%	97%	100%	97%
15.00	100%	100%	100%	100%	93%	100%	98%

Life Table for Six Month Age Bands Giving the Percentage of Children With Each Tooth Emerged In Each of the Age Bands (4 – 15) For the Teeth in Quadrant 4 (t41 – t47)

Table A8.4 All Children Quadrant 4							
	t41	t42	t43	t44	t45	t46	t47
4.00	0%	0%	0%	0%	0%	0%	0%
4.50	0%	0%	0%	0%	0%	0%	0%
5.00	3%	0%	0%	0%	0%	2%	0%
5.50	11%	1%	0%	0%	0%	10%	0%
6.00	37%	3%	0%	0%	0%	32%	0%
6.50	65%	12%	0%	0%	0%	58%	0%
7.00	86%	31%	0%	0%	0%	81%	0%
7.50	97%	56%	0%	0%	0%	94%	0%
8.00	99%	76%	1%	1%	0%	97%	0%
8.50	99%	89%	3%	2%	0%	99%	0%
9.00	100%	96%	8%	7%	1%	100%	0%
9.50	100%	98%	19%	13%	3%	100%	1%
10.00	100%	100%	38%	23%	6%	100%	6%
10.50	100%	100%	52%	41%	15%	100%	9%
11.00	100%	100%	71%	61%	27%	100%	22%
11.50	100%	100%	80%	74%	41%	100%	39%
12.00	100%	100%	88%	87%	59%	100%	58%
12.50	100%	100%	96%	92%	69%	100%	66%
13.00	100%	100%	97%	96%	77%	100%	80%
13.50	100%	100%	98%	96%	78%	100%	84%
14.00	100%	100%	100%	100%	97%	100%	93%
14.50	100%	100%	100%	100%	95%	100%	97%
15.00	100%	100%	100%	100%	95%	100%	98%

Life Table for Six Month Age Bands Giving the Percentage of Boys With Each Tooth Emerged In Each of the Age Bands (4 – 15) For the Teeth in Quadrant 1 (t11 – t17)

Table A8.5 Boys Quadrant 1							
	t11	t12	t13	t14	t15	t16	t17
4.00	0%	0%	0%	0%	0%	0%	0%
4.50	0%	0%	0%	0%	0%	0%	0%
5.00	0%	0%	0%	0%	0%	3%	0%
5.50	1%	0%	0%	0%	0%	7%	0%
6.00	4%	0%	0%	0%	0%	26%	0%
6.50	16%	0%	0%	0%	0%	50%	0%
7.00	36%	0%	0%	1%	0%	70%	0%
7.50	69%	2%	0%	0%	0%	93%	0%
8.00	85%	13%	0%	0%	0%	98%	0%
8.50	92%	33%	0%	2%	0%	99%	0%
9.00	98%	51%	1%	5%	1%	100%	0%
9.50	100%	72%	2%	9%	3%	100%	0%
10.00	100%	90%	7%	26%	10%	100%	1%
10.50	100%	95%	12%	34%	10%	100%	4%
11.00	100%	97%	24%	48%	24%	100%	9%
11.50	100%	98%	45%	66%	39%	100%	21%
12.00	100%	99%	64%	75%	52%	100%	37%
12.50	100%	100%	72%	86%	64%	100%	50%
13.00	100%	100%	75%	90%	79%	100%	60%
13.50	100%	100%	84%	89%	79%	100%	84%
14.00	100%	100%	100%	100%	97%	100%	89%
14.50	100%	100%	100%	100%	95%	100%	94%
15.00	100%	100%	100%	100%	100%	100%	95%

Life Table for Six Month Age Bands Giving the Percentage of Boys With Each Tooth Emerged In Each of the Age Bands (4 – 15) For the Teeth in Quadrant 2 (t21 – t27)

Table A8.6 Boys Quadrant 2							
	t21	t22	t23	t24	t25	t26	t27
4.00	0%	0%	0%	0%	0%	0%	0%
4.50	0%	0%	0%	0%	0%	0%	0%
5.00	0%	0%	0%	0%	0%	2%	0%
5.50	1%	0%	0%	0%	0%	7%	0%
6.00	4%	0%	0%	0%	0%	26%	0%
6.50	13%	0%	0%	0%	0%	48%	0%
7.00	35%	2%	0%	1%	0%	73%	0%
7.50	68%	13%	0%	0%	0%	93%	0%
8.00	85%	33%	0%	1%	0%	97%	0%
8.50	94%	53%	0%	3%	1%	99%	0%
9.00	98%	74%	1%	4%	1%	100%	0%
9.50	100%	89%	1%	9%	3%	100%	0%
10.00	100%	94%	7%	22%	7%	100%	2%
10.50	100%	98%	16%	33%	11%	100%	3%
11.00	100%	99%	25%	49%	22%	100%	9%
11.50	100%	100%	45%	65%	36%	100%	23%
12.00	100%	100%	61%	78%	55%	100%	42%
12.50	100%	100%	69%	87%	62%	100%	52%
12.00	100%	100%	76%	90%	75%	100%	61%
13.50	100%	100%	84%	95%	79%	100%	84%
14.00	100%	100%	100%	100%	92%	100%	89%
14.50	100%	100%	97%	100%	98%	100%	97%
15.00	100%	100%	95%	100%	95%	100%	100%

Life Table for Six Month Age Bands Giving the Percentage of BoysWith Each Tooth Emerged In Each of the Age Bands (4 – 15) For the Teeth in Quadrant 3 (t31 – t37)

Table A8.7 Boys Quadrant 3							
	t31	t32	t33	t34	t35	t36	t37
4.00	0%	0%	0%	0%	0%	0%	0%
4.50	1%	0%	0%	0%	0%	0%	0%
5.00	2%	0%	0%	0%	0%	2%	0%
5.50	7%	0%	0%	0%	0%	7%	0%
6.00	30%	1%	0%	0%	0%	29%	0%
6.50	57%	8%	0%	0%	0%	56%	0%
7.00	79%	23%	0%	0%	0%	75%	0%
7.50	94%	49%	0%	0%	0%	95%	0%
8.00	98%	72%	0%	0%	0%	97%	0%
8.50	99%	85%	1%	1%	0%	99%	0%
9.00	100%	95%	2%	4%	1%	100%	0%
9.50	100%	99%	11%	9%	2%	100%	1%
10.00	100%	100%	22%	20%	7%	100%	5%
10.50	100%	99%	39%	30%	10%	100%	4%
11.00	100%	100%	58%	52%	18%	100%	17%
11.50	100%	100%	71%	70%	37%	100%	34%
12.00	100%	100%	86%	83%	53%	100%	57%
12.50	100%	100%	94%	91%	63%	100%	68%
13.00	100%	100%	95%	94%	66%	100%	74%
13.50	100%	100%	89%	95%	79%	100%	63%
14.00	100%	100%	100%	100%	97%	100%	95%
14.50	100%	100%	100%	100%	98%	100%	98%
15.00	100%	100%	100%	100%	90%	100%	100%

Life Table for Six Month Age Bands Giving the Percentage of Boys With Each Tooth Emerged In Each of the Age Bands (4 – 15) For the Teeth in Quadrant 4 (t41 – t47)

Table A8.8 Boys Quadrant 4							
	t41	t42	t43	t44	t45	t46	t47
4.00	0%	0%	0%	0%	0%	0%	0%
4.50	0%	0%	0%	0%	0%	0%	0%
5.00	2%	0%	0%	0%	0%	3%	0%
5.50	8%	0%	0%	0%	0%	7%	0%
6.00	32%	2%	0%	0%	0%	27%	0%
6.50	59%	8%	0%	0%	0%	52%	0%
7.00	81%	21%	0%	0%	0%	75%	0%
7.50	96%	51%	0%	0%	0%	93%	0%
8.00	98%	72%	0%	1%	0%	96%	0%
8.50	99%	85%	1%	2%	7%	99%	0%
9.00	100%	95%	3%	5%	7%	100%	0%
9.50	100%	97%	9%	9%	2%	100%	1%
10.00	100%	99%	25%	20%	6%	100%	5%
10.50	100%	100%	39%	32%	9%	100%	3%
11.00	100%	100%	59%	52%	2%	100%	17%
11.50	100%	99%	71%	69%	36%	100%	34%
12.00	100%	100%	83%	81%	57%	100%	55%
12.50	100%	100%	95%	93%	66%	100%	65%
13.00	100%	100%	95%	93%	72%	100%	73%
13.50	100%	100%	95%	89%	74%	100%	74%
14.00	100%	100%	100%	100%	97%	100%	92%
14.50	100%	100%	100%	100%	96%	100%	96%
15.00	100%	100%	100%	100%	95%	100%	97%

Life Table for Six Month Age Bands Giving the Percentage of Girls With Each Tooth Emerged In Each of the Age Bands (4 – 15) For the Teeth in Quadrant 1 (t11 – t17)

Table A8.9 Girls Quadrant 1							
	t11	t12	t13	t14	t15	t16	t17
4.00	0%	0%	0%	0%	0%	0%	0%
4.50	0%	0%	0%	0%	0%	0%	0%
5.00	0%	0%	0%	0%	0%	3%	0%
5.50	1%	0%	0%	0%	0%	13%	0%
6.00	6%	0%	0%	0%	0%	36%	0%
6.50	25%	2%	0%	0%	0%	58%	0%
7.00	49%	10%	0%	0%	0%	81%	0%
7.50	80%	26%	0%	1%	0%	95%	0%
8.00	90%	50%	0%	0%	0%	97%	0%
8.50	98%	70%	0%	3%	1%	99%	0%
9.00	99%	85%	3%	10%	3%	100%	0%
9.50	100%	93%	5%	15%	5%	100%	1%
10.00	100%	97%	16%	30%	7%	100%	3%
10.50	100%	98%	23%	43%	21%	100%	10%
11.00	100%	99%	48%	65%	38%	100%	19%
11.50	100%	99%	55%	72%	48%	100%	27%
12.00	100%	100%	77%	90%	68%	100%	46%
12.50	100%	100%	82%	92%	68%	100%	49%
13.00	100%	100%	91%	99%	88%	100%	74%
13.50	100%	100%	88%	92%	85%	100%	85%
14.00	100%	100%	94%	100%	92%	100%	94%
14.50	100%	100%	99%	100%	99%	100%	90%
15.00	100%	100%	100%	100%	98%	100%	96%

Life Table for Six Month Age Bands Giving the Percentage of Girls With Each Tooth Emerged In Each of the Age Bands (4 – 15) For the Teeth in Quadrant 2 (t21 – t27)

Table A8.10 Girls Quadrant 2

	t21	t22	t23	t24	t25	t26	t27
0.00	0%	0%	0%	0%	0%	0%	0%
4.50	0%	0%	0%	0%	0%	0%	0%
5.00	0%	0%	0%	0%	0%	3%	0%
5.50	1%	0%	0%	0%	0%	14%	0%
6.00	6%	0%	0%	0%	0%	37%	0%
6.50	26%	2%	0%	0%	0%	59%	0%
7.00	48%	10%	0%	0%	0%	82%	0%
7.50	82%	29%	0%	0%	0%	95%	0%
8.00	90%	49%	0%	0%	0%	98%	0%
8.50	97%	71%	0%	3%	1%	99%	0%
9.00	99%	87%	2%	8%	4%	100%	0%
9.50	100%	93%	5%	15%	5%	100%	0%
10.00	100%	95%	16%	29%	10%	100%	4%
10.50	100%	97%	23%	41%	21%	100%	8%
11.00	100%	99%	46%	64%	35%	100%	19%
11.50	100%	99%	60%	73%	47%	100%	27%
12.00	100%	100%	77%	91%	62%	100%	50%
12.50	100%	100%	86%	93%	70%	100%	48%
13.00	100%	100%	90%	98%	88%	100%	76%
13.50	100%	100%	88%	92%	88%	100%	88%
14.00	100%	100%	94%	100%	92%	100%	92%
14.50	100%	100%	98%	100%	96%	100%	91%
15.00	100%	100%	100%	100%	100%	100%	96%

Life Table for Six Month Age Bands Giving the Percentage of Children With Each Tooth Emerged In Each of the Age Bands (4 – 15) For the Teeth in Quadrant 3 (t31 – t37)

Table A8.11 Girls Quadrant 3							
	t31	t32	t33	t34	t35	t36	t37
4.00	0%	0%	0%	0%	0%	0%	0%
4.50	0%	0%	0%	0%	0%	0%	0%
5.00	4%	0%	0%	0%	0%	2%	0%
5.50	16%	0%	0%	0%	0%	15%	0%
6.00	41%	2%	0%	0%	0%	42%	0%
6.50	70%	13%	0%	0%	0%	64%	0%
7.00	90%	45%	0%	0%	0%	87%	0%
7.50	99%	61%	1%	1%	0%	96%	0%
8.00	99%	82%	2%	0%	0%	97%	0%
8.50	100%	93%	6%	2%	0%	99%	0%
9.00	100%	99%	14%	10%	2%	100%	0%
9.50	100%	99%	30%	18%	5%	100%	1%
10.00	100%	100%	53%	26%	8%	100%	8%
10.50	100%	100%	63%	51%	18%	100%	15%
11.00	100%	100%	85%	71%	33%	100%	28%
11.50	100%	100%	91%	79%	45%	100%	46%
12.00	100%	100%	94%	94%	63%	100%	64%
12.50	100%	100%	98%	92%	66%	100%	76%
13.00	100%	100%	100%	99%	87%	100%	92%
13.50	100%	100%	100%	100%	85%	100%	92%
14.00	100%	100%	100%	100%	94%	100%	94%
14.50	100%	100%	100%	100%	95%	100%	96%
15.00	100%	100%	100%	100%	96%	100%	96%

Life Table for Six Month Age Bands Giving the Percentage of Girls With Each Tooth Emerged In Each of the Age Bands (4 – 15) For the Teeth in Quadrant 4 (t41 – t47)

Table A8.12 Girls Quadrant 4

	t41	t42	t43	t44	t45	t46	t47
4.00	0%	0%	0%	0%	0%	0%	0%
4.50	0%	0%	0%	0%	0%	0%	0%
5.00	3%	0%	0%	0%	0%	2%	0%
5.50	15%	1%	0%	0%	0%	14%	0%
6.00	42%	3%	0%	0%	0%	37%	0%
6.50	72%	16%	0%	0%	0%	65%	0%
7.00	91%	42%	0%	0%	0%	87%	0%
7.50	99%	62%	1%	1%	0%	95%	0%
8.00	99%	82%	2%	1%	0%	97%	0%
8.50	100%	93%	5%	3%	0%	100%	0%
9.00	100%	98%	14%	10%	2%	100%	0%
9.50	100%	99%	29%	17%	4%	100%	1%
10.00	100%	100%	52%	27%	7%	100%	7%
10.50	100%	100%	66%	51%	20%	100%	14%
11.00	100%	100%	83%	70%	35%	100%	27%
11.50	100%	100%	91%	78%	47%	100%	44%
12.00	100%	100%	96%	94%	62%	100%	62%
12.50	100%	100%	96%	91%	72%	100%	67%
13.00	100%	100%	98%	99%	84%	100%	89%
13.50	100%	100%	100%	100%	81%	100%	92%
14.00	100%	100%	100%	100%	97%	100%	94%
14.50	100%	100%	100%	100%	94%	100%	98%
15.00	100%	100%	100%	100%	96%	100%	98%

Appendix 9

Graphical Representation of the Life Tables for Six Month Age Bands

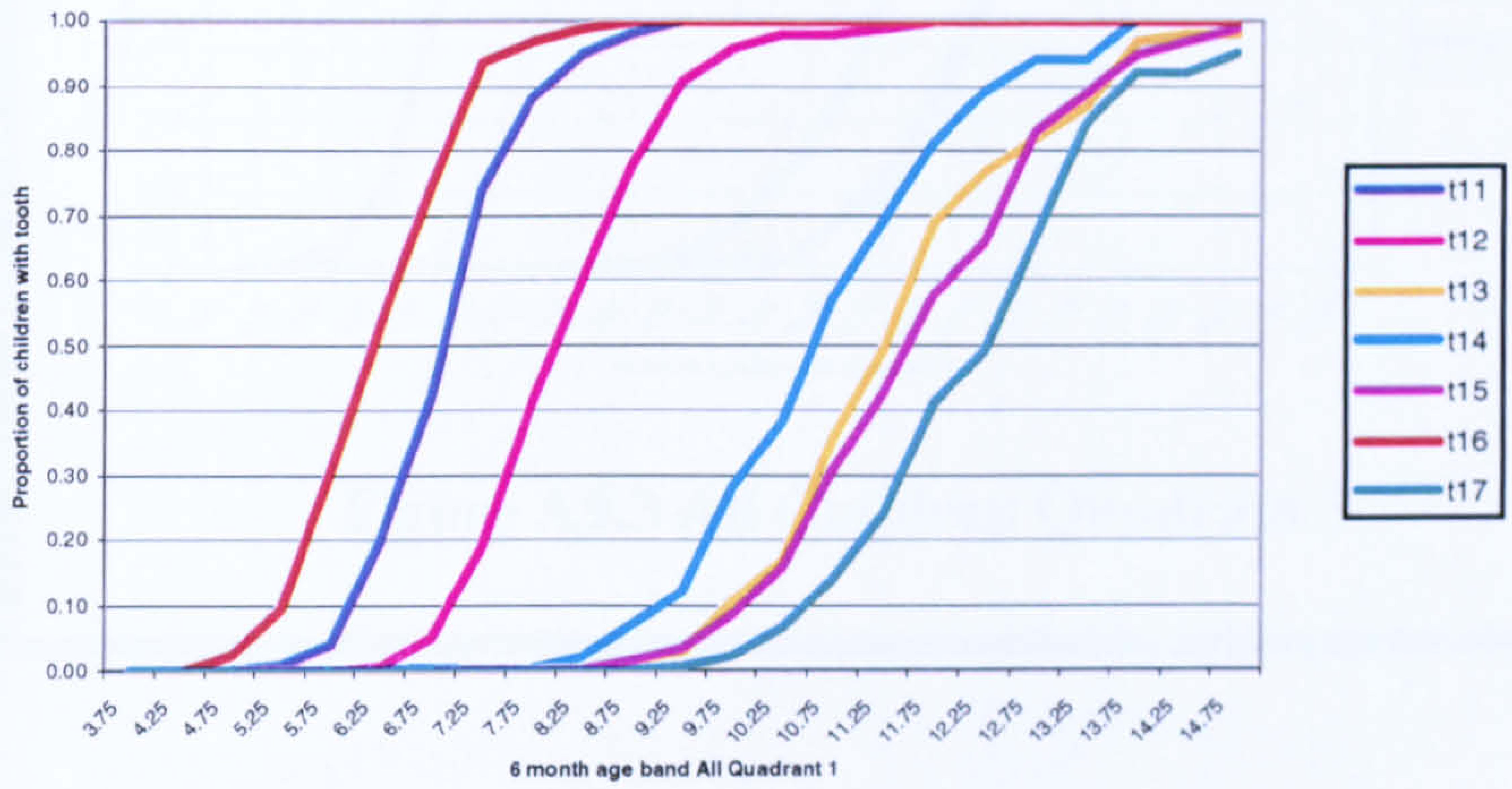

Figure A9.1 All Children Quadrant 1

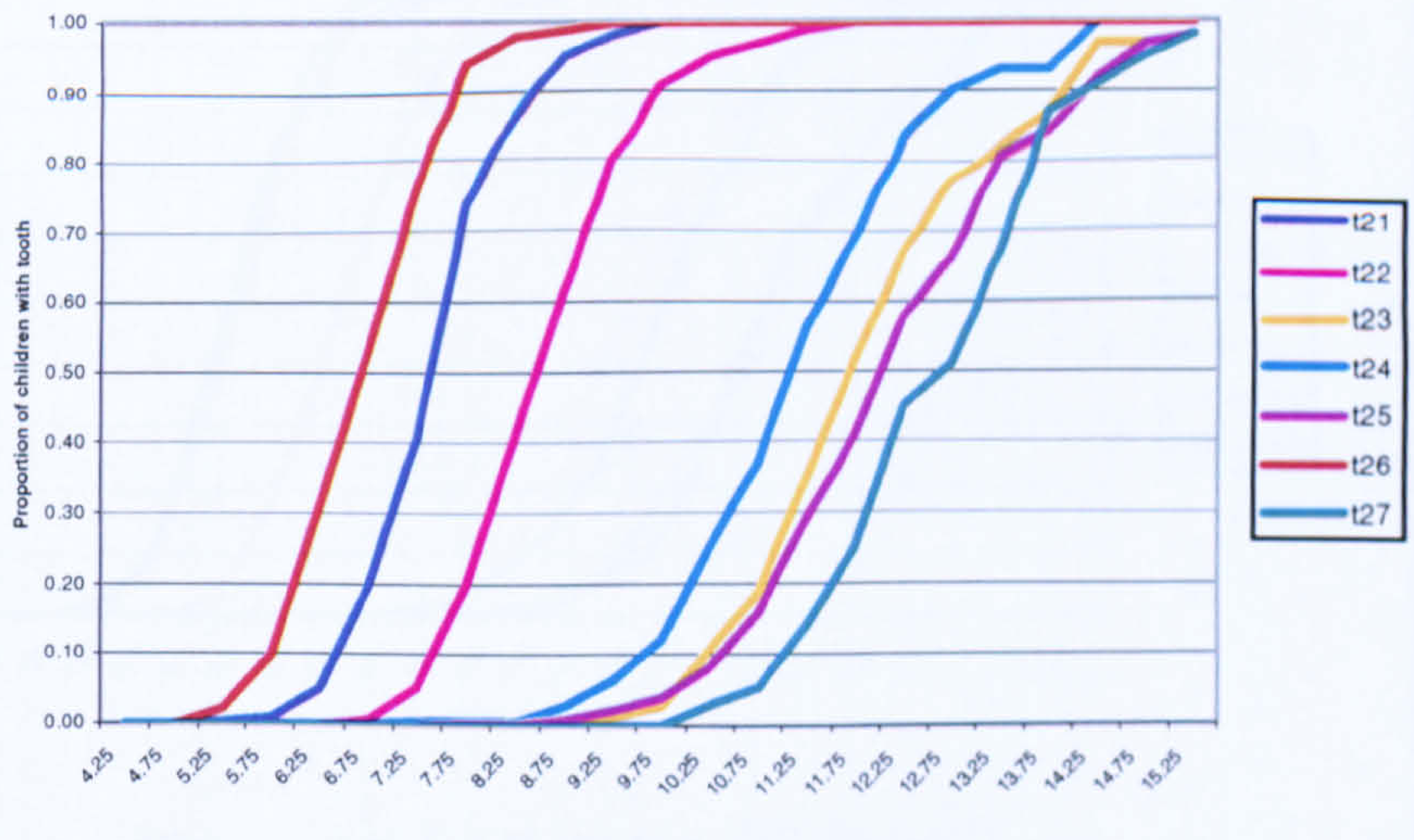

Figure A9.2 All Children Quadrant 2

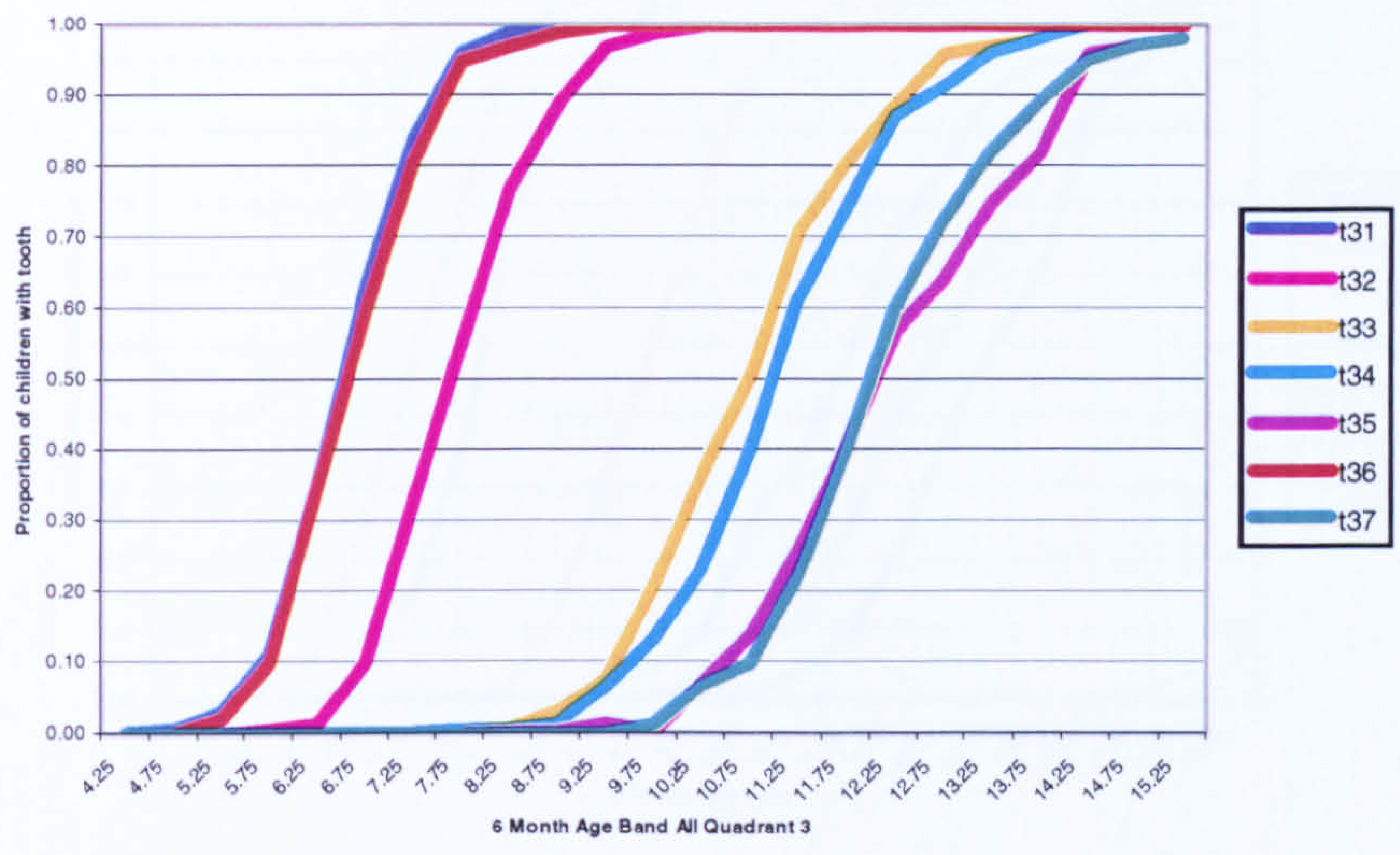

Figure A9.3 All Children Quadrant 3

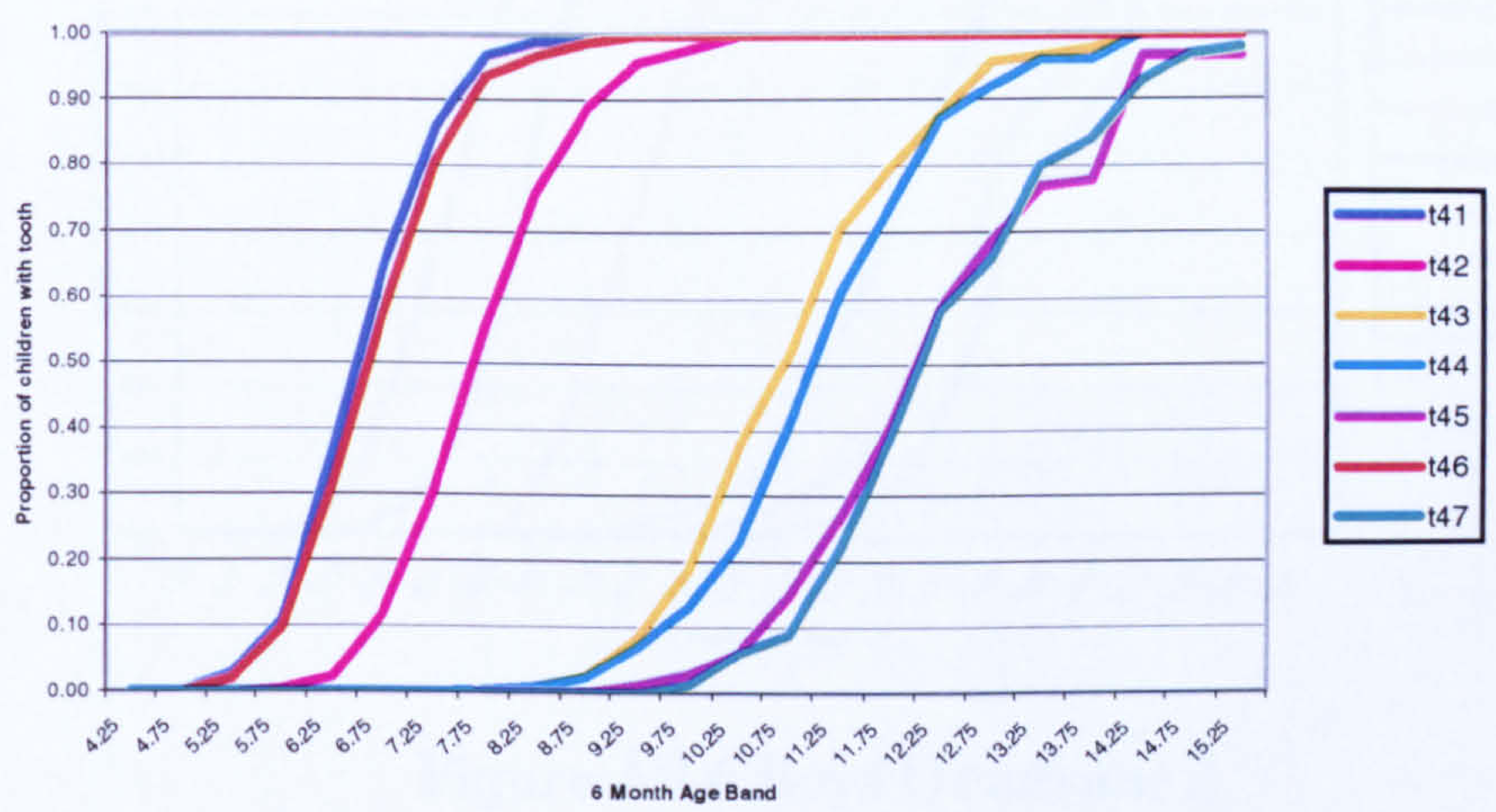

Figure A9.4 All Children Quadrant 4

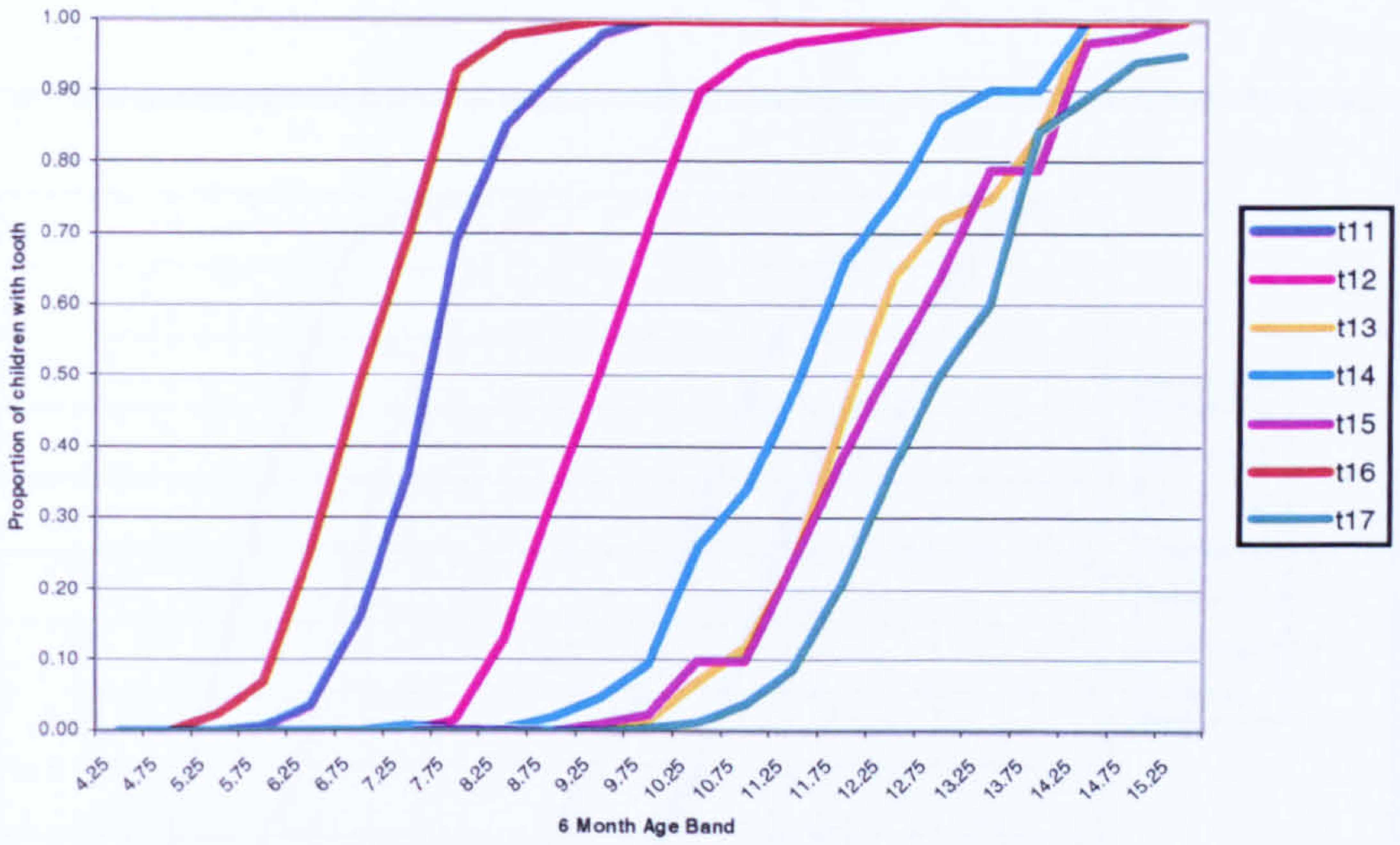

Figure A9.5 Boys Quadrant 1

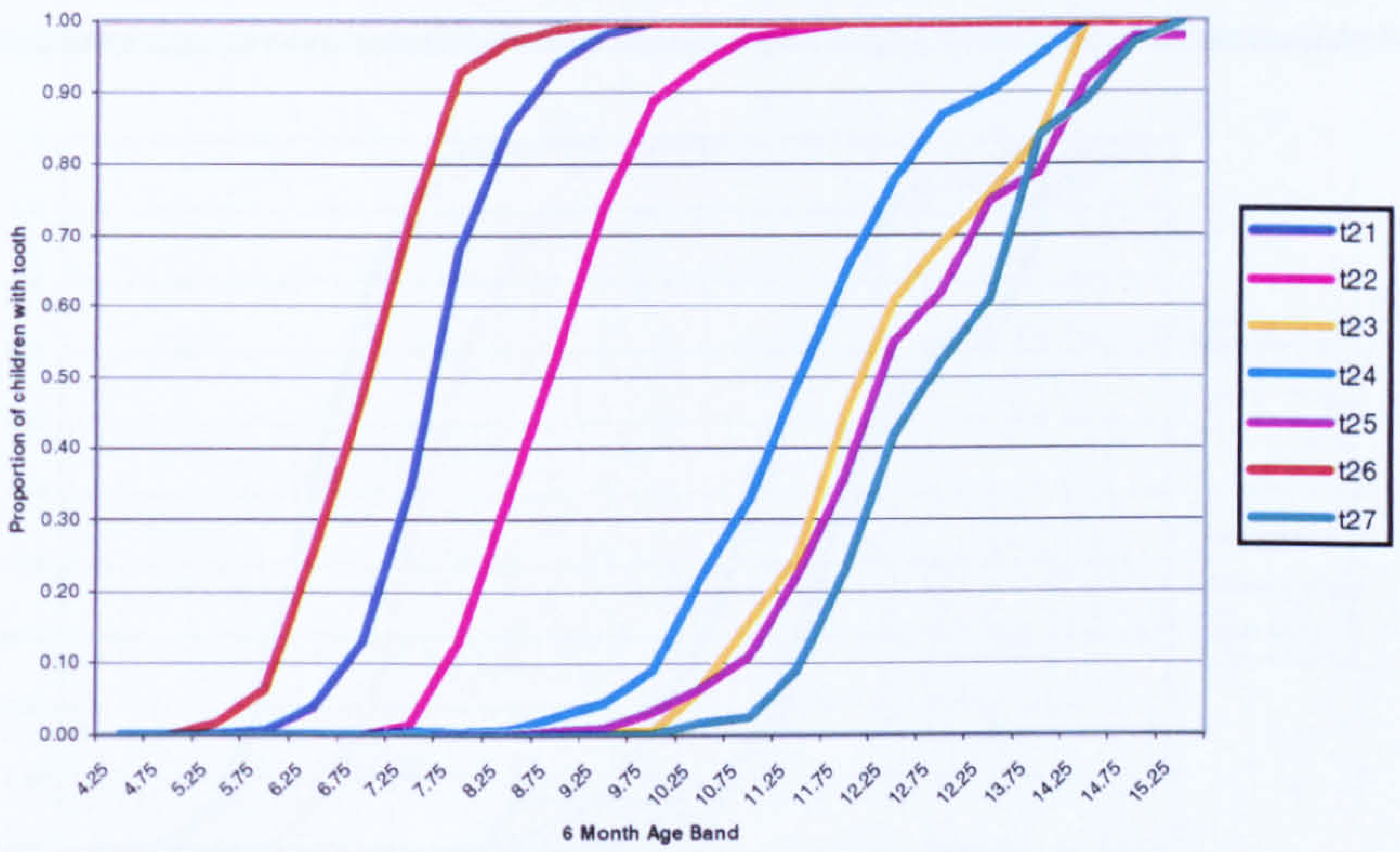

Figure A9.6 Boys Quadrant 2

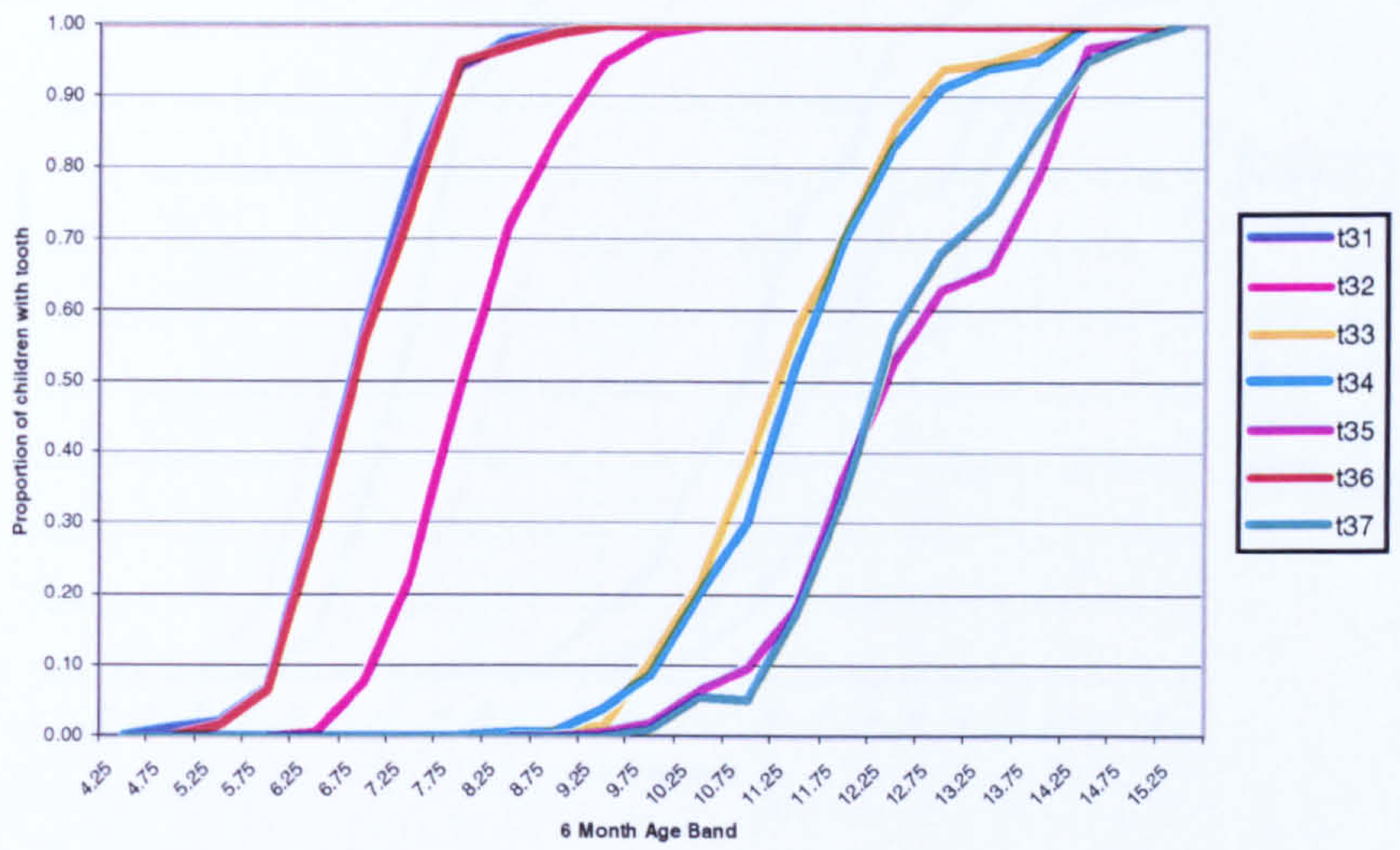

Figure A9.7 Boys Quadrant 3

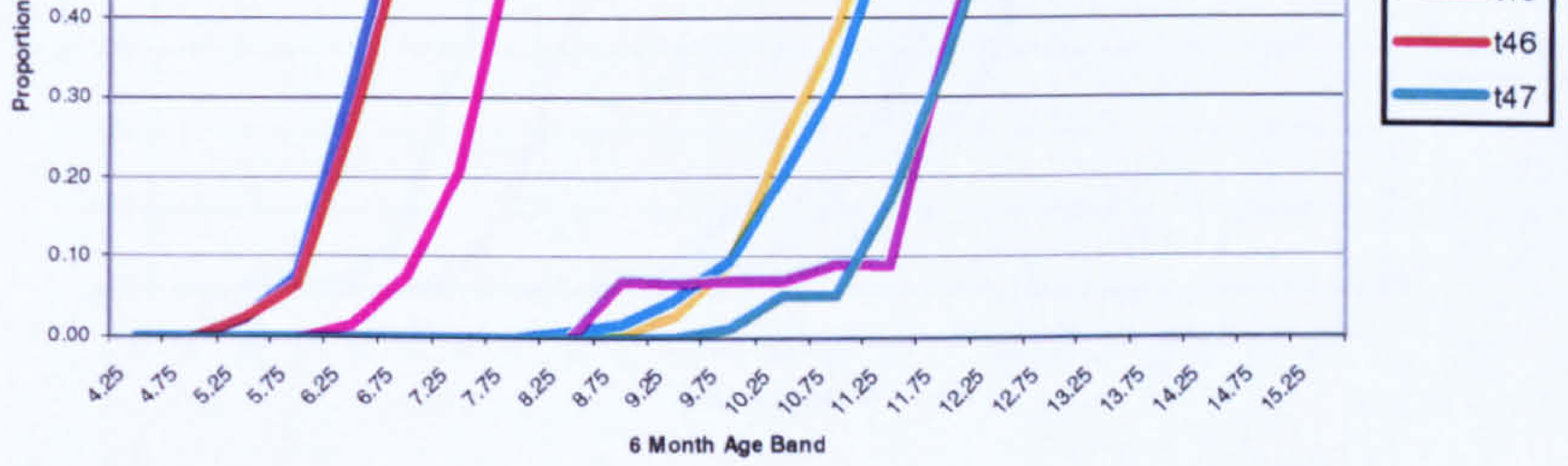

Figure A9.8 Boys Quadrant 4

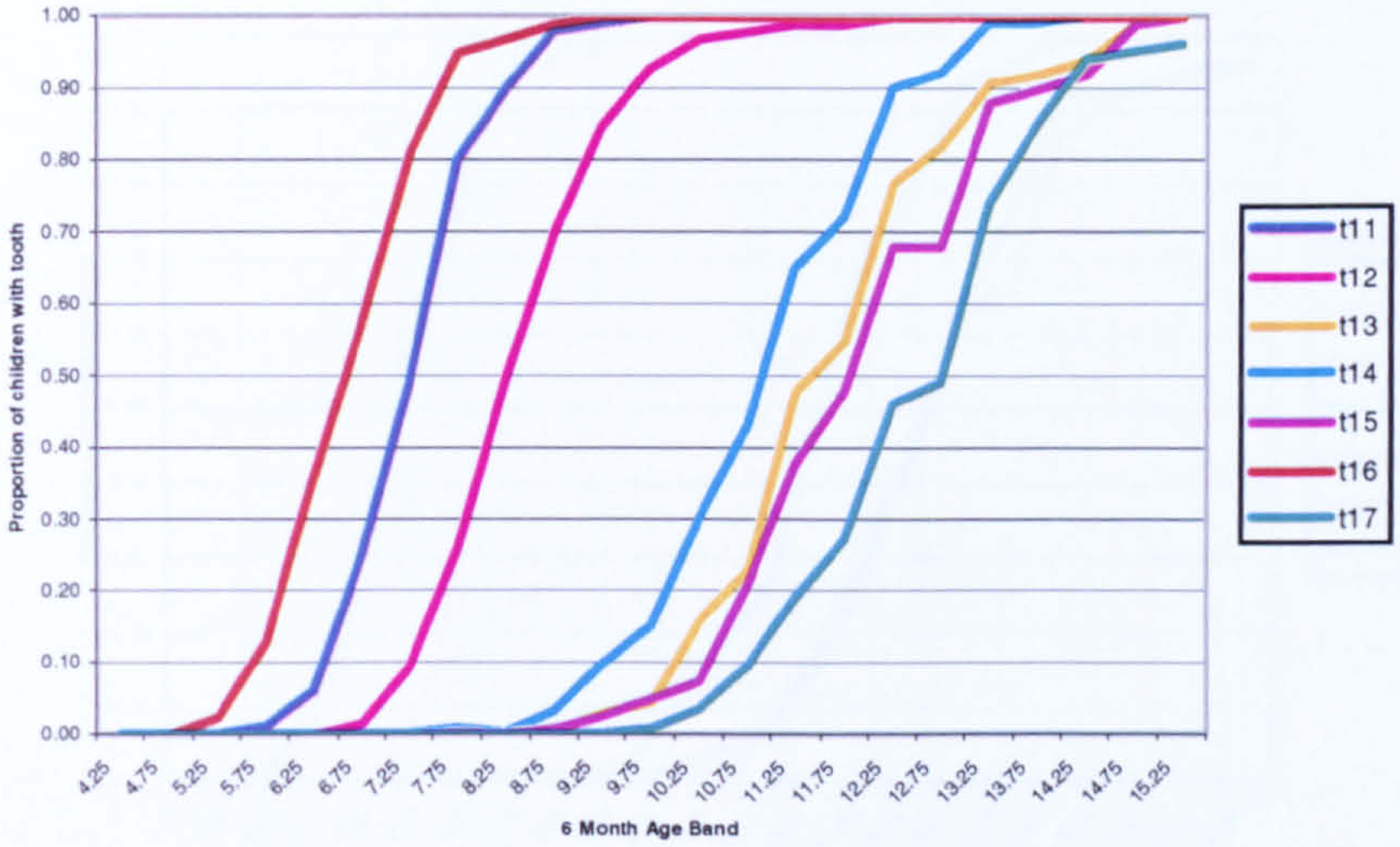

Figure A9.9 Girls Quadrant 1

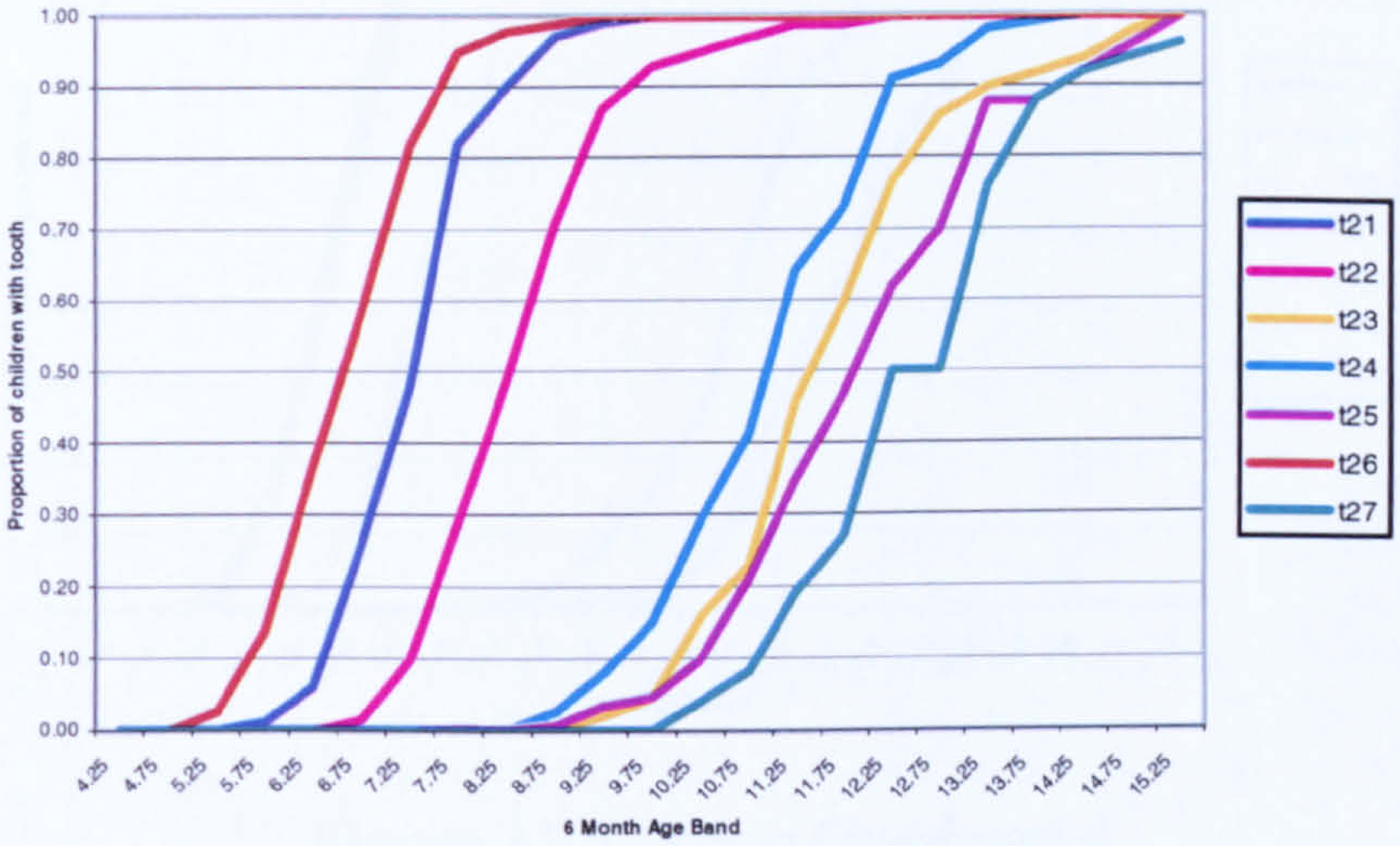

Figure A9.10 Girls Quadrant 2

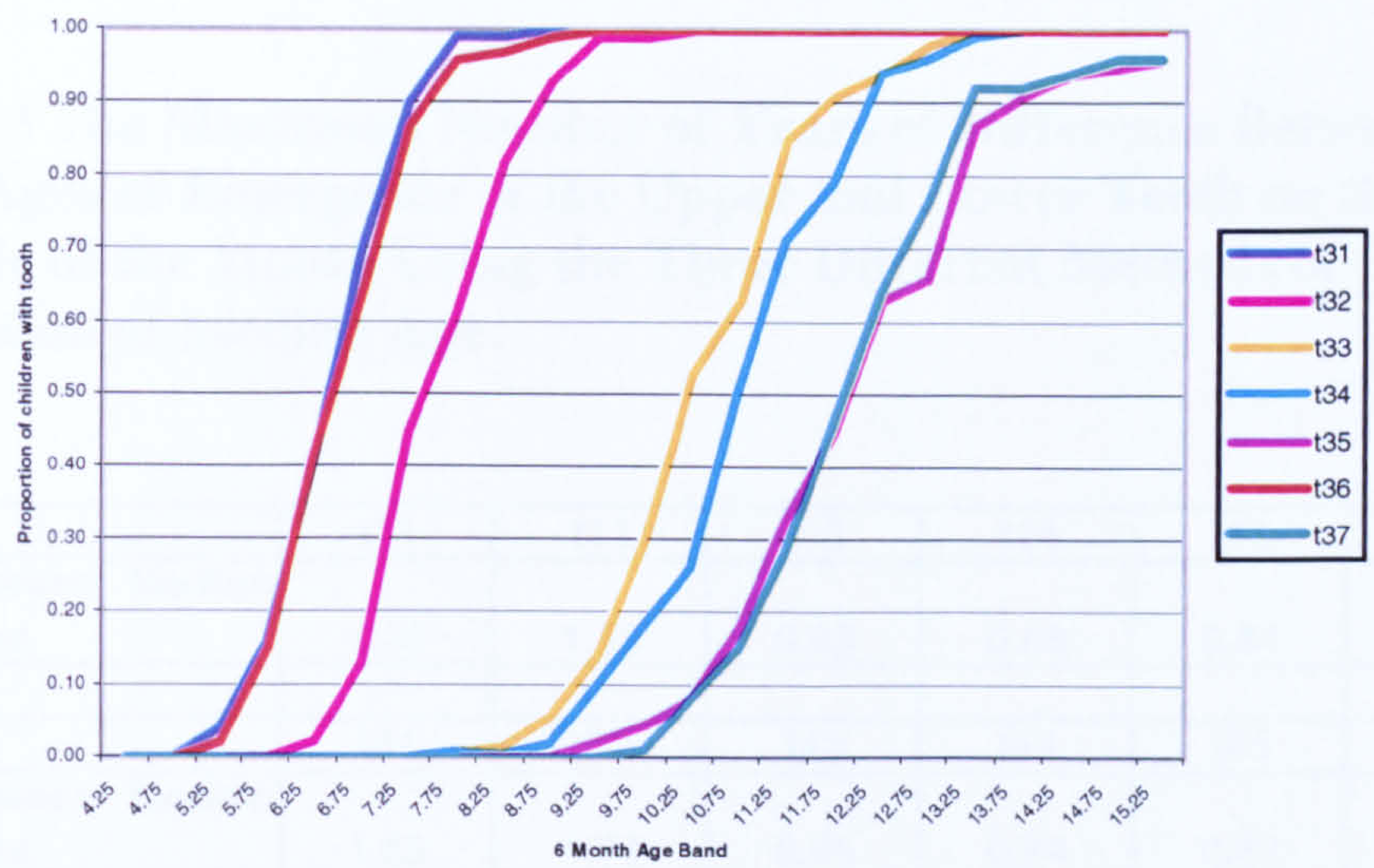

Figure A9.11 Girls Quadrant 3

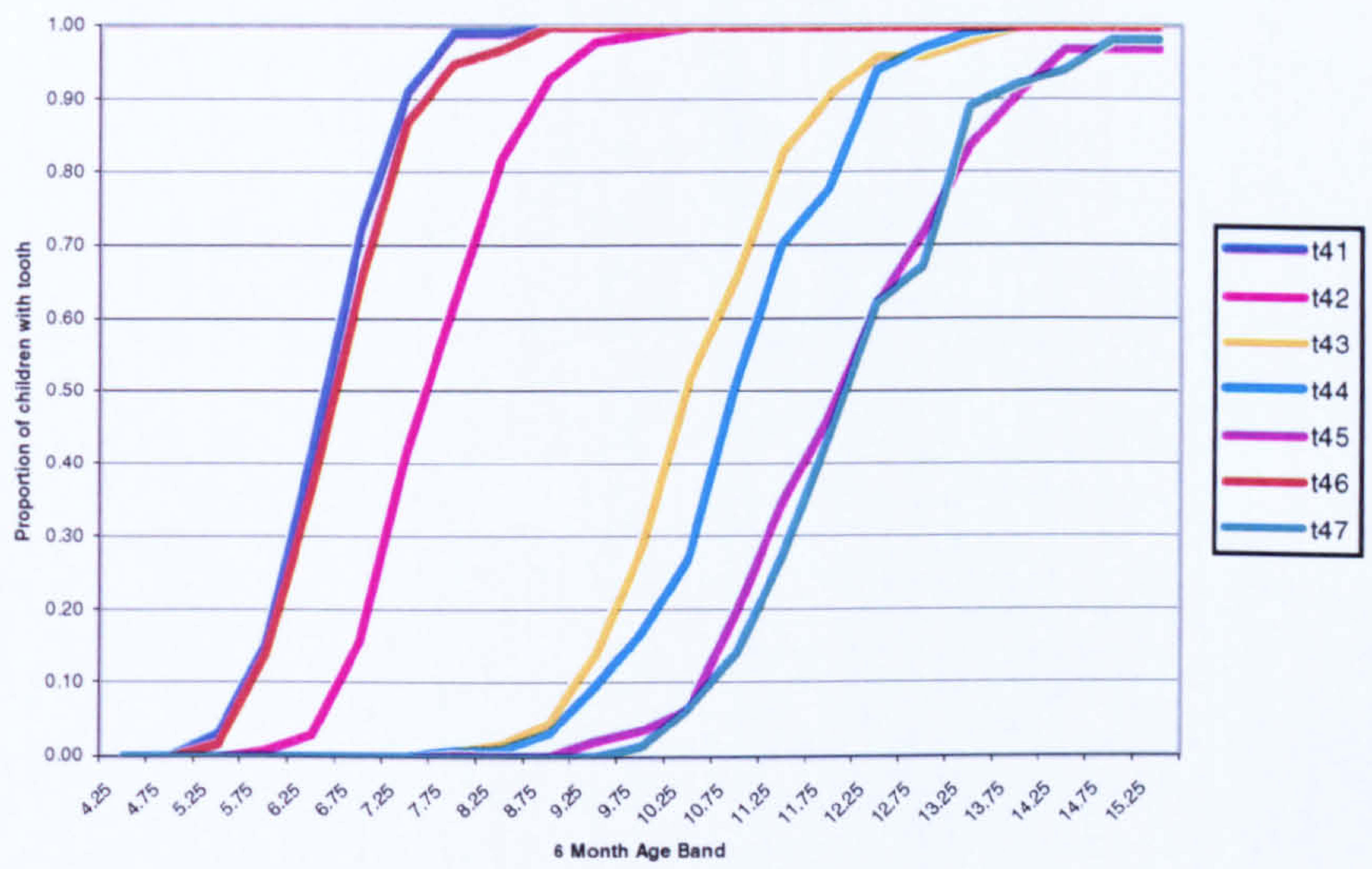

Figure A9.12 Girls Quadrant 4

Appendix 10

Table A10 The Maximum Number of Years of Difference Between the Median Ages of Emergence of the Upper and Lower Teeth on the Right-Hand Side of the Mouth Using the Three Different Methods of Investigation of Median Age.

Tooth	t11	t12	t13	t14	t15	t16	t17
Years Between Median Calculations	1.39	1.53	0.68	0.68	0.64	1.92	0.54
Tooth	t41	t42	t43	t44	t45	t46	t47
Years Between Median Calculations	1.63	1.79	0.95	0.74	0.67	1.59	0.61

Appendix 11

Table A11 The Median Ages of Emergence Given in Comparable Papers

MRC 1925	12.07	6.12	10.72	9.77	11.20	8.37	7.20		MRC 1925	7.20	8.37	11.20	9.77	10.72	6.12	12.07
Leslie (NZ) 1952	12.21	6.35	11.24	10.52	10.83	7.91	6.87		Leslie (NZ) 1952	6.79	7.80	10.80	10.51	11.23	6.40	12.19
Lavelle 1976	11.30	5.90	11.20	9.90	10.60	7.80	6.20		Lavelle 1976	6.20	7.80	10.60	9.90	11.20	5.90	11.30
elmes age range	12.27-12.77	6.07-6.57	11.30-11.80	10.41-10.91	10.89-11.39	7.75-8.25	6.77-7.27		elmes age range	6.78-7.28	7.77-8.27	10.89-11.39	10.45-10.95	11.35-11.85	6.05-6.55	11.75-12.25
median age girls	12.52	6.32	11.55	10.66	11.14	8.00	7.02		median age girls	7.03	8.02	11.14	10.70	11.60	6.30	12.00
MRC 1925	12.33	6.34	10.89	9.96	11.73	8.81	7.42		MRC 1925	7.42	8.81	11.73	9.96	10.89	6.34	12.33
Leslie (NZ) 1952	12.47	6.43	11.74	10.85	11.40	8.37	7.28		Leslie (NZ) 1952	7.23	8.26	11.41	11.17	11.75	6.51	12.46
Lavelle 1976	11.90	6.20	11.40	10.40	11.40	8.30	7.20		Lavelle 1976	7.20	8.30	11.40	10.40	11.40	6.20	11.90
elmes age range	12.25-12.75	6.25-6.75	11.67-12.17	10.88-11.38	11.38-11.88	8.73-9.23	7.46-7.96		elmes age range	6.98-7.48	8.18-8.68	11.41-11.91	10.78-11.28	11.61-12.11	6.29-6.79	12.15-12.65
median age boys	12.50	6.50	11.92	11.13	11.63	8.98	7.71		median age boys	7.23	8.43	11.66	11.03	11.86	6.54	12.40
James / Pitts 1912	12.50	6.25	11.00	10.00	11.75	8.75	7.50			7.50	8.75	11.75	10.00	11.00	6.25	12.50
elmes age range	12.28-12.78	6.17-6.67	11.48-11.98	10.56-11.06	11.25-11.75	7.98-8.48	6.88-7.38		elmes age range	6.89-7.39	7.97-8.47	11.19-11.69	10.59-11.09	11.51-12.01	6.17-6.67	12.17-12.67
median age all	12.53	6.42	11.73	10.81	11.50	8.23	7.13		median age all	7.14	8.22	11.44	10.84	11.76	6.42	12.42
tooth	t17	t16	t15	t14	t13	t12	t11		tooth	t21	t22	t23	t24	t25	t26	t27
tooth	t47	t46	t45	t44	t43	t42	t41		tooth	t31	t32	t33	t34	t35	t36	t37
median age all	11.79	6.34	11.75	10.73	10.43	7.38	6.23		median age all	6.27	7.39	10.17	10.98	11.78	6.30	11.75
elmes age range	11.54-12.04	6.09-6.59	11.50-12.00	10.48-10.98	10.18-10.68	7.13-7.63	5.98-6.48		elmes age range	6.02-6.52	7.14-7.64	9.92-10.42	10.73-11.23	11.53-12.03	6.05-6.55	11.50-12.00
James / Pitts 1912	12.00	6.00	12.00	10.50	10.50	7.50	6.50		James / Pitts 1912	6.50	7.50	10.50	10.50	12.00	6.00	12.00
median age boys	11.88	6.46	11.84	10.95	10.78	7.49	6.34		median age boys	6.38	7.52	10.79	10.96	11.90	6.40	11.85
elmes age range	11.63-12.13	6.21-6.71	11.59-12.09	10.70-11.20	10.53-11.03	7.24-7.74	6.09-6.59		elmes age range	6.13-6.63	7.27-7.77	10.54-11.04	10.71-11.21	11.65-12.15	6.15-6.65	11.60-12.10
Lavelle 1976	11.40	6.10	12.00	11.40	10.50	7.30	6.20		Lavelle 1976	6.20	7.30	10.50	11.40	12.20	6.10	11.40
Leslie (NZ) 1952	11.86	6.42	12.13	11.35	10.76	7.41	6.38		Leslie (NZ) 1952	6.38	7.44	10.80	11.33	12.24	6.49	11.92
MRC 1925	11.86	6.24	11.80	10.86	10.80	7.72	6.49		MRC 1925	6.49	7.72	10.80	10.86	11.80	6.24	11.86
median age girls	11.67	6.23	11.51	10.55	9.96	7.45	6.31		median age girls	6.15	7.16	9.94	10.68	11.64	6.18	11.61
elmes age range	11.42-11.92	5.98-6.48	11.26-11.76	10.30-10.80	9.71-10.21	7.20-7.70	6.06-6.56		elmes age range	5.90-6.40	6.91-7.41	9.69-10.19	10.43-10.93	11.39-11.89	5.93-6.43	11.36-11.86
Lavelle 1976	11.30	5.90	11.70	10.80	9.40	7.00	5.90		Lavelle 1976	5.90	7.00	9.40	10.80	11.70	5.90	11.30
Leslie (NZ) 1952	11.47	6.27	11.69	10.52	9.78	7.15	6.15		Leslie (NZ) 1952	6.23	7.18	9.69	10.56	11.77	6.32	11.25
MRC 1925	11.52	5.95	11.21	10.36	9.90	7.50	6.23		MRC 1925	6.23	7.50	9.90	10.36	11.21	5.95	11.52