Age estimation by dental developmental stages in children and adolescents in Iceland

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**Ritgerð til meistaraþráðu
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Heilbrigðisvísindasvið

HÁSKÓLI ÍSLANDS

Aldursákvarðanir af tönnum á myndunarskeiði í íslenskum börnum og ungmennum

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Ágrip

Inngangur

Í aldaraðir hafa tennur verið notaðar til að bera kennsl á menn og til aldursgreiningar í réttarrannsóknnum og í öðrum vísindalegum tilgangi. Aldursgreining barna og ungmenna er talin mjög nákvæm með staðalfrávik allt frá nokkrum mánuðum til 1-2 ár. Í fullorðnum, þegar tennur eru fullmyndaðar, eru hrörnunarbreytingar tanna notaðar til aldursgreiningar, en nákvæmni þeirra er mun minni en við aldursgreiningu ungmenna. Mikilvægt er talið að þekkja tannþroska barna og ungmenna fyrir hverja þjóð. Ekki hefur fyrr verið gerð rannsókn hér á landi á tannþroska barna og ungmenna með tilliti til aldursgreiningar út frá myndunarskeiði tanna. Þekking þessi er mjög gagnleg fyrir íslenska réttartannlækna svo og aðra tannlækna, lækna, mannfræðinga og fornleifafræðinga, sem nýta í störfum sínum tannþroska barna og ungmenna. Einnig þarf að bera saman niðurstöður við sambærilegar erlendar rannsóknir og kanna hvort þær aðferðir sem mest eru notaðar t.d. við aldursgreiningar í öðrum löndum gildi fyrir íslenskt þýði.

Efniviður og aðferðir

Þroskastig tanna voru rannsökuð af breiðmyndum (orthophan röntgenmyndum) af 1100 íslenskum börnum og ungmennum á aldrinum 4-25 ára. Þroskastig Havikko voru notuð til viðmiðunar í rannsókninni. Gerð var forrannsókn á 100 myndum. Einnig voru 200 myndir skoðaðar bæði hægra og vinstra megin, og að auki voru 800 skoðaðar hægra megin.

Niðurstöður

Tannþroski var fundinn fyrir allar tennur, þegar úrtakið leyfði, og fyrir bæði kynin, frá því að króna byrjar að kalka og þar til rót lokast. Áreiðanleiki rannsóknaraðferða var reiknaður með Cronbach's Alpha og reyndist vera $r = 0,982$, sem merkir mikinn áreiðanleika. Stúlkur ná fullum tannþroska 17.81 ára í efri kjálka og 18.47 ára í þeim neðri. Drengir ná fullum tannþroska 18.00 ára í efri kjálka en 17.63 í þeim neðri. Sterk fylgni var milli hægri og vinstri hliðar þar sem $r = 0,95-1,00$. Það var ekki marktækur munur milli kynja nema við myndun róta í augntönnum í efri og neðri gómi, þar sem stúlkur ná fyrr rótarlokun en drengir.

Samantekt

Með rannsókn þessari hefur tekist að gera nákvæman gagnagrunn yfir tannþroska barna og ungmenna sem er sambærilegur við erlenda gagnagrunna af sama meiði. Grunnurinn mun auðvelda nákvæma aldursgreiningu íslenskra barna og ungmenna og mun gagnast öðrum stéttum sem nota tannþroska þessa aldurshóps í störfum sínum.

Abstract

Background

For centuries teeth have been used both for identification of unknown persons and for estimating age for forensic and other scientific purposes. The dental age estimation technique is considered to be highly reliable in children and adolescents. In the developmental stages of teeth in this age group, the standard deviation is from a few months to 1 to 2 years. In adults where teeth have reached full development, regression changes are used but the accuracy is much less than in children.

Objectives

Studies have shown that it is necessary to create a database for dental maturity for every population and compare it to others. The present study is the first one for the Icelandic population, in the age range of 4-25 years. It will create a database for forensic purposes to determine age estimation from dental maturity with accuracy. It will also help dentists, physicians, anthropologists, archaeologists and other professionals who need to determine and work with developmental age assessment in children and adolescents.

Material and methods

In the present study which is a retrospective cross-sectional study, dental maturity was determined from 1100 Icelandic children and young adolescents from orthopantomograms (OPGs). The first 100 were used for a pilot study. Another 1000 were used for the main study. A total of 23 were excluded. The sample consisted of 508 girls and 469 boys from the age of 4-25 years. Haavikko's scoring system was used as a standard for determination of dental maturity stages. A total of 200 OPGs were studied both on the left and right side and the rest on the right side.

Results

Dental maturity was established for all teeth and both genders, when the sample permitted, from the beginning of crown formation to the root apex closure. The reliability of the study instruments was found by using Cronbach's Alpha reliability test. R was 0.982, which showed good reliability.

Girls in Iceland reach full dental maturity (stage 10) at 17.81 years of age for the maxillary and 18.47 years in the mandibular teeth. Boys reach full dental maturity at 18.00 years of age in the maxilla and 17.63 in the mandible.

There was no significant difference between left and right side ($r = 0.95-1.00$). There was no difference between genders, except in root formation in maxillary and mandibular canines where girls reached apex closure earlier than boys.

Conclusion

A reliable database has been established for age estimation for the Icelandic population in the age range of 4-25 years, which is compatible with other studies in other countries. These results will help forensic odontologists and other professionals to estimate accurately age and maturity in Icelandic children and adolescents.

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List of abbreviations

ta = peg tooth,

v = tooth missing

ex = extraction

k = unreadable due to rotation crowding etc.

b = deciduous teeth

r = resorption

en= endodontic treatment

T = tooth

I = Incisor

C = canine

P = premolar

M = molar

M₁ = first molar

M₂ = second molar

M₃ = third molar

OPG = orthopantomogram

SD = standard deviation

1. INTRODUCTION

Studies have shown that it is necessary to create a database for dental maturity based on developmental stages for every population and compare it to others (Liversidge, 2008). This study is the first for the Icelandic population for dental development. It has created a database for forensic purposes to determine age estimation from dental maturity with accuracy. It will also help other Icelandic professionals who need to determine and work with developmental age assessment in children and adolescents.

1.1 Historical background

There is a strong historical background in using dental tissues as a method for estimating the age of an individual and dates back to the early nineteenth century (Miles, 1963) and even longer before that (Stavrianos, 2009). The oldest case known where identification from teeth was used is the murder of Lollia Paulina in Rome in the year 49 (William, 1996).

Much of the early work was carried out in England where there were strong penal laws and children over 7 years could be held responsible for crimes. In addition, child labor was common during the Industrial Period in the late 17th and early 18th centuries. In 1833 the Factory Act was passed by Parliament, which stated that children under 9 years of age were not allowed to work in factories and mills. Furthermore, children between 9 and 13 years of age were no longer allowed to work more than 9 hours per day. At this time poverty was common and families tried to smuggle their children in to work in factories in order to have the advantage of the added income. To solve this problem age estimation was performed from tooth eruption to decide if the children were old enough to work. Thomson, an authority on medical jurisprudence at the University of London, suggested that the age of children might be assessed by tooth emergence (Fanning, 1961; Schmeling, 2010; William, 1996).

Saunders presented the publication "The Teeth, a Test of Age, Considered with Reference to the Factory Children" in 1837 (Cameriere et al., 2007). It was based on an address to the members of both Houses of Parliament in which he expounded upon the value of dental emergence for age estimation. His studies were performed on 1000 children and he stated that with the aid of his tables and a little "industrious application" the assessment of age in line with the requirements of the Factory Act could be conducted by "relatively untrained people". One year earlier, Thomson (1836) reported that "if the third molar (first permanent molar) had not protruded, you can have no hesitation in affirming that the culprit has not passed his seventh year". This prevented a significant number of young children from being subjected to the harsh penal code of this time (Schmeling, 2010).

Today the developmental stages of the dentition are widely and regularly used in dentistry and medicine to time interventionist treatments and in archaeology and a forensic context, including odontology and anthropology, to estimate the age of the living and the deceased.

1.2 Use of developmental stages in forensic odontology

In the field of forensic odontology it is often mandatory to be able to estimate the age of people, both living and dead. The age determination can be approached from many perspectives:

1. To identify a person, it is necessary to get as much information about the person to be identified and to be able to compare it to any information that is at hand. In all accounts, the age of the person is estimated from teeth using developmental stages or regressive changes of teeth that are fully developed.
2. When determining the age of children it is often necessary to rely on developmental stages when all the teeth are intact and dental records show no dental work on their teeth, such as restorations. This is extremely important in mass disasters, where many people are missing (Richter & Vidisdottir, 2005).
3. Adopted children from countries where birth certificates are not reliable, age estimation has to be done from developmental stages to determine dental age and to try to find, as accurately as possible, the right chronological age.
4. "The assignment of age to address appropriate and fair processing of asylum and refugee seekers is influenced heavily by issues pertaining to international human rights" (Black et al., 2010). These issues are largely governed by the UN Convention on the Rights of the Child from 1989 (UNHCR, 2006) and the UN Guidelines on Policies and Procedures in Dealing with Unaccompanied Children Seeking Asylum (UN, 1997). Both documents follow the guiding principles that the best interests of the child take precedence and that the child should be given the benefit of the doubt if their chronological age remains uncertain.

For most countries that recognize the 1989 convention, the legal age of maturity is accepted as 18 years of age and this is largely supported by the modern legal framework of most nations. If an individual claims to be younger than 18 years of age, and there is some doubt, then there may be a statutory obligation that the receiving nation is required to offer asylum and support to that minor until age is established to the satisfaction of the authorities. Therefore, the demarcation between 17 and 18 years is a key milestone with regards to both legal and social responsibility – from the perspective of both the state and the individual (Schmeling, 2010) . Age estimation from teeth which fall into this category is becoming more common in the Nordic countries (Solheim, 2003; Solheim & Vonen, 2006) and a few have been done in Iceland.

When estimating the age of an individual from teeth the accuracy can vary, depending on the age-period of life, therefore the estimation for each period needs its own method. The age-period can be

categorized as followed: prenatal, infancy, early childhood , late childhood adolescence and adulthood (Schour & Massler, 1941) (Figure 1).

Figure 1. Schour and Massler Dental Developmental Diagrams. Source: (Schour & Massler, 1941)

The dental age estimation technique is considered to be highly reliable in children. In the developmental stages of teeth, from the prenatal to the teenage stages, the standard deviation is from a few months to 1 to 2 years (Anderson et al., 1976; Bosmans et al., 2005; Demirjian & Goldstein, 1976; Demirjian et al., 1973; Haavikko, 1970, 1974; Kullman et al., 1992; Mincer et al., 1993). In adults where teeth have reached full development, regression changes in teeth are used but the accuracy is much less than in children. When using regression changes the use of morphological changes with multiple regression models for the changes are applied (Gustafson, 1950; Kvaal & Solheim, 1994), where the SD can be up to 8 years for younger individuals and 15 years for the older (Bang & Ramm, 1970; Kvaal et al., 1995; Solheim, 1993; Solheim & Sundnes, 1980). The most reliable method for older persons (SD up to 5 years) is racemization of aspartic acid, but this requires good laboratory facilities and the tooth has to be extracted (Yekkala et al., 2006).

It is often mandatory for professional use, to be able to estimate the chronological age of children and adolescents (Liversidge, 2008). The chronological age of children can be determined by their dental developmental status. Physiological findings can be misleading because external environmental factors can affect development (Liversidge, 2008).

For clinical diagnosis, treatment planning, endocrine pathology, orthopedics, orthodontics and other dental and medical purposes, an accurate standard is required to get a realistic developmental maturity status. There is a strong indication that odontogenesis is under genetic control and there is accordingly a higher correlation with chronological age of the subject than exists for the other indicators of developmental age (Gron, 1962).

The concept of physiological age was first defined by Crampton, using signs of pubescence in boys as a measure of their developmental maturity (Crampton, 1944). Developmental differences among children of the same chronological age have led to the concept of physiological age, which provides a way to define the progress toward the completeness of development or maturity in each child. Physiological age (biological or developmental age) gives measures for describing the status of each child, but chronological age shows only a rough approximation of this status because of the range in development observed for any given age (Fanning, 1961). Physiological age is estimated by the maturation of one or more tissue systems and is best expressed in terms of each system studied. Maturation is identified by the occurrence of one event or the sequence of multiple events that are irreversible (Moorrees et al., 1963). The four main methods to establish the chronological age of children are skeletal age, secondary sex characteristics, somatic measurements or morphological age, and dental age (Moorrees et al., 1963). The option is to use each individual method or to use them jointly to determine the chronological growth age of a child (Schmeling, 2010).

Dental age is a good indication for many professionals such as orthodontists when they plan a treatment for different orthodontic problems in relation to maxillofacial growth. It is also of interest for the forensic odontologist to estimate the age of human skeletal remains and other remains when parts of the body are missing and to estimate age for legal purposes (Lewis, 1960; Schmeling, 2010).

Developing systems for normal variations for each sex in every population are required to identify those that deviate markedly from the average. Such norms are now available for many populations in the form of atlases for the hand and wrist and for the knee, charts for height, weight, and stages of sexual maturation, as well as tables of tooth emergence, shredding, root resorption, and tooth formation (Demirjian et al., 1973; Haavikko, 1970; Magnusson, 1976; Schmeling, 2010; Trotter & Gleser, 1952).

Dental development is thought to be the most accurate and reliable way of correlating growth and development, as it is a system little affected by environmental factors (Gustafson & Koch, 1975; Liversidge, 1998). Dental developmental stages also exhibit lower levels of variation than are evidenced in the skeletal system (Garn et al., 1960). Dental maturation is furthermore believed to be independent of somatic, skeletal and sexual maturation, because teeth are derived from different

embryonic origins and thus under alternative mechanisms of control, the former being mesodermal in origin whereas dental structure is derived from the ectomesenchyme (Demirjian et al., 1985).

Tooth development is less affected by environmental factors and diseases and has better correlation with chronological age than skeletal growth or maturation (Demirjian et al., 1985). It is possible to estimate dental age from eruption and from dental development (Demirjian et al., 1973; Haavikko, 1970; Magnusson, 1976). But appropriate norms for various tissues must be available. Dental development, for the purposes of age assessment, is a much more reliable method than eruption, when almost all teeth can be viewed at the same time in dental development, while eruption is more a time associated phenomenon. Eruption is a phase that takes a short time and with only a few teeth at a time. Moreover, it is highly coincidental whether the time of inspection coincides with the actual emergence time. Additionally, many exogenous factors can interfere with eruption, for example infection, injury, shredding, crowding, obstruction, and extraction of deciduous or adjoining permanent teeth. Earlier studies have been done for the Icelandic population on tooth emergence by Dr. Þórður Eydal Magnússon (Magnusson, 1976) .

Eruption of the permanent teeth was more often used earlier to determine dental maturity and dental age. Norms from Logan and Kronfeld and modified by Schour and Massler, Hurme and Clements, Davies-Thomas and Pickett were mostly used (Clements et al., 1957; Demirjian et al., 1973; Hurme, 1949; Logan & Kronfeld, 1933; Schour & Massler, 1940). Since Hunter's investigation in 1771, tooth formation has been studied by gross inspection of skulls, and in the nineteenth century histological techniques were added. Röse (1891), Zuckerkandl (1891) and Zsigmondy (1894) were the first to describe the material and method they used. They mostly studied the beginning of calcification and the development of teeth. They also observed the time difference between maxillary and mandibular teeth, and the sequence in which they began to calcify (Fanning, 1961; Haavikko, 1970).

After Röntgen's discovery in 1895 "radiographs provided a new method for studying developing teeth; accurate data of age and sex could be obtained in living persons and Lambertz (1900), Witxel (1907), and Symington and Rankin (1908) were the first to use this method. " (Fanning, 1961).

Most contemporary references to tooth formation and its variability are derived directly or indirectly from the studies of Logan and Kronfeld in 1933 and from the tables of Kronfeld published in 1935 (Kronfeld, 1935; Logan & Kronfeld, 1933). Their study was a histological and roentgenological investigation that consisted of 25 jaws, the subjects ranging from 0-15 years. In 1933 Kronfeld made tables and diagrams of calcification of the deciduous and the permanent dentition as well as the eruption sequence. The findings of Logan and Kronfeld are in truth the foundation for later diagrams and charts.

1.3 Earlier studies

To estimate dental age from dental formation, it is mandatory to define developmental stages. The first developmental stages were defined by Gleiser and Hunt, Garn and Lewis, Nolla, Fanning and Moorrees et al. (Demirjian et al., 1973; Fanning, 1961; Garn et al., 1957; Gleiser & Hunt, 1955; Moorrees et al., 1963; Nolla, 1960). The stages usually begin with the calcification of the crown and end with the closure of the apex of the root. Each stage has to be easily recognizable for every tooth and all teeth go through these stages in their formation. The stages are an indication of maturity but not size, therefore identifying and assessing these stages give more of a subjective evaluation.

Findings for the beginning of calcification of the permanent teeth show that in the most studied tooth, the first molar, the calcification starts at the tip of the mesio-buccal cusp and continues to the disto-buccal, to the mesio-lingual and finally to the disto-lingual cusp (Kronfeld, 1935).

The velocity of formation has been shown to begin slowly in the initiation of crown formation, but the rate of calcification speeds up before completion of the crown. Then when the root begins to form the process again slows down until the root is half completed, when it speeds up again to its maximum (Fanning, 1961; Schour & Massler, 1940).

Permanent teeth, C-M₃, start to develop around and after birth, except for the M₁ and the four permanent incisors which start to develop in the prenatal period. On average, the crown starts to develop in the canines at 6 months, the first premolar around 1.8 years, the second premolar at around 3.0 years, the second molar around 3.5 years, and the third molar at around 9.4 years of age (Moorrees et al., 1963).

Numerous studies have been carried out on the development of permanent teeth, especially their eruption sequence and numbers (Haavikko, 1970; Magnusson, 1976). It is fair to say that there is no great individual difference between eruption times among Caucasians nor the number of teeth erupted per time or their sequence. But there is a difference between races (Haavikko, 1970). Dental age estimation from developmental stages has many advantages. Development of teeth can be examined from birth until the time when all teeth have fully developed around 20 years of age.

To find a more accurate estimation of chronological age, the developmental stage of every tooth is compared with age estimation tables. The first tables for this purpose are from Nolla, Fanning, Moorrees, Nanda and Chawla, and Haavikko (Demirjian et al., 1973; Fanning, 1961; Moorrees et al., 1963; Nanda & Chawla, 1966; Nolla, 1960). The dental age is then determined by calculating the mean of all of the developmental stages. This method is rather complicated and time consuming. A less time consuming method has been developed where a few selected teeth are used which reflect the whole dental developmental process because they have the best correlation to chronological age (Demirjian & Goldstein, 1976; Haavikko, 1974).

Moorrees and Fanning at the Harvard University School of Public Health conducted a big longitudinal study in 1959 to analyze various aspects of dental development (Fanning, 1961; Moorrees et al., 1963). It is a one-of-a-kind study as the sample was lateral skull radiographs, taken at birth,

two weeks after birth, at three-month interval to the age of one year, and after that at six-month intervals between 4.0 to 11.5 years of age. Intraoral radiographs of the maxillary and mandibular incisors were taken at six-month intervals between 4.0 to 11.5 years of age to study the incisors of both jaws. The developmental scoring system used was from Gleiser and Hunt with 20 developmental stages (Gleiser & Hunt, 1955). Today, such a longitudinal study with this much radiological exposure would never be allowed.

1.4 More recent studies

In 1970 Kaarina Haavikko published a big cross-sectional OPG study; “*The formation and the alveolar and clinical eruption of the permanent teeth*”. It was the first big cross-sectional study published where dental developmental age estimation, involving 1162 children and sub-adults from 2-21 years of age, was carried out. Her studies show growth and movement of teeth inside the jawbone, eruption sequence and development of the teeth. Codes were made for tooth developmental stages and diagrams of the same stages (Figure 3). Twelve stages were used in her study, whereas Gleiser and Hunt used 15 stages (Gleiser & Hunt, 1955). The twelve developmental stages chosen to serve the purposes of the study gave an adequately detailed picture of tooth formation without requiring excessive exactitude, excessive in the sense of going beyond roentgenological perceptibility (Haavikko, 1970).

Front teeth and premolars

Tooth crown

Molars

Tooth crown

Tooth root

Tooth Root

Stages of crown formation.

O crypt, no calcification. **C_i** initial calcification. **C_{co}** coalescence of cusps. **Cr_{1/2}** crown 1/2 complete. **Cr_{3/4}** crown 3/4 complete. **Cr_c** crown complete.

Stages of root formation.

R_i initial root formation. **R_{1/4}** root length 1/4. **R_{1/2}** root length 1/2. **R_{3/4}** root length 3/4. **R_c** root length complete. **A_c** apex closed.

Figure 2. Haavikko's developmental stages. Source: "Practical Forensic Odontology" (Clark, 1992)

All teeth were assigned a developmental stage for each given time, and the median and the 10th and the 90th percentile points found. The left and right side results were tested by means of a t-test and showed no statistical differences (Haavikko, 1970).

The teeth recommended for use when using only a few teeth are teeth 47, 46, (16), 44, and 41 from birth to 9 years of age, and teeth 47, 44, 13, 43 from 10 years onwards (Haavikko, 1974).

Demirjian et al published a new system of dental age assessment (Demirjian et al., 1973). His study was of the Canadian-French population and involved 1446 boys and 1482 girls. He defined developmental stages from A to H, A for the beginning of formation to H for closure of the apex (Figure 3). He developed a maturity scoring system derived from the Tanner, Whitehouse, Takaishi and Healy scoring system for skeletal maturations (Tanner et al., 1962; Tanner et al., 1966a, 1966b). The skeletal maturity found by Tanner, Whitehouse and Healy consisted of mathematical approach by scaling many attributes in the development of a child like secondary sex characteristics, the teeth and the bones of various joints including the wrist and knee. The scoring system was in percentile scale. This scale was used for deriving a score for each stage of each tooth (Healy & Goldstein, 1976). The Demirjian's study was done on the radiological appearance of 7 teeth on the left side of the mandible.

Eight stages of calcification for each tooth are identified and described and each one is allocated a score. The sum of these scores for an individual provides an estimate of dental maturity on a scale measuring from 0 – 100. Scores and percentiles are given separately for boys and girls for the age range 3 – 16 years (Demirjian et al., 1973) and can be seen in Table 1 and Table 2.

Figure 3. Demirjian's stages of tooth calcification (Demirjian et al., 1973).

Table 1. Self-weighted scores for dental stages, 7 teeth (mandibular left side)
Source: (Demirjian et al., 1973).

Boys									
Tooth	Stage								
	0	A	B	C	D	E	F	G	H
M ₂	0.0	2.1	3.5	5.9	10.1	12.5	13.2	13.6	15.4
M ₁				0.0	8.0	9.6	12.3	17.0	19.3
PM ₂	0.0	1.7	3.1	5.4	9.7	12.0	12.8	13.2	14.4
PM ₁			0.0	3.4	7.0	11.0	12.3	12.7	13.5
C				0.0	3.5	7.9	10.0	11.0	11.9
I ₂				0.0	3.2	5.2	7.8	11.7	13.7
I ₁					0.0	1.9	4.1	8.2	11.8
Girls									
Tooth	Stage								
	0	A	B	C	D	E	F	G	H
M ₂	0.0	2.7	3.9	6.9	11.1	13.5	14.2	14.5	15.6
M ₁				0.0	4.5	6.2	9.0	14.0	16.2
PM ₂	0.0	1.8	3.4	6.5	10.6	12.7	13.5	13.8	14.6
PM ₁			0.0	3.7	7.5	11.8	13.1	13.4	14.1
C				0.0	3.8	7.3	10.3	11.6	12.4
I ₂				0.0	3.2	5.6	8.0	12.2	14.2
I ₁					0.0	2.4	5.1	9.3	12.9

NB: Stage 0 is no calcification

Table 2. Conversion of maturity scores to dental age (7 teeth). Source: (Demirjian et al., 1973)

Age	Score	Age	Score	Age	Score	Age	Score
3.0	12.	7.0	46.7	11.0	92.0	15.0	97.6
.1	12.9	.1	48.3	.1	92.2	.1	97.7
.2	13.5	.2	50.0	.2	92.5	.2	97.8
.3	14.0	.3	52.0	.3	92.7	.3	97.8
.4	14.5	.4	54.3	.4	92.9	.4	97.9
.5	15.0	.5	56.8	.5	93.1	.5	98.0
.6	15.6	.6	59.6	.6	93.3	.6	98.1
.7	16.2	.7	62.5	.7	93.5	.7	98.2
.8	17.0	.8	66.0	.8	93.7	.8	98.2
.9	17.6	.9	69.0	.9	93.9	.9	98.3
4.0	18.2	8.0	71.6	12.0	94.0	16.0	98.4
.1	18.9	.1	73.5	.1	94.2		
.2	19.7	.2	75.1	.2	94.4		
.3	20.4	.3	76.4	.3	94.5		
.4	21.0	.4	77.7	.4	94.6		
.5	21.7	.5	79.0	.5	94.8		
.6	22.4	.6	80.2	.6	95.0		
.7	23.1	.7	81.2	.7	95.1		
.8	23.8	.8	82.0	.8	95.2		
.9	24.6	.9	82.8	.9	95.4		
5.0	25.4	9.0	83.6	13.0	95.6		
.1	26.2	.1	84.3	.1	95.7		
.2	27.0	.2	85.0	.2	95.8		
.3	27.8	.3	85.6	.3	95.9		
.4	28.6	.4	86.2	.4	96.0		
.5	29.5	.5	87.7	.5	96.1		
.6	30.3	.6	87.2	.6	96.2		
.7	31.1	.7	87.7	.7	96.3		
.8	31.8	.8	88.2	.8	96.4		
.9	32.6	.9	88.6	.9	96.5		
6.0	33.6	10.0	89.0	14.0	96.6		
.1	34.7	.1	89.3	.1	96.7		
.2	35.8	.2	89.7	.2	96.8		
.3	36.9	.3	90.0	.3	96.9		
.4	38.0	.4	90.3	.4	97.0		
.5	30.2	.5	90.6	.5	97.1		
.6	40.6	.6	91.0	.6	97.2		
.7	42.0	.7	91.3	.7	97.3		
.8	43.6	.8	91.6	.8	97.4		
.9	45.1	.9	91.8	.9	97.5		

The 8 stages A – H are defined from the beginning of calcification to the closure of the root apex (Demirjian et al., 1973).

Analysis and classification:

1. Teeth used to determine age are in the lower jaw and are rated in the following order: 2nd molar, 1st molar, 2nd premolar, 1st premolar, canine, lateral incisor, central incisor.
2. All teeth are rated on a scale of A to H. The rating is assigned by following carefully the written criteria for each stage, and comparing the tooth with the diagrams and X-ray pictures given in Figure 3. The illustrations should only be used as an aid, not as the sole source of comparison. For each stage there are one, two or three written criteria marked a), b) and c). If only one definition is applied then this must be met for the stage to be taken as reached for that tooth. If two definitions are given it is enough that the first definition is met for the stage to be recorded as reached for that tooth. If three definitions apply, then the tooth has to fall into the definition of the first two criteria for the tooth to have reached that stage. At each stage, in addition to the criteria for that stage, the criteria for the previous stage must be satisfied. In borderline cases the earlier stage is always assigned.
3. There are no absolute measurements to be taken. A pair of dividers is sufficient to compare the relative length (crown/root). To determine apex closure stages no magnifying glass is necessary. The ratings should be made with the naked eye.
4. The crown height is defined as being the maximum distance between the highest tip of the cusps and the cemento-enamel junction. When the buccal and lingual cusps are not at the same level, the midpoint between them is considered as the highest point.

Stage description

If no initiation of calcification is evident, then that developmental stage is given as 0. The crypt formation is not given as a developmental stage (no calcification evident).

- A In both uniradicular and multiradicular teeth, a beginning of calcification is seen at the superior level of the crypt in the form of an inverted cone or cones. There is no fusion of these calcified points.
- B Fusion of the calcified points forms one or several cusps which unite to give a regularly outlined occlusal surface.
- C a) Enamel formation is complete at the occlusal surface. Its extension and convergence towards the cervical region is seen.
- b) The beginning of a dental deposit is seen.
- c) The outline of the pulp chamber has a curved shape at the occlusal border.
- D a) The crown formation is completed down to the cemento-enamel junction.
- b) The superior border of the pulp chamber in the uniradicular teeth has a definite curved form, being concave towards the cervical region. The projection of the pulp horns, if present, gives an outline shaped like an umbrella top. In molars the pulp chamber has a trapezoidal form.
- c) Beginning of root formation is seen in the form of specula.
- E Uniradicular teeth:
- a) The walls of the pulp chamber now form straight lines whose continuity is broken by the presence of the pulp horn, which is larger than in the previous stage.
- b) The root length is less than the crown height.
- Molars:
- a) Initial formation of the radicular bifurcation is seen in the form of either a calcified point or a semi-lunar shape.
- b) The root length is still less than the crown height.
- F Uniradicular teeth:
- a) The walls of the pulp chamber now form a more or less isosceles triangle. The apex ends in a funnel shape.

- b) The root length is equal to or greater than the crown height.

Molars:

The calcified region of the bifurcation has developed further down from its semi-lunar stage to give the roots a more definite and distinct outline with funnel shaped endings.

The root length is equal to or greater than the crown height.

G a) The walls of the root canal are now parallel and its apical end is still partially open (distal root in molars).

H) a) The apical end of the root canal is completely closed. (Distal root in molars).

The periodontal membrane has a uniform width around the root and the apex.

Anderson developed yet another system. The method by Anderson et al. was based on a study of an Anglo-Saxon population in Canada. He used similar developmental stages as Haavikko, but he used in all 14 (Table 3.)(Anderson et al., 1976).

Table 3. Anderson's developmental scoring system. Source: (Anderson et al., 1976)

Developmental stage	Codes
Beginning of cusp formation	C (i)
Coalescence of cusps	C (co)
Crown outline seen	C (oc)
Crown ½ complete	Cr ½
Crown ¾ complete	Cr ¾
Crown complete	Cr (c)
Initial root formation	R (i)
Root-furcation initiated	Cl (i)
Root length ¼	R ¼
Root length ½	R ½
Root ¾ complete	R ¾
Root length complete	R (c)
Apex closed ½	A ½
Apex closed	A (c)

After the age of 14-16 (16.2 with boys and 15.1 with girls) according to Haavikko all teeth except the third molars are fully developed (Haavikko, 1970). After that age the third molars are the only way to establish dental age estimation until they are fully developed at the age of around 20 years.

Methods have been developed to establish age estimations from the third molars (Kullman, 1995a; Kullman et al., 1992; Kullman et al., 1995; Liversidge, 2008; Mincer et al., 1993; Nortje, 1983).

Kullman developed a method and used 7 stages for root development and apex closure of the mandibular third molar (Kullman et al., 1992). In his study he used radiographs from a Swedish population.

The Kullman's classifications of the lower third molar root developmental stages are shown in Figure 4 and Table 4. In Figure 5 is an example of a radiograph of a third molar estimated to be from a sixteen year old person.

Figure 4. Classification of different stages of root development of the lower third molar. Source: (Kullman et al., 1992).

- $R_i - R_{1/4}$ or **1**: Root development initiated but less than $\frac{1}{4}$ of the estimated root length has been formed.
- $R_{1/4} - R_{1/2}$ or **2**: $\frac{1}{4}$ or more has been formed of the estimated full length of the root, but not yet $\frac{1}{2}$ the estimated root length.
- $R_{1/2} - R_{3/4}$ or **3**: $\frac{1}{2}$ or more of the estimated root length has been formed but not yet $\frac{3}{4}$ of the estimated root length.
- $R_{3/4} - R_c$ or **4**: $\frac{3}{4}$ or more has been formed but not yet the whole estimated root length.
- $R_c - A_{ci}$ or **5**: The full estimated root length has been formed but the initiation of apex closure has not started.
- $A_{ci} - A_c$ or **6**: Apex closure has been initiated but the apex is not closed.
- A_c or **7**: Apex is fully closed, the root development is completed.

Table 4 . Mean ages and standard deviations in years for different stages and sexes (Kullman et al. 1992).

Stages	Male		Female	
	Mean age	SD	Mean age	SD
1	15.0	1.3	15.4	0.9
2	15.9	1.0	16.6	1.7
3	16.9	1.1	16.8	1.6
4	17.3	1.2	17.9	1.6
5	18.0	1.2	18.6	1.8
6	19.2	1.0	19.9	1.6

Figure 5. Radiograph of mandibular third molar, tooth 38, which could be from a 16 year old male or female according to root stages in figure 4 and table 4.

Mincer developed another method based on maxillary and mandibular third molars (Mincer et al., 1993). Their study was done on an American and a Canadian population. Mincer et al. classifications of the third molar root developmental stages are shown in Figure 6 and Table 5.

Figure 6. Schematic drawings and brief descriptions of the eight stages of crown and root formation used to score third molar development. Source: (Mincer et al., 1993).

Table 5. Mean ages and standard deviations in years for different stages and sexes (Mincer 1993).

Gender	Developmental stages				
	D	E	F	G	H
Maxilla					
Male	16.0 SD 1.97	16.6 SD 2.38	17.7 SD 2.28	18.2 SD 1.91	20.2 SD 2.09
Female	16.0 SD 1.55	16.9 SD 1.85	18.0 SD 1.95	18.8 SD 2.27	20.6 SD 2.09
Mandible					
Male	15.5 SD 1.59	17.3 SD 2.47	17.5 SD 2.14	18.3 SD 1.93	20.5 SD 1.97
Female	16.0 SD 1.64	16.9 SD 1.75	17.7 SD 1.80	19.1 SD 2.18	20.9 SD 2.01

Another method was developed by Nortje (Nortje, 1983). He used 5 developmental stages of the mesial root of permanent mandibular third molars on a South African population (Figure 7).

Figure 7. Nortje's developmental stages. Source: (Nortje, 1983).

Studies have shown that it is necessary to create a database for dental maturity for every population and compare it to others (Liversidge, 2008).

Today most of the studies done on developmental stages of teeth are performed to create a reliable standard for every population. To have standards for the mean age for every tooth is mandatory for forensic work. The present study is the first one for the Icelandic population. It creates a standard mean age for forensic purposes, such as to determine age estimation accurately from dental maturity. It will also help other professionals that need to determine and work with developmental age assessment in Icelandic children and adolescents.

2. AIMS OF THE STUDY

The aim of this study was to find the mean and median age for every developmental stage in each tooth with standard deviation (SD) in Icelandic children and adolescents. The aim is also to find the time it takes for a tooth to develop and to find if there is a difference between the left and the right side. Also to evaluate if there is a difference between genders in tooth developmental time.

3. MATERIAL AND METHODS

The present study is a retrospective cross-sectional study of dental maturity using 1100 digital orthopantomograms (OPG) of Icelandic children and young adolescents. One hundred of the 1100 radiographs were used for a pilot study and 1000 were used for the main study.

The OPGs were obtained from a private orthodontic clinic in the Reykjavik area. The OPGs were from the years 2004-2009. They cover a variety of patients who came to the dental office both for orthodontic treatment and for consultation and from other dentists in the area who needed OPGs to use for their treatment planning.

The selection of 1000 OPGs was equally divided between genders. The sample consisted of 508 girls and 469 boys 4-25 years of age. Twenty-three OPGs were excluded due to hypodontia, distortion of the OPGs and fixed orthodontic appliances. A developmental tooth scoring system, with 12 developmental stages, was used for determination of dental maturity stages. A total of 200 OPGs were studied, on both the left and the right side, and the remaining 800 OPGs showed the right side.

The study was approved by The National Bioethics Committee and The Data Protection Authority.

3.1 Protocols for the material

In the study design the ideal study material would be persons aged from 2 – 25 years (the age group 0-2 years would also be suitable but not realistic). The person should be healthy, with no hereditary disease or other long term illness. They should be Icelandic (both parents should be Icelandic and have Icelandic grandparents). Persons should not have dental developmental problems. The OPGs should be easily readable by the naked eye and should not be distorted. In the design there should also be age groups divided in 1 year categories, equal amount of persons in each group and both gender. The ideal group in the study material is shown in Table 6.

Table 6. The ideal group for the study.

AGE PR GROUP	BOYS	GIRLS	TOTAL
2.00 – 2.99	24	24	48
3.00 – 3.99	24	24	48
4.00 – 4.99	24	24	48
5.00 – 5.99	24	24	48
6.00 – 6.99	24	24	48
7.00 – 7.99	24	24	48
8.00 – 8.99	24	24	48
9.00 – 9.99	24	24	48
10.00 – 10.99	24	24	48
11.00 – 11.99	24	24	48
12.00 – 12.99	24	24	48
13.00 – 13.99	24	24	48
14.00 – 14.99	24	24	48
15.00 – 15.99	24	24	48
16.00 – 16.99	24	24	48
17.00 – 17.99	24	24	48
18.00 – 18.99	24	24	48
19.00 – 19.99	24	24	48
20.00 – 20.99	24	24	48
21.00 – 21.99	24	24	48
22.00 – 22.99	24	24	48
23.00 – 23.99	24	24	48
24.00 – 24.99	24	24	48
Total	552	552	1104

3.2 Selection of the sample

Sample selection started January 15, 2009, and ended March 25, 2009. A total of 1100 OPSs were selected with a randomized number table, where the patient's number was used to select each OPG. The youngest children available were in the age group 4.00-4.99. No OPGs were available for younger individuals. The database consisted of date of birth, date of exposure and patient number given at the first entrance of the patient's file.

Protocol for the collection of the sample was to:

- 1) -write down name ID number and exposure date
-investigate personal history
-investigate health history
- 2) Calculate real age at exposure date
- 3) Give each OPG a working number
- 4) Girls labeled as 0 and boys as 1

3.3 Study material collected

The radiographic database at the dental clinic consisted of OPGs for 7570 persons (some persons had 2 or 3 OPGs in the database), from the year 2003 to the present day (March 2012). The same x-ray machine was used, The Planmega® PM 2002 CC Proline with total filtration of 2.5 mm Al. The exposure used was 72KVp, 12 mA with exposure time of 18 sec. (Isoardi & Ropolo, 2003). The OPGs were taken by trained dental nurses, using the protocol recommended by the manufacturer for the lineup for all OPG. The patient was standing upright, his chin was in a position tray and special positioning light and arms were used. A specialist in orthodontics evaluated all OPGs.

Each patient was given a patient number. The Dolphin® imaging 11 software (Dolphin Imaging & Management solutions, a Patterson Technology) was used to store all images with that number. They were stored in a jpeg format at 1600 x 1200 resolution (24 bits per pixel). Different software Tannsi® (Tannsi ehf. Tölvuþjónusta tannlækna. Borgartúni 29, 105 Reykjavík.) was used for storing the health and treatment data.

The patient numbering system was used to select the OPGs, using a random number table. An Excel® (Microsoft Corporation) formula was used to convert the age of the individual selected to actual age at the day of exposure. Random number selection was used at first to select the OPGs. If the estimated number in each group was not reached a selective pick for that age was performed. The age had to be from 4 years and less than 25 years. Ethnicity was based on both the patient's name (Icelandic names) and photographs in the patient's records. If in doubt, a reliable staff member was questioned.

All OPGs that showed tooth developmental anomaly were excluded. OPGs of patients with fixed orthodontic appliances were excluded. All OPGs that showed general root resorption were excluded. OPGs that showed distortion were excluded.

3.4 Developmental stages assigned

An Excel® (Microsoft Corporation) file was used to list the developmental stages for each tooth (Figure 8). The numbering system for teeth used was the FDI notation system (FDI Two-Digit Notation). In this part of the study the age and gender of the person belonging to the OPG was not known to the examiner. Each OPG was listed by the given patient number.

In Figure 10 it looks as if the apex is still in development while in fact this person is a 24.8 year old male and had all his apices closed. In this and similar cases it was decided to exclude these teeth from the study.

Even though there is an enlargement of about 3-10% in OPG radiographs, this does not affect the outcome because the scoring system is based on relative values rather than absolute length measurements.

The OPGs were studied in a Mac OS X (Version 10.6.8) computer with a display resolution of 1440 x 900 and in full brightness. The software used to examine the OPGs was Preview® version 5.0.3 (504.1) (Apple Inc.), where 1 image pixel equals 1 screen pixel. This program allows many features like zooming, changing exposure, contrast, saturation, temperature, tint, sepia and sharpness. If needed, images could be zoomed or changed to enable more reliable reading, as seen in Figure 11 (Benediktsdóttir & Wenzel, 2004).

Figure 11. Dark image, changed with more exposure, less saturation, less sepia and with red tint.

Templates were designed on transparent films. A few very clear and readable OPGs were drawn on the films (Figure 12). These templates were used randomly when developmental stages were unclear. They were only used as an accessory tool.

Figure 12. A template with developmental stages on roots.

The developmental stages for each tooth were determined and listed on the worksheet from the OPGs by the observer. Figure 13 is an example of an OPG with given developmental stages.

Chronological age and sex was unknown to the observer. There was one observer and he had been calibrated before the study in a pilot study.

When teeth had two or more roots, the mesial root was used to determine the developmental stage (Fanning, 1961)

Figure 13. Developmental stages in an OPG. 47, stage 6. 46, stage 10. 45, stage 6. 44, stage 7. 43, stage 8. 42, stage, stage 10. 41, stage 11.

3.5 Pilot study and main study

A pilot study was done on a total of 100 OPGs, girls and boys with an age range of 4-25 years, a sample which was not included in the main sample of the 1000 OPGs (Lancaster et al., 2004) . Dental developmental stages on both right and left side were recorded. The purpose was to try out the design of the study and the examiner before the main study was performed. The pilot sample was reevaluated after four weeks to achieve intra-rater reliability. Mean, medians and SD of age was found.

Haavikko's (Haavikko, 1970) and Demirjian's (Demirjian et al., 1973) descriptions of developmental stages were used to train the examiner in the pilot study.

The main study was performed in the same manner with the sample of 1000 girls and boys. The first 200 OPGs were examined, both for the maxillary and mandibular teeth on the left and the right side, to evaluate if there was any difference between sides. After that only the right side was examined.

When all developmental stages were filled in, the list with real age and gender was delivered to the examiner and entered to the work sheets.

The chronological age at the time of exposure was calculated by finding the difference between the date of the exposure and the date of birth, thus giving the age of the person when the OPG was taken. The age was then changed to the decimal age. The mean and median age for every tooth in every developing stage was found for both genders.

3.6 Statistical analysis

All data were analyzed using SPSS® (IBM Corporation) and Excel®. Descriptive statistics were obtained by calculating the mean, median and SD for all developing stages, when the data was available, in all teeth. In addition to the usual way of calculating means and SD's, the median was also calculated in order to detect possible skewness in the underlying distribution. In calculating significant difference between groups a paired t-test with 95% confidence interval was used. A significance test was done for every tooth and every developing stage between genders. In the 200 cases where developmental stages were recorded both on the right and left sides, comparison was made to find out if there was a significant difference between the two sides with a paired t-test. Cronbach's Alpha Reliability test was used to assess the study model (Santos, 1999). For interpreting strengths of correlations, Pearson's r was used.

4. RESULTS

The study material consisted of a sample of 1000 OPGs. A group of 23 was excluded. The remaining 977 were assessed and consisted of 508 girls and 469 boys aged 4-25 years. Children under the age of 4 were not available. A developmental tooth scoring system was used for determination of dental maturity stages. A total of 200 OPGs were studied on both the left and right sides and the remaining OPGs on the right side only. The mean age of the sample was 15.00 years.

All results are presented separately for girls and boys.

4.1 Mean and median age

The mean age, the median, SD and N in all developmental stages in all teeth for both genders of 977 OPGs, where 200 were assessed on both the right and left side, and the remaining only on the right side, shown in Table 7.

Table 7. Mean age, median age, SD and N for all developmental stages in all teeth for both genders. (-) No developmental stage in tooth, (-) SD only one value and therefore no SD.

Girls					Boys				
T18					T18				
Stage	Mean	Median	SD	N	Stage	Mean	Median	SD	N
0	8.62	8.28	1.90	116	0	8.53	8.29	1.85	94
1	10.78	10.41	1.45	10	1	9.97	9.74	1.40	17
2	10.90	11.10	2.05	15	2	11.10	10.54	2.03	16
3	11.13	10.62	2.09	18	3	12.37	12.32	1.23	20
4	12.04	11.36	1.84	17	4	12.03	11.74	1.35	20
5	13.33	12.95	2.06	11	5	12.79	12.06	1.93	26
6	13.40	13.30	1.60	57	6	13.49	13.67	1.75	40
7	14.85	14.65	2.19	33	7	14.38	14.62	1.60	23
8	16.36	16.08	2.23	33	8	15.41	15.22	1.79	14
9	17.55	17.51	1.44	27	9	16.07	16.03	1.23	22
10	17.81	17.54	1.26	14	10	18.00	18.17	0.67	5

Girls					Boys				
T17					T17				
Stage	Mean	Median	SD	N	Stage	Mean	Median	SD	N
0	-				0	-			
1	-				1	-			
2	4.49	4.49	-	1	2	-			
3	-				3	4.78	4.78	-	1
4	6.74	6.74	0.42	2	4	6.42	6.32	0.62	5
5	7.41	6.85	1.30	9	5	6.99	7.07	0.84	6
6	7.66	7.51	1.06	49	6	7.99	7.58	1.29	33
7	8.69	8.56	1.19	33	7	8.91	8.73	1.19	49
8	10.29	10.21	1.02	35	8	10.61	10.46	1.30	35
9	11.41	11.35	1.16	45	9	11.91	11.63	1.17	43
10	13.14	12.72	1.69	16	10	13.27	13.45	1.19	30

Girls	T16			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	-			
3	-			
4	-			
5	-			
6	4.49	4.49	-	1
7	-			
8	6.15	6.15	0.78	2
9	7.29	6.91	0.98	30
10	8.12	7.97	1.15	34

Boys	T16			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	-			
3	-			
4	-			
5	-			
6	-			
7	4.78	4.78	-	1
8	6.78	6.47	1.28	6.0
9	7.71	7.58	0.97	23
10	8.26	8.16	0.95	37

Girls	T15			
Stage	Mean	Median	SD	N
0	-			
1	4.49	4.49	-	1
2	-			
3	-			
4	-			
5	7.51	7.27	1.32	8
6	7.41	7.16	0.94	46
7	9.00	8.78	1.16	44
8	10.21	10.29	0.88	25
9	11.29	11.48	1.16	23
10	11.78	11.44	1.11	13

Boys	T15			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	-			
3	5.99	5.99	-	1
4	6.02	5.96	1.08	4
5	8.52	8.52	-	1
6	7.92	7.95	1.06	49
7	9.28	9.16	1.39	40
8	10.28	10.16	1.24	31
9	11.72	11.53	1.43	19
10	12.50	12.35	1.23	16

Girls	T14			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	-			
3	4.49	4.49	-	1
4	-			
5	7.77	7.66	1.66	5
6	7.11	6.84	0.72	39
7	8.42	8.37	0.84	39
8	9.88	9.70	1.00	33.00
9	10.78	11.16	1.04	19
10	11.38	11.29	0.93	19

Boys	T14			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	-			
3	4.78	4.78	-	1
4	6.11	6.11	0.16	2
5	6.53	6.53	1.17	2
6	7.59	7.58	0.78	35
7	8.99	8.57	1.64	41
8	9.96	9.78	1.28	36
9	11.06	11.05	1.23	23
10	11.90	12.14	1.11	18

Girls	T13			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	-			
3	4.49	4.49	-	1
4	-			
5	-			
6	6.65	6.77	0.56	7
7	7.41	7.18	0.91	45
8	8.93	8.88	0.99	46
9	10.25	10.29	1.01	27
10	11.42	11.34	1.03	23

Boys	T13			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	-			
3	-			
4	-			
5	4.78	4.78	-	1
6	6.90	6.70	0.89	12
7	7.95	7.87	0.92	50
8	9.47	9.27	1.04	38
9	10.95	10.82	1.25	34
10	11.84	11.72	1.23	21

Girls	T12			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	-			
3	-			
4	-			
5	-			
6	6.81	6.09	1.28	3
7	6.76	6.78	0.24	15
8	7.46	7.54	0.90	24
9	8.65	8.56	1.20	27
10	9.21	9.17	0.74	10

Boys	T12			
Stage	Mean	Median	SD	N
0	6.86	6.86	-	1
1	-			
2	-			
3	-			
4	-			
5	5.24	5.24	0.65	2
6	6.39	6.32	0.32	5
7	7.60	7.49	0.74	12
8	7.92	7.99	0.70	28
9	9.03	9.17	0.98	21
10	9.34	9.26	1.04	15

Girls	T11			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	-			
3	-			
4	4.49	4.49	-	1
5	-			
6	-			
7	6.57	6.71	0.36	5
8	6.92	6.80	1.00	16
9	7.70	7.82	0.84	31
10	8.63	8.47	0.97	16

Boys	T11			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	-			
3	-			
4	-			
5	5.70	5.70	-	1
6	5.50	5.50	1.02	2
7	7.25	6.62	1.37	3
8	7.25	7.36	0.81	11
9	8.00	8.02	0.93	35
10	8.79	8.82	1.02	19

Girls	T21			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	-			
3	-			
4	-			
5	-			
6	-			
7	6.65	6.65	0.47	2
8	7.31	6.98	0.80	4
9	7.68	7.82	0.82	8
10	8.59	8.37	0.75	3

Boys	T21			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	-			
3	-			
4	-			
5	-			
6	-			
7	-			
8	7.29	7.22	0.56	4
9	8.18	8.03	0.98	15
10	9.80	10.25	1.80	3

Girls	T22			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	-			
3	-			
4	-			
5	-			
6	8.29	8.29	-	1
7	7.01	6.85	0.71	7
8	7.69	7.82	0.68	6
9	8.93	8.74	0.43	3
10	9.04	9.04	0.94	2

Boys	T22			
Stage	Mean	Median	SD	N
0	6.86	6.86	-	1
1	-			
2	-			
3	-			
4	-			
5	-			
6	-			
7	7.54	7.63	0.45	5
8	7.96	8.00	0.65	10
9	9.93	9.74	1.06	6
10	10.37	10.81	1.29	4

Girls	T23			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	-			
3	-			
4	-			
5	-			
6	6.66	6.82	0.30	3
7	7.60	7.53	0.81	10
8	9.02	8.75	0.97	12
9	10.99	10.93	0.62	6
10	11.16	11.11	1.23	5

Boys	T23			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	-			
3	-			
4	-			
5	-			
6	7.21	6.89	0.65	3
7	8.09	7.93	0.88	17
8	10.22	10.28	1.14	9
9	11.46	11.39	1.03	9
10	12.07	11.72	1.22	9

Girls	T24			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	-			
3	-			
4	-			
5	-			
6	7.14	6.92	0.75	10
7	8.42	8.34	0.64	8
8	9.24	9.25	0.75	7
9	11.15	11.36	0.67	8
10	10.86	11.11	0.86	4

Boys	T24			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	-			
3	-			
4	-			
5	-			
6	7.98	7.58	1.74	13
7	9.12	8.70	1.24	12
8	10.72	11.17	1.25	7
9	11.22	11.05	1.04	8
10	12.21	12.42	0.82	5

Girls	T25			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	-			
3	-			
4	-			
5	6.85	6.85	-	1
6	7.59	7.23	1.11	9
7	8.25	8.43	0.83	12
8	10.37	10.41	0.90	6
9	11.04	11.10	0.62	5
10	11.45	11.44	1.18	7

Boys	T25			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	-			
3	-			
4	-			
5	7.58	7.58	-	1
6	7.84	7.81	0.76	13
7	9.65	10.25	1.34	11
8	11.49	11.44	1.21	9
9	11.49	11.18	1.06	8
10	13.22	13.85	1.30	3

Girls	T26			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	-			
3	-			
4	-			
5	-			
6	-			
7	-			
8	-			
9	7.10	6.85	0.67	9
10	8.15	8.39	0.67	8

Boys	T26			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	-			
3	-			
4	-			
5	-			
6	-			
7	-			
8	6.84	6.84	0.08	2
9	7.85	7.76	0.78	8
10	8.43	8.23	0.99	12

Girls	T27			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	-			
3	-			
4	-			
5	7.00	6.85	0.76	3
6	7.46	7.17	0.79	10
7	8.81	8.69	0.71	10
8	10.85	11.10	0.79	9
9	11.27	11.35	0.87	9
10	12.41	12.25	1.70	6

Boys	T27			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	-			
3	-			
4	7.15	7.15	0.36	2
5	7.08	7.08	0.42	2
6	7.80	7.87	0.52	12
7	9.77	9.22	1.22	9
8	11.40	11.36	1.26	14
9	11.76	11.60	0.96	14
10	13.51	13.72	0.57	6

Girls	T28			
Stage	Mean	Median	SD	N
0	8.39	8.24	1.55	24
1	10.16	10.16	0.47	2
2	8.75	8.75	0.17	2
3	10.46	10.50	1.66	5
4	11.75	11.11	1.51	5
5	12.10	12.05	0.81	5
6	14.04	13.30	2.03	13
7	15.08	14.59	2.71	11
8	15.54	15.50	1.16	11
9	17.19	16.94	0.80	4
10	17.91	17.91	-	1

Boys	T28			
Stage	Mean	Median	SD	N
0	8.31	8.03	1.20	25
1	10.24	10.24	0.32	2
2	11.92	11.53	1.35	8
3	12.47	11.96	1.20	8
4	11.59	11.53	0.98	6
5	13.37	12.96	1.60	6
6	13.01	13.15	1.70	12
7	13.98	14.05	1.01	8
8	15.91	15.07	2.64	4
9	16.06	15.61	1.59	3
10	18.27	18.27	-	1

Girls	T48			
Stage	Mean	Median	SD	N
0	8.77	8.19	2.16	113
1	10.22	9.92	1.60	34
2	11.87	11.55	1.47	16
3	12.11	12.15	1.50	19
4	12.69	12.32	1.47	22
5	13.42	13.30	1.64	22
6	13.98	14.06	1.83	35
7	15.35	15.29	1.96	21
8	17.45	17.30	2.08	45
9	18.75	18.05	2.38	27
10	18.47	18.88	1.26	11

Boys	T48			
Stage	Mean	Median	SD	N
0	8.67	8.40	1.90	102
1	10.59	10.25	1.93	17
2	12.02	12.21	1.71	31
3	11.57	11.57	0.66	21
4	12.25	11.75	1.65	23
5	13.33	13.71	1.64	22
6	14.49	14.50	1.51	24
7	15.11	14.89	1.37	19
8	16.09	15.73	1.62	27
9	17.32	17.32	1.22	19
10	17.63	17.85	1.05	7

Girls	T47			
Stage	Mean	Median	SD	N
0	-			
1	4.49	4.49	-	1
2	8.74	8.74	-	1
3	8.77	8.77	0.98	2
4	8.27	6.91	3.09	3
5	7.24	6.85	0.97	20
6	7.80	7.82	1.04	47
7	9.38	9.10	1.41	25
8	10.62	10.46	1.29	43
9	11.63	11.53	1.14	41
10	13.08	13.08	1.13	28

Boys	T47			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	4.78	4.78	-	1
3	5.85	5.85	0.21	2
4	7.07	7.09	0.76	9
5	7.33	7.40	0.50	15
6	8.25	8.23	1.19	37
7	9.58	9.28	1.14	37
8	11.01	10.82	1.27	41
9	12.18	12.06	1.24	41
10	13.61	13.73	1.15	31

Girls	T46			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	-			
3	-			
4	-			
5	-			
6	6.87	6.87	3.36	2
7	-			
8	6.75	6.71	0.70	5
9	7.31	6.98	0.95	35
10	8.1	7.97	0.95	31

Boys	T46			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	-			
3	-			
4	-			
5	-			
6	-			
7	-			
8	6.05	6.17	0.67	7
9	7.73	7.58	0.88	32
10	8.40	8.40	0.80	32

Girls	T45			
Stage	Mean	Median	SD	N
0	4.49	4.49	-	1
1	-			
2	-			
3	-			
4	7.48	7.48	0.48	2
5	7.47	7.11	1.12	16
6	7.65	7.45	1.20	44
7	9.15	8.90	1.08	36
8	9.74	9.64	1.06	24
9	11.73	11.58	1.12	35
10	11.94	12.28	1.22	17

Boys	T45			
Stage	Mean	Median	SD	N
0	6.22	6.22	-	1
1	-			
2	-			
3	4.78	4.78	-	1
4	6.05	6.08	0.27	4
5	7.19	7.38	0.51	3
6	7.95	7.81	1.06	45
7	9.33	9.18	1.48	42
8	10.92	10.81	1.42	36
9	11.76	11.75	1.31	27
10	12.85	12.79	1.42	24

Girls	T44			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	4.49	4.49	-	1
3	-			
4	-			
5	6.75	6.77	0.34	3
6	7.16	6.88	0.97	34
7	8.30	8.30	0.90	45
8	9.59	9.62	0.96	29
9	10.81	10.97	0.97	26
10	11.64	11.27	1.20	22

Boys	T44			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	-			
3	-			
4	5.50	5.50	1.02	2
5	5.94	5.94	0.33	2
6	7.58	7.40	1.28	27
7	8.52	8.45	1.18	49
8	10.19	10.24	1.28	42
9	11.36	11.50	0.98	23
10	12.11	12.17	1.26	17

Girls	T43			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	-			
3	4.49	4.49	-	1
4	-			
5	-			
6	7.04	6.85	0.58	7
7	7.23	6.98	0.96	39.0
8	8.57	8.50	0.96	37
9	9.72	9.61	1.06	32
10	10.61	10.57	0.81	12

Boys	T43			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	-			
3	-			
4	-			
5	4.78	4.78	-	1
6	6.35	6.27	0.43	8
7	7.84	7.61	0.80	48
8	9.51	9.19	1.33	39
9	10.54	10.46	1.24	37
10	11.69	11.46	0.99	26

Girls	T42			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	-			
3	-			
4	4.49	4.49	-	1
5	-			
6	-			
7	6.95	6.96	0.69	5
8	6.96	6.72	1.10	13
9	7.33	7.14	0.89	24
10	8.55	8.53	1.00	26

Boys	T42			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	-			
3	-			
4	-			
5	-			
6	5.70	5.85	0.66	4
7	6.92	6.62	0.71	5
8	7.51	7.36	0.75	17
9	7.77	7.62	0.69	14
10	8.48	8.29	1.33	25

Girls	T41			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	-			
3	-			
4	4.49	4.49	-	1
5	-			
6	-			
7	-			
8	7.45	7.04	1.74	5
9	7.05	6.80	0.75	26
10	7.30	7.63	0.73	12

Boys	T41			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	-			
3	-			
4	-			
5	-			
6	-			
7	5.60	5.70	0.77	3
8	6.71	6.62	0.75	5
9	7.49	7.39	0.77	16
10	7.53	7.56	0.60	18

Girls	T31			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	-			
3	-			
4	-			
5	-			
6	-			
7	-			
8	7.23	7.23	-	1
9	7.09	6.92	0.56	6
10	7.37	7.82	0.90	5

Boys	T31			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	-			
3	-			
4	-			
5	-			
6	-			
7	6.78	6.78	-	1
8	7.93	7.93	-	1
9	7.28	7.32	0.29	4
10	7.50	7.63	0.45	5

Girls	T32			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	-			
3	-			
4	-			
5	-			
6	-			
7	6.98	9.98	-	1
8	7.04	7.04	0.27	2
9	7.35	6.96	1.06	8
10	8.99	8.56	1.14	9

Boys	T32			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	-			
3	-			
4	-			
5	-			
6	-			
7	7.36	7.36	0.81	2
8	7.12	7.12	0.37	2
9	7.69	7.42	0.83	6
10	8.74	8.29	1.84	9

Girls	T33			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	-			
3	-			
4	-			
5	-			
6	6.59	6.59	0.37	2
7	7.06	6.90	0.64	6
8	8.23	8.34	0.51	10
9	9.91	9.82	0.99	11
10	10.99	10.99	0.70	2

Boys	T33			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	-			
3	-			
4	-			
5	-			
6	6.78	6.78	-	1
7	7.59	7.40	0.66	11
8	9.72	9.12	1.62	16
9	10.76	10.84	1.07	10
10	11.84	11.72	0.81	11

Girls	T34			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	-			
3	-			
4	-			
5	-			
6	6.94	6.84	0.60	8
7	8.04	7.97	0.50	7
8	9.24	9.06	0.90	10
9	10.73	10.50	0.71	8
10	11.09	11.11	0.34	4

Boys	T34			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	-			
3	-			
4	-			
5	-			
6	7.44	7.48	0.46	8
7	8.17	8.36	0.75	12
8	10.76	10.63	1.20	13
9	11.52	11.73	0.86	7
10	11.87	11.63	1.07	6

Girls	T35			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	-			
3	-			
4	-			
5	6.79	6.85	0.23	3
6	7.60	7.82	0.82	11
7	9.04	8.63	0.66	5
8	10.27	10.41	0.98	8
9	11.08	11.28	0.81	10
10	12.68	12.88	0.62	4

Boys	T35			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	-			
3	-			
4	-			
5	7.48	7.48	0.14	2
6	7.62	7.63	0.65	13
7	10.08	10.28	1.57	13
8	11.03	11.17	1.00	9
9	11.63	11.73	0.86	7
10	12.88	13.21	1.21	8

Girls	T36			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	-			
3	-			
4	-			
5	-			
6	-			
7	-			
8	-			
9	7.26	6.98	0.77	11
10	8.15	8.39	0.56	6

Boys	T36			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	-			
3	-			
4	-			
5	-			
6	-			
7	-			
8	6.78	6.78	-	1
9	7.72	7.61	0.72	10
10	8.31	8.36	0.73	8

Girls	T37			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	-			
3	8.74	8.74	-	1
4	-			
5	7.17	6.85	0.75	7
6	7.68	7.90	0.74	8
7	9.41	8.87	1.25	7
8	10.64	10.50	0.98	12
9	11.75	11.51	1.14	8
10	13.27	13.26	1.14	13

Boys	T37			
Stage	Mean	Median	SD	N
0	-			
1	-			
2	-			
3	-			
4	7.50	7.58	0.50	5
5	7.48	7.39	0.59	4
6	7.98	7.92	0.76	8
7	10.25	10.31	1.52	12
8	11.34	11.40	0.69	10
9	11.94	12.04	1.13	15
10	13.81	13.87	1.00	13

Girls	T38			
Stage	Mean	Median	SD	N
0	8.93	8.29	2.41	25
1	9.47	9.48	0.88	6
2	11.28	11.34	1.66	5
3	11.63	11.76	0.91	6
4	11.40	11.23	0.47	4
5	13.52	13.30	1.23	6
6	14.32	14.54	1.70	12
7	11.13	11.13	-	1
8	16.33	16.37	1.80	12
9	18.96	16.69	4.02	5
10	-			

Boys	T38			
Stage	Mean	Median	SD	N
0	8.89	8.29	2.19	27
1	10.62	10.37	0.58	4
2	11.50	11.40	1.15	8
3	12.36	12.05	1.43	10
4	12.54	12.42	1.08	7
5	12.39	11.72	1.51	5
6	14.02	13.65	1.14	8
7	14.23	14.62	1.10	5
8	14.78	14.87	0.77	4
9	17.28	17.83	1.35	3
10	-			

4.2 Standard deviation

The mean and SD for all teeth in developmental stage 10 root fully developed, apex not closed, can be seen in Table 8 arranged according to the minimum and maximum of SD. The lowest SD for girls was 0.34 years in tooth 34 and 0.45 years in tooth 31 for boys.

Table 8. Mean age and SD for stage 10, root fully developed, apex not closed, arranged according to the minimum and maximum of SD.

Tooth/Girls	mean	SD	Tooth/Boys	mean	SD
34	11.09	0.34	31	7.50	0.45
36	8.15	0.56	27	13.51	0.57
35	12.68	0.62	41	7.53	0.60
26	8.15	0.67	18	18.00	0.67
33	10.99	0.70	36	8.31	0.73
41	7.30	0.73	46	8.40	0.80
12	9.21	0.74	33	11.84	0.81
21	8.59	0.75	24	12.21	0.82
43	10.61	0.81	16	8.26	0.95
24	10.86	0.86	26	8.43	0.99
31	7.37	0.90	43	11.69	0.99
14	11.38	0.93	37	13.81	1.00
22	9.04	0.94	11	8.79	1.02
46	8.10	0.95	12	9.34	1.04
11	8.63	0.97	48	17.63	1.05
42	8.55	1.00	34	11.87	1.07
13	11.42	1.03	14	11.90	1.11
15	11.78	1.11	47	13.61	1.15
47	13.08	1.13	17	13.27	1.19
32	8.99	1.14	35	12.88	1.21
37	13.27	1.14	23	12.07	1.22
16	8.12	1.15	15	12.50	1.23
25	11.45	1.18	13	11.84	1.23
44	11.64	1.20	44	12.11	1.26
45	11.94	1.22	22	10.37	1.29
23	11.16	1.23	25	13.22	1.30
18	17.81	1.26	42	8.48	1.33
48	18.47	1.26	45	12.85	1.42
17	13.14	1.69	21	9.80	1.80
27	12.41	1.70	32	8.74	1.84
28	17.91	n/v	28	18.27	n/v
38	n/v	n/v	38	0	n/v

4.3 Time of development

The average time for tooth to develop can be categorized as the total tooth formation time, formation of crown and formation of root. All permanent teeth had fully developed, except the third molar, at the mean age of 13.27 years for girls and 13.81 years for boys.

The mean time for the third molars to develop, from the beginning of crown formation until roots had reached stage 10 was 9.42-9.50 years. From the beginning of crown formation until the crown is completed at stage 5, was 4.08-4.37 years and from root initiation stage to stage 10 was 4.41-4.61 years (Table 9). Other mean developmental time can be seen in Table 15 in appendix.

Table 9. Mean developmental time of the third molars, crown, root and the total developmental time from the beginning of crown formation (stage 0) until stage 10 was reached.

Mean developmental time of third molars.						
Boys				Girls		
tooth	tooth	crown	root	tooth	crown	root
18	9,47	4,26	4,51	9,91	4,71	4,41
28	9,96	5,06	5,26	9,51	3,70	3,87
48	8,96	4,66	3,14	9,98	4,65	4,77
38	9,28	3,50	4,15	n/v	4,59	n/v
mean	9,42	4,37	4,61	9,50	4,08	4,41

4.4 Mean developmental stage according to age.

Taking age as the factor, all teeth start at developmental stage 0 and end in developmental stage 11. To plot the age against the mean developmental stage reached, all teeth approach stage 11 at certain time point. Tooth 17 in girls at 12 years of age (12.00-12.99) have all reached stage 10. From 13-16 they are slowly going into stage 11 until they reach age 17, when they have all reached stage 11 (Table 10 a-d).

Table 10. Developmental stages according to age. Tables a-d. Age was from 4.00-4.99 etc.

Table 10-a. Developmental stages according to age. Teeth 18-28 girls.

Girls. Mean developmental stage according to age																
Age	18	17	16	15	14	13	12	11	21	22	23	24	25	26	27	28
4	0.00	2.00	6.00	1.00	3.00	3.00		4.00								
5																
6	0.00	5.84	9.16	5.92	5.96	6.76	7.42	8.12	8.00	7.17	6.50	6.00	6.00	9.00	5.67	0
7	0.07	6.11	10.00	6.19	6.43	7.33	8.42	9.42	9.00	7.75	7.40	6.60	6.60	9.60	6.00	0
8	0.46	6.85	10.46	6.85	7.23	7.85	9.60	10.24	9.75	8.78	7.56	7.11	6.78	10.22	6.67	0.78
9	0.62	7.31	10.64	7.64	7.69	8.31	10.23	10.62	10.80	10.25	8.40	8.20	7.80	11	7.80	0.80
10	1.86	8.39	10.89	8.59	9.18	9.71	10.67	10.85	11	11	9.60	9.20	8.80	11	8.40	1.60
11	3.80	8.97	11	9.59	9.91	10.11	10.94	11	11	11	10.09	10.00	9.50	11	8.64	4.09
12	4.83	10.00	11	10.48	10.75	10.90	11	11	11	11	10.60	10.60	10.75	11	9.60	5.00
13	5.19	10.81	11	10.91	10.97	10.94	11	11	11	11	11	11	10.86	11	11.00	6.14
14	6.00	10.86	11	10.96	11	11	11	11	11	11	11	11	11	11	11.00	6.60
15	7.40	10.93	11	11	11	11	11	11	11	11	11	11	11	11	10.86	7.60
16	8.40	10.96	11	11	11	11	11	11	11	11	11	11	11	11	11	8.13
17	9.40	11	11	11	11	11	11	11	11	11	11	11	11	11	11	8.33
18	9.09	11	11	11	11	11	11	11	11	11	11	11	11	11	11	8.25
19	10.35	11	11	11	11	11	11	11								
20	10.45	11	11	11	11	11	11	11	11	11	11	11	11	11	11	7.00
21	10.64	11	11	11	11	11	11	11								
22	11	11	11	11	11	11	11	11								
23	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
24	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
25																

Table 10-b. Developmental stages according to age. Teeth 48-38 girls.

Girls. Mean developmental stage according to age																
Age	48	47	46	45	44	43	42	41	31	32	33	34	35	36	37	38
4	0	1.00	6.00	0.00	2.00	3.00	4.00	4.00								
5																
6	0	5.40	8.96	5.71	5.96	6.80	8.28	9.12	9.33	8.50	6.67	6.00	5.50	9.00	5.17	0
7	0.04	5.93	9.64	5.86	6.71	7.43	9.64	10.14	9.60	9.40	7.80	6.80	6.00	9.40	5.80	0
8	0.23	6.19	10.35	6.85	7.19	8.15	10.50	10.88	10.67	10.11	8.11	7.44	6.63	10.11	6.00	0.22
9	0.88	7.23	10.54	7.24	7.77	8.85	10.65	10.92	11	10.60	9.40	8.20	7.80	11	7.80	1.20
10	1.18	8.14	10.89	8.50	9.25	10.11	10.86	10.89	11	10.80	9.60	9.20	8.60	11	8.00	1.60
11	2.91	8.71	11	9.37	9.86	10.49	10.97	11	11	10.91	10.55	9.91	9.18	11	8.55	3.73
12	3.69	9.69	11	10.45	10.79	11.00	11	11	11	11	11	11	10.40	11	9.40	3.00
13	4.00	10.27	11	10.59	10.91	11	11	11	11	11	11	11	10.71	11	10.14	4.43
14	5.08	10.67	11	10.93	10.96	11	11	11	11	11	11	11	11	11	10.56	5.11
15	6.88	10.97	11	11	11	11	11	11	11	11	11	11	11	11	10.83	6.43
16	7.88	11	11	11	11	11	11	11	11	11	11	11	11	11	11	8.00
17	9.14	11	11	11	11	11	11	11	11	11	11	11	11	11	11	8.00
18	8.61	11	11	11	11	11	11	11	11	11	11	11	11	11	11	9.50
19	10.05	11	11	11	11	11	11	11								
20	10.24	11	11	11	11	11	11	11	11	11	11	11	11	11	11	8.00
21	10.14	11	11	11	11	11	11	11								
22	10.67	11	11	11	11	11	11	11								
23	10.90	11	11	11	11	11	11	11	11	11	11	11	11	11	11	10.33
24	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
25																

Table 10-c Developmental stages according to age. Teeth 18-28 boys.

Boys. Mean developmental stage according to age																	
Age	18	17	16	15	14	13	12	11	21	22	23	24	25	26	27	28	
4	0	3.00	7.00	4.00	3.00	5.00	5.00	6.00									
5	0	4.50	8.00	3.50	4.50	6.00	5.50	6.50									
6	0	5.33	8.83	5.82	6.00	6.58	6.45	8.00	8.33	3.50	6.33	6.00	6.00	8.33	5.00	0	
7	0.04	6.28	10.00	6.24	6.44	7.04	7.90	9.09	8.89	7.56	6.89	6.22	6.00	9.56	5.67	0	
8	0.16	6.71	10.13	6.61	6.94	7.23	8.72	9.60	9.57	8.86	7.29	6.71	6.43	9.86	6.57	0	
9	1.04	7.40	10.36	7.20	7.76	8.20	9.71	10.38	9.67	8.67	7.33	7.67	7.00	9.67	7.00	0	
10	2.71	8.04	10.93	8.07	8.57	8.86	10.67	10.88	10.67	10.44	8.80	8.60	8.30	10.90	8.10	2.60	
11	3.75	8.97	11	9.29	9.66	9.87	10.93	10.97	10.91	10.67	9.45	9.27	8.70	11	8.33	3.17	
12	4.29	9.58	11	10.07	10.29	10.50	11	11	11	11	10.45	10.30	9.91	11	9.64	4.91	
13	5.08	10.23	11	10.82	10.50	10.77	11	11	11	11	10.75	10.42	10.64	11	10.09	5.30	
14	6.13	10.55	11	10.87	10.98	10.95	11	11	11	11	10.90	11	10.89	11	10.70	6.00	
15	7.81	10.96	11	10.96	11	11	11	11	11	11	11	11	11	11	11	7.25	
16	7.53	11	11	11	11	11	11	11	11	11	11	11	11	11	11	6.00	
17	10.11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	9.00	
18	10.76	11	11	11	11	11	11	11	11	11	11	11	11	11	11	10.50	
19	10.86	11	11	11	11	11	11	11	11	11	11	11	11	11	11	8.00	
20	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	
21	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	
22	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	
23	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	
24	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	
25																	

Table 10-d Developmental stages according to age. Teeth 48-38 boys.

Boys. Mean developmental stage according to age																
Age	48	47	46	45	44	43	42	41	31	32	33	34	35	36	37	38
4	0	2.00	8.00	3.00	4.00	5.00	6.00	7.0								
5	0	3.00	8.00	4.00	5.50	6.00	6.00	7.5								
6	0	4.92	8.67	5.08	5.92	6.50	7.92	8.8	8.67	8.00	6.67	6.33	6.00	8.67	5.00	0
7	0.04	5.48	9.68	6.13	6.56	7.16	9.00	9.9	9.56	9.00	7.11	6.33	5.78	9.44	4.89	0
8	0.10	6.26	9.97	6.65	7.06	7.58	9.90	10.6	11	10.43	8.14	7.14	6.71	10.14	6.29	0
9	0.68	7.12	10.44	7.38	7.72	8.32	10.76	11	11	10.00	7.67	7.33	7.00	9.67	6.67	0
10	2.04	7.82	10.96	8.11	8.57	8.96	10.96	11	11	11.00	8.90	8.90	8.33	11	8.10	2.20
11	2.75	8.72	11	9.00	9.59	9.88	11.00	11	11	11.00	9.33	9.25	8.50	11	8.17	2.64
12	3.50	9.32	11	9.63	10.16	10.52	11.00	11	11	11.00	10.55	10.36	9.80	11	9.27	4.00
13	4.17	9.58	11	10.35	10.54	10.69	10.96	11	11	10.92	10.67	10.67	10.45	11	9.91	4.92
14	5.57	10.43	11	10.73	10.98	11	11	11	11	11	11	11	10.78	11	10.40	4.80
15	7.14	10.92	11	10.88	11	11	11	11	11	11	11	11	11	11	10.80	6.75
16	7.37	11	11	11	11	11	11	11	11	11	11	11	11	11	11	6.00
17	9.40	11	11	11	11	11	11	11	11	11	11	11	11	11	11	9.00
18	10.35	11	11	11	11	11	11	11	11	11	11	11	11	11	11	10.00
19	10.61	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
20	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
21	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
22	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
23	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
24	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
25																

4.5 Comparison between right and left side

When comparing the right and left side, the data from the first 200 OPGs were used. The mean developmental stage in each tooth was found with SD. Each tooth was then paired with the corresponding tooth on the other side. A paired t-test was performed with 95% confidence, as can be seen in Table 16 in appendix. There was no significant difference between the left and right side except in a few instances.

Correlation was found using Pearson's R. There was a good correlation between the left and right side ($r = 0.95 - 1.00$) and significant (Table 11).

Table 11. Correlation between the right and left sides.

Correlation between sides 1 and 2				Correlation between sides 3 and 4			
Teeth	N	Correlation	Significance	Teeth	N	Correlation	Significance
18 and 28	185	0.99	0.00	48 and 38	181	0.99	0.00
17 and 27	197	0.98	0.00	47 and 37	196	0.98	0.00
16 and 26	196	0.95	0.00	46 and 36	201	1.00	0.00
15 and 25	183	0.98	0.00	45 and 35	192	0.98	0.00
14 and 24	195	0.98	0.00	44 and 34	201	0.98	0.00
13 and 23	199	0.98	0.00	43 and 33	201	0.99	0.00
12 and 22	185	0.99	0.00	42 and 32	199	0.99	0.00
11 and 21	190	1.00	0.00	41 and 31	200	0.99	0.00

4.6 Difference between genders

Comparison between genders was done by pairing the mean age (from Table 7) in all teeth for every developmental stage as can be seen in Table 17 in appendix. A paired t-test was used. The comparison showed no significant difference except in some stages in few teeth. In tooth 13 there was a significant difference in stages 7, 8 and 9 ($p < 0.01$ and 0.05) and tooth 43 there was significant difference in stages 6, 7, 8, 9 and 10 ($p < 0.01-0.05$).

4.7 Reliability

Reliability of the study instruments was found by using the Cronbach's Alpha reliability test. Cronbach's alpha determines the internal consistency or average correlation of items in an instrument used in a study, to gauge its reliability (Santos, 1999). In the present study the instrument used was the reading of the OPGs by the examiner. The Cronbach's Alpha was 0.982 (see Table 18 and Table 19 in appendix).

The reliability and correlation with the total score for the study instruments can be seen in Table 12.

Table 12. Reliability and correlation for the total score.

Reliability and correlation for the total score				
	Scale mean if item is deleted	Scale variance if item is deleted	Correlated item-total correlation	Cronbach's Alpha if item deleted
T18	286.86047	2374.543	.878	.982
T17	282.41860	2535.214	.943	.980
T16	280.74419	2668.582	.796	.982
T15	282.17829	2527.148	.953	.980
T14	282.02326	2531.617	.954	.980
T13	281.80620	2556.267	.951	.980
T12	281.26357	2588.555	.792	.981
T11	280.90698	2641.616	.805	.981
T21	280.91473	2640.625	.802	.981
T22	281.26357	2589.024	.791	.981
T23	281.81395	2554.246	.955	.980
T24	281.98450	2533.969	.957	.980
T25	282.18605	2525.809	.951	.980
T26	280.75969	2666.778	.804	.982
T27	282.49612	2523.533	.953	.980
T28	286.96124	2376.788	.879	.982
T48	287.34109	2395.352	.848	.982
T47	282.75194	2514.594	.939	.981
T46	280.75969	2664.731	.796	.982
T45	282.32558	2523.471	.955	.980
T44	282.00000	2536.547	.952	.980
T43	281.72093	2566.797	.939	.981
T42	280.80620	2656.251	.760	.982
T41	280.61240	2685.161	.623	.982
T31	280.62016	2683.503	.609	.982
T32	280.81395	2655.434	.761	.982
T33	281.65116	2572.104	.940	.981
T34	281.93023	2540.394	.959	.980
T35	282.28682	2520.175	.964	.980
T36	280.75194	2665.922	.793	.982
T37	282.68992	2504.247	.962	.980
T38	287.37209	2397.360	.844	.982

4.8 Intra-rater reliability

Intra-rater reliability is a type of reliability assessment in which the same assessment is completed by the same rater on two or more occasions.

In the pilot study the examination was done twice with a for week interval for the 100 OPGs from the 1100 OPGs taken in the beginning. This was done to rate the examiner. The results showed intra-rater reliability Pearson's $r = 0.847-0.993$. Values can be seen in Table in appendix.

The Cronbach's Alpha for the pilot study instrument on both the first and secondary assessments and showed reliability with Cronbach's Alpha for the first examination as 0.981 and for the second examination as 0.981 as well, and can be seen in Table 21 in appendix.

4.9 Exclusion in the study

A total of 23 OPGs were excluded from the sample. Exclusion was due to multiple hypodontia, patients with fixed orthodontic appliances, rampant caries, distortion of OPGs and the wrong registration of the patient to the sample. Exclusion of teeth in the study due to preset criteria was 421 teeth out of 31,264 teeth studied which was 1.3%. Most of the teeth excluded was due to hypodontia $N = 286$ (Table 13).

Table 13. Exclusion of teeth due to preset criteria. ta = peg tooth, v = hypodontia, ex = extracted, k = unreadable due to rotation, crowding etc., b = deciduous tooth, r = resorption, en = endodontically treated.

Excluded teeth due to preset criteria																																					
N		18	17	16	15	14	13	12	11	21	22	23	24	25	26	27	28	48	47	46	45	44	43	42	41	31	32	33	34	35	36	37	38				
0	ta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
286	v	63	1	0	37	4	2	19	3	1	5	0	0	6	1	0	10	66	3	2	31	4	0	2	3	0	1	0	0	7	0	5	10				
6	ex	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
113	k	15	3	3	9	4	3	18	15	5	5	1	2	5	2	2	2	10	0	0	0	0	0	1	1	1	1	0	0	0	0	0	5				
0	b	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0					
0	r	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0					
15	en	0	0	1	1	0	0	1	4	4	0	0	1	0	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0					
1	tt	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0					
421																																					

5. DISCUSSION

Dental maturity was established from the beginning of crown formation to the root apex closure, when the sample allowed, for all teeth for both genders. The mean and median age for all teeth and all dental developmental stages when the sample allowed was established. The SD was found for all stages calculated. The Cronbach's Alpha analysis of 0.982 showed very good internal consistency or reliability of the study instrument. Developmental time for third molars was found and their crown and root formation time. Mean developmental stages according to age was established. Comparison on the left and right side was done and showed significant differences in only a few instances and no significant difference between the left and right sides. (Pearson's $r = 0.95-1.00$).

Difference between genders was only found in the root formation in maxillary and mandibular canines. Reliability for the study instrument showed good reliability. Intra-rater reliability also showed good reliability.

Girls in Iceland reach full dental maturity (stage 10) at 17.81 years of age based on the maxillary third molars and 18.47 years of age based on the mandibular third molars. Boys reach full dental maturity at 18.17 years of age based on the maxillary third molars and 17.63 years of age based on the mandibular third molars.

5.1 The sample

When planning the present study it was decided to have the sample of digital OPGs from as an Icelandic population and for the age group that was needed. The sample was selected from a private orthodontic practice in the Reykjavik area where OPGs are taken both for the orthodontic practice and also for other practitioners in the area. The OPGs selected were always from the first OPG taken of the patient, so if an orthodontic treatment was needed, the treatment had not started. The OPGs were from the orthodontist, but also from 10 other dentists and one oral surgeon who use the OPGs for diagnostic purposes. Many studies on age estimation are based on orthodontic sample (Haavikko, 1970; Willems et al., 2001). The sample consisted of 1100 OPGs of patients from 4-25 years of age. The total population in Iceland in 2011 was 318,452. Of these 94,263 were in the age group chosen. The sample was 1.17% of that age group, 0.35% of the total population (Table 14).

Table 14. Icelandic population compared to the sample. Source: (Statistics Iceland, 2012)

	Sample	Popul.	%
Total	1.100	94.263	1.17
10 years	52	4.420	1.18
Sample	1.100	318.452	0.35
Tot. Pop.	94.263	318.452	29.60

This was a cross-sectional study based on OPGs from 2004-2009. The sample was not taken from a random population, but instead available OPGs were used to minimize the risk of radiation. An ideal study model would be a longitudinal study where periapical intraoral radiographs would be taken every 3 months of the same person from birth until the teeth had reached full development. The research in 1961 by Fanning was of that kind (Fanning, 1961). This would put the sample at risk of radiation poisoning and would never be approved as a study method today.

5.2 Pilot study

When the study design was finished, a sample of 100 OPGs was selected and a pilot study performed. When a large study is done it is advisable to do a pilot study in order to evaluate feasibility, time, cost, and adverse events, in an attempt to predict and improve upon the study design prior to the performance of a full-scale research project. It is also a good way to try out examiners. The design can be altered or improved at this time and to calculate the reliability and the strength of the results before the main study is performed (Lancaster et al., 2004). A pilot study was done on a similar sample, but not on the main sample. The pilot sample was studied twice with a four week interval to achieve an intra-rater reliability test. The mean and SD was found, but sample was too small to achieve reliable results.

These ratings were then compared, by means of correlation (Suri & Verma, 2010).

Haavikko's (Haavikko, 1970) and Demirjian's (Demirjian et al., 1973) descriptions of developmental stages were used to train the examiner in the pilot study.

5.3 Problems in the diagnostic phase

When the OPGs were examined, the examiner did not know the age and gender of the participants. Therefore it was difficult to see if a tooth had developmental stage 0 or was missing. When all the OPGs had been examined a computerized search was done to find where stage 0 did not match the age, and then reexamined to rule out bias.

When studying just the right side and a tooth had to be excluded, it was possible to use the corresponding tooth on the left side. Only if neither tooth were useable, that tooth was excluded, but not the whole OPG. In Haavikko's and Demirjian's study (Demirjian et al., 1973; Haavikko, 1970) they used the same method and drew the conclusion that right and left were identical, and rather than exclude the whole OPG and miss out valuable data, they used the other side.

A problem arises when teeth reach stage 11, root fully developed with closure of the apex. Because the sample consisted of participants from 4-25 years of age, all teeth reached stage 11 much earlier than 25 and therefore stage 11 was distributed from the time each tooth reached apex closure

to the chronological age of that individual. If apex closure is at the age of 11 for tooth 17 and that individual is in the study at the age of 16, then the stage 11 recorded as 16 year old instead of 11 years old (Table 10). In some studies stage 10 is often used to decide on the fully developed tooth (Haavikko, 1970; Kullman et al., 1992). Haavikko did not address this problem except by saying that there was no reliable way to decide the final formation stage, apex closed. Knowledge was not available of the age at which this stage was reached in the individuals and it continues to give the same last developing score, apex closed through the years to come (Haavikko, 1974). In the present study stage 10 was used as tooth fully developed, apex not closed and all conclusions were driven from this.

When deciding on a developmental stage in a tooth with multiple roots Fanning found that the mesial root finished its formation before the distal one (Fanning, 1961). In the present study the procedure was to always evaluate each root separately, and if there was a difference between stages, which was very seldom, the mesial root prevailed.

Even though there is an enlargement of about 3-10% in OPG radiographs, this does not affect the outcome because the scoring system is based on relative values rather than absolute length measurements.

5.4 Time of development

Fanning did a study on velocity of tooth growth, to approximate the growth velocity of the permanent teeth at different periods during their development (Fanning, 1961). The author related the average occlusal-apical measurements to the average intervals of time between the stages of formation. The mean increase in linear growth of permanent teeth for the intervals between stages of formation revealed a deceleration in rate when crown formation was complete and root development began. This deceleration was followed by acceleration in root development during the active eruption of the tooth that continued to the attainment of the total root length. A second deceleration was seen during the completion and apical closure of the root. The present study showed the mean age for a third molar to develop from stage 0-10 was 9.42-9.5 years. The mean age for crown formation from stage 0-5 is 4.08-4.37 years and the root formation from stage 6-10 is 4.41-4.61 years (Table 9).

The permanent teeth start to develop just before and around birth, first the M_1 and I_1 and after that the I_2 . The C starts to develop around 6 months. P_1 around 1.8 years and P_2 at 3 years. M_2 start at 3.5 years and M_3 at 9.4 years (Moorrees et al., 1963). The youngest individual in the present study was 4.49 years old. For that reason there is a lack of crown formation age for many teeth.

It takes 13.27 years for girls to reach stage 10 for all teeth except for the third molars and 13.81 years for boys (Table 22 in appendix). In Finland Haavikko found that girls reach this stage at 15.1 years and boys 16.2 years (Haavikko, 1970). In Canada Anderson got similar findings where boys reached this stage in 14.8 years of age and girls 13.8 years (Anderson et al., 1976). In the present study Icelandic children and adolescents reached the stage of fully developed teeth (except third

molars) earlier than the Finnish children, but were more in line with children in Canada. This will stress upon the need that each population should have its own database of mean age developmental stages to refer to. Researchers have been trying to establish a general gender-specific dental maturity scores (Willems et al., 2010), or adapt other findings in dental age assessments to the population in hand (Chaillet et al., 2004; Nykanen et al., 1998; Schmeling et al., 2003; Williamson et al., 2002). But still it is necessary to establish a database of dental development for each population.

5.5 Mean age and SD for fully developed teeth

In the present study the dental maturity was established for all teeth from the beginning of crown formation until the root apex closure, when the sample allowed, for both genders. The mean age for teeth that had reached stage 10 on the right side with standard deviation is shown in Table 23 in appendix.

Haavikko did a study on a few selected teeth to establish the least variable teeth in formation for the purpose of minimizing work when doing age estimation. Her conclusion was that the most stable teeth were 47,46,(16),44 and 41 from birth to nine years and teeth 47,44,13 and 43 from 10 years of age and onwards (Haavikko, 1974). In this study teeth that were most stable under 10 years are 41 and 46 and over 10 years 43 and 14.

In some instances in Table 7 the age score is not in the right sequence. In most of the cases the reason was that the N (the number of cases/developmental stage) was too low and did not give an accurate mean age for that particular developmental stage. The few that were based on enough number of teeth but were not in sequence were most likely explainable by the natural variability in the biological phenomena.

5.6 Third molars

The third molars show the most fluctuation in formation. In Haavikko's study the range in age estimation of the third molars was SD 2.8-6.5 years. Haavikko stated that the third molars were not the best candidates for age estimation (Haavikko, 1970). Kullman did his studies on third molars alone and used different methods to find a more accurate way to use developmental stages for age estimation. He studied intra-oral radiographs to try to establish a computer program for more accurate measurements for developmental stages. His findings showed that the computer program was less reliable than the conventional way (Kullman, 1995a, 1995b; Kullman et al., 1992; Kullman et al., 1995). Today the use of age estimation from third molars is widely used for the age group from 14-25 years, when other permanent teeth have fully developed. Asylum seekers claiming to be under the age of 18 years fall under the Convention on the Rights of the Child (1989). If countries have legally approved these laws they are obligated to follow the guidelines governed by the UN Convention on the

Rights of the Child from 1989 (UNHCR, 2006) and the UNHCR Guidelines on Policies and Procedures in Dealing with Unaccompanied Children Seeking Asylum (1997) to determine if he or she is still a child. Even though third molars are not the most accurate teeth for age estimation, they are the best way and sometimes the only way to establish the chronological age of these persons.

5.7 Comparison of the right and left sides

In the present study 200 OPGs were studied on both the right and left sides for comparison. There was no significant difference between the sides, except between teeth 18 and 28, 17 and 27, 44 and 35, and 43 and 33 (Table 17 in appendix). The difference between the means showed that the numerical value was small, 0.05-0.09. It can be discussed if the difference has practical relevance. The comparison was done on the mean developmental stages in each tooth. The correlation was very high (Pearson's $R = 0.98-1.00$) (Table 11). In Haavikko's study there was no difference between sides and she combined the results on both sides (Haavikko, 1970). In the present study the reason for the difference in few teeth could be from the fact that only 200 OPGs were examined on both the right and left side.

5.8 Difference between genders

The present study showed no significant difference between genders except in some stages in a few teeth. In tooth 13 there was significant difference in stages 7, 8 and 9 ($p < 0.01$ and 0.05) and for tooth 43 there was significant difference in stages 6, 7, 8, 9 and 10 ($p < 0.01-0.05$). In these two teeth the difference made a pattern in the developmental stages of the roots which indicated that there was a difference between the genders. In other teeth there were only 1 or 2 stages which did not make a pattern (Table 17 appendix). In earlier studies significant differences have been reported between genders where girls were earlier in the development (Haavikko, 1970). Haavikko stated that even though there seemed to be some differences between genders from 0.3-0.6 years, if examined at the earlier (Cr_c) and later (A_c) formation stages, it may generally be noted that the sex differences were smaller at the earlier ages and became more pronounced at later stages of formation and at a later age (Haavikko, 1970). Researchers have generally noted differences (Demirjian et al., 1973; Haavikko, 1970), except Nada and Chawla (1966) who found the differences in their sample was so small as to warrant combining the results (Nanda & Chawla, 1966), and Garn et al. reported a sex differences only in about 3% of their sample (Garn et al., 1958). Newer studies show no differences between genders except in a few teeth. Zeng et al. showed no differences in third molars (Zeng et al., 2010) and Demirjian in showed no differences between genders in the earlier stages of development whereas in older ages the girls had advance faster than boys in the later stages (Demirjian &

Levesque, 1980). Liversidge also stated that there was no significant difference between stages even though the findings seemed to show some numerical differences (Liversidge, 2008).

5.9 Disturbance in development

Dental development is believed to be a very stable process in the human body (Fanning, 1961). Sometimes developmental anomalies arise and are mostly due to genetic disturbances, acquired or idiopathic. Genetic disturbance like osteopetrosis (Dick & Simpson, 1972) or ectodermal dysplasia (Lexner et al., 2007) can arise. Even though such dental disturbances affect the formation of the teeth, they do not affect the velocity of development (Lexner et al., 2007). Treatment for different kind of cancer in children where radiation and chemotherapy were combined has shown developmental disturbances (Goho, 1993; Hwang & Yoon, 2011; Kaste et al., 1994; Zarina & Nik-Hussein, 2005). Tooth development disturbances following haematopoietic stem cell transplantation in young children has been reported (van der Pas-van Voskuilen et al., 2010). Nearly all children had tooth developmental disturbances, including agenesis, shortened roots and arrested root development after treatment. A study group showed a significantly higher prevalence of agenesis than the standard values for first and second premolars in both maxilla and mandible, as well as for second molars in the mandible. Children younger than 3 years of age at the start of the treatment were missing significantly more teeth than older children. The mean root-crown length ratios of several tooth types were lower when compared with a control group. The mean dental age was higher than the mean chronological age due to early final apical root formation. It is not known whether the cause of the dental developmental disturbance was the total body radiation or cancer medications used in the treatment (van der Pas-van Voskuilen et al., 2010). In the present study it was ensured that the sample consisted of healthy individuals, who had not suffered from long term illness, had been through cancer treatment, or had diseases that can interfere with tooth development.

5.10 Future perspectives

Inter-population differences in skeletal and dental growth and maturation are acknowledged frequently in the biological, anthropological and dental literature. These growth differences have implications for the reliability of standards for the estimation of age (Buckley & Tayles, 2003).

The results raise an important question for forensic odontologists of the appropriateness of available aging methods. The present study emphasized the need for the use of appropriate methodologies in the collection and presentation of dental developmental data. There are differences in growth and development among populations that affect the reliability of the ageing standards used by forensic odontologists.

A similar database of populations of varying origin may reveal in further studies more specific age-estimation techniques and possible differences or agreements in dental development between members of diverse nationalities or distinct ethnical groups.

A Future respective would be to create computer software to read all OPGs with respect to their developmental stages. Also to find a sample for children of 0-4 years in Iceland to complete the database.

6 CONCLUSIONS

The present study has established a reliable dental maturity database for Icelandic children and adolescents, to use in age estimation. It can be of help to estimate accurately age and maturity in Icelandic children and adolescents and can be useful for professionals who rely on the maturity and age of young individuals for their work.

Dental maturity was established from the beginning of crown formation to the root apex closure, when the sample allowed, for all teeth for both genders. The Cronbach's Alpha analysis of 0.982 showed very good internal consistency or reliability of the study instrument. There was no significant difference between the left and right sides. (Pearson's $r = 0.95-1.00$).

Girls in Iceland reach full dental maturity at 17.81 years of age based on the maxillary third molars and 18.47 years of age based on the mandibular third molars. Boys reach full dental maturity at 118.00 years of age based on the maxillary third molars and 17.63 years of age based on the mandibular third molars.

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Appendix

Table 15. Mean developmental time, crown, root and the total developmental time from the beginning of crown formation (stage 0) until stage 10 is reached.

Boys (blue) and Girls (pink) mean per development						
tooth	tooth dev.	tooth dev.	crown	crown	root	root
18	9.47	9.91	4.26	4.71	4.51	4.41
17					5.28	5.48
16						
15					4.58	4.37
14					4.31	4.27
13					4.94	4.77
12					2.95	2.40
11					3.29	
21						
22						n/v
23					4.86	4.50
24					4.23	3.72
25					5.38	3.86
26						
27					5.71	4.95
28	9.96	9.51	5.06	3.70	5.26	3.87
48	8.96	9.98	4.66	4.65	3.14	4.77
47		8.59		2.75	5.36	5.28
46						
45					4.90	4.29
44					4.53	4.48
43					5.34	3.57
42					2.78	
41						
31						
32						
33					5.06	4.40
34					4.43	4.15
35					5.26	5.08
36						
37					5.83	5.59
38	9.28	n/v	3.50	4.59	4.15	n/v
mean	9,42	9,50	4,37	4,08	4,61	4,41

**Table 16. Difference between the developmental stages on the maxillary right and left sides
(side 1 and 2.)and mandibular right and left sides (side 3and 4).**

Difference between developmental stages on side 1 and 2				
Teeth	Mean	N	SD	Signif.
18	4.78	185	3.78	*
28	4.69	185	3.76	
17	9.26	197	1.92	*
27	9.20	197	2.02	
16	10.71	196	0.63	
26	10.69	196	0.67	
15	9.48	183	1.96	
25	9.46	183	1.97	
14	9.56	195	1.91	
24	9.60	195	1.90	
13	9.79	199	1.63	
23	9.77	199	1.66	
12	10.33	185	1.48	
22	10.33	185	1.48	
11	10.57	190	0.92	
21	10.57	190	0.93	

Significance is based on 95% confidence

18 and 28: $t(184) = 2.00, p < 0.05$

17 and 27: $t(196) = 2.01, p < 0.05$

Standard deviation T12 and T22 is not exactly the same when more decimals are applied (T12 1.483 and T22 are 1.479)

Difference between developmental stages on side 3 and 4				
Teeth	Mean	N	SD	Signif.
48	4.26	181	3.85	
38	4.24	181	3.84	
47	8.96	196	2.13	
37	8.94	196	2.14	
46	10.70	201	0.68	
36	10.71	201	0.67	
45	9.31	192	2.01	
35	9.34	192	2.01	
44	9.63	201	1.82	*
34	9.68	201	1.78	
43	9.87	201	1.55	*
33	9.93	201	1.49	
42	10.65	199	0.81	
32	10.65	199	0.82	
41	10.81	200	0.59	
31	10.80	200	0.62	

Significance is based on 95% confidence

44 and 34: $t(200) = -2.32, p < 0.05$

43 and 33: $t(200) = -3.12, p < 0.01$

Table 17. Differences between genders, a-d.

Table 17 – a: Teeth 18-11								
Dev. stage	T18		T17		T16		T15	
	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys
0	8.62	8.53	-	-	-	-	-	-
1	10.79	9.97	-	-	-	-	4.49	-
2	10.90	11.10	4.49	-	-	-	-	-
3	11.13	12.37 ***	-	4.78	-	-	-	5.99
4	12.05	12.03	6.74	6.42	-	-	-	6.02
5	13.33	12.79	7.41	6.99	-	-	7.51	8.52
6	13.40	13.49	7.66	7.99	4.49	-	7.41	7.92 ***
7	14.85	14.38	8.69	8.91	-	4.78	9.00	9.28
8	16.36	15.41	10.29	10.61	6.15	6.78	10.21	10.28
9	17.55	16.07 *	11.41	11.91 ***	7.29	7.71	11.29	11.72
10	17.81	18.00	13.14	13.27	8.12	8.26	11.78	12.50
11	21.35	20.72 ***	18.31	18.55	16.18	16.17	17.72	17.94
Dev. stage	T14		T13		T12		T11	
	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys
0	-	-	-	-	-	6.86	-	-
1	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-
3	4.49	4.78	4.49	-	-	-	-	-
4	-	6.11	-	-	-	-	4.49	-
5	7.77	6.53	-	4.78	-	5.24	-	5.70
6	7.11	7.59 **	6.65	6.90	6.81	6.39	-	5.50
7	8.42	8.99	7.41	7.95 **	6.76	7.60 **	6.58	7.25
8	9.88	9.96	8.93	9.47 ***	7.46	7.92 ***	6.92	7.25
9	10.78	11.06	10.25	10.95 ***	8.65	9.03	7.70	8.00
10	11.38	11.90	11.42	11.84	9.21	9.34	8.63	8.79
11	17.70	17.80	17.59	17.79	16.53	16.70	16.25	16.39
*(p < .001) ** (p < .01) *** (p < .05)								

Table 17 – b : Teeth 21-28									
Dev. stage	T21		T22		T23		T24		
	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	
0	-	-	-	6.86	-	-	-	-	
1	-	-	-	-	-	-	-	-	
2	-	-	-	-	-	-	-	-	
3	-	-	-	-	-	-	-	-	
4	-	-	-	-	-	-	-	-	
5	-	-	-	-	-	-	-	-	
6	-	-	8.29	-	6.66	7.21	7.14	7.98	
7	6.65	-	7.01	7.55	7.60	8.09	8.42	9.12	
8	7.32	7.29	7.69	7.96	9.02	10.22	9.24	10.72	***
9	7.68	8.18	8.93	9.93	10.99	11.46	11.15	11.22	
10	8.59	9.80	9.04	10.37	11.16	12.07	10.86	12.21	***
11	15.03	14.97	15.27	15.25	16.50	16.55	16.47	16.46	
Dev. stage	T25		T26		T27		T28		
	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	
0	-	-	-	-	-	-	8.40	8.31	
1	-	-	-	-	-	-	10.16	10.24	
2	-	-	-	-	-	-	8.75	11.92	***
3	-	-	-	-	-	-	10.46	12.47	***
4	-	-	-	-	-	7.15	11.75	11.59	
5	6.85	7.58	-	-	7.00	7.08	12.10	13.37	
6	7.59	7.84	-	-	7.46	7.80	14.04	13.01	
7	8.25	9.65	**	-	8.81	9.77	15.08	13.98	***
8	10.37	11.49	-	6.84	10.85	11.40	15.54	15.91	
9	11.05	11.49	7.10	7.85	***	11.27	11.76	17.19	16.06
10	11.45	13.22	8.15	8.43	12.41	13.51	17.91	18.27	
11	17.08	16.44	15.02	14.95	17.54	17.47	23.26	22.14	
*(p < .001) ** (p < .01) *** (p < .05)									

Table 17 – c : Teeth 48-41										
Dev. stage	T48			T47		T46		T45		
	Girls	Boys		Girls	Boys	Girls	Boys	Girls	Boys	
0	8.77	8.67		-	-	-	-	4.49	6.22	
1	10.22	10.59		4.49	-	-	-	-	-	
2	11.87	12.02		8.74	4.78	-	-	-	-	
3	12.11	11.57		8.77	5.85	-	-	-	4.78	
4	12.69	12.25		8.27	7.07	-	-	7.48	6.05	**
5	13.42	13.33		7.24	7.33	-	-	7.47	7.19	
6	13.98	14.49		7.80	8.25	6.87	-	7.65	7.95	
7	15.35	15.11		9.38	9.58	-	-	9.15	9.33	
8	17.45	16.09	**	10.62	11.01	6.75	6.05	9.74	10.92	**
9	18.75	17.32	***	11.63	12.18	***	7.31	7.73	11.73	11.76
10	18.47	17.63		13.08	13.61		8.10	8.40	11.94	12.85
11	21.64	21.06		18.67	18.83		16.29	16.22	17.97	18.25
Dev. stage	T44			T43		T42		T41		
	Girls	Boys		Girls	Boys	Girls	Boys	Girls	Boys	
0	-	-		-	-	-	-	-	-	
1	-	-		-	-	-	-	-	-	
2	4.49	-		-	-	-	-	-	-	
3	-	-		4.49	-	-	-	-	-	
4	-	5.50		-	-	4.49	-	4.49	-	
5	6.75	5.94		-	4.78	-	-	-	-	
6	7.16	7.58		7.04	6.35	***	-	5.70	-	-
7	8.30	8.52		7.23	7.84	**	6.95	6.92	-	5.60
8	9.59	10.19	***	8.57	9.51	**	6.96	7.51	7.45	6.71
9	10.81	11.36		9.72	10.54	**	7.33	7.77	7.05	7.49
10	11.64	12.11		10.61	11.69	**	8.55	8.48	7.30	7.53
11	17.75	17.83		17.23	17.81		16.19	16.11	15.79	15.73
*(p < .001) ** (p < .01) *** (p < .05)										

Table 17 – b : Teeth 31-38									
Dev. stage	T31		T32		T33		T34		
	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	
0	-	-	-	-	-	-	-	-	
1	-	-	-	-	-	-	-	-	
2	-	-	-	-	-	-	-	-	
3	-	-	-	-	-	-	-	-	
4	-	-	-	-	-	-	-	-	
5	-	-	-	-	-	-	-	-	
6	-	-	-	-	6.59	6.78	6.94	7.44	
7	-	6.78	6.98	7.36	7.06	7.59	8.04	8.17	
8	7.23	7.93	7.04	7.12	8.23	9.72	9.25	10.76	**
9	7.09	7.28	7.35	7.69	9.91	10.76	10.73	11.52	
10	7.37	7.50	8.99	8.74	10.99	11.84	11.09	11.87	
11	14.68	14.20	15.23	14.70	16.12	16.69	16.63	16.41	
Dev. stage	T35		T36		T37		T38		
	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	
0	-	-	-	-	-	-	8.93	8.89	
1	-	-	-	-	-	-	9.47	10.62	
2	-	-	-	-	-	-	11.28	11.50	
3	-	-	-	-	8.74	-	11.63	12.36	
4	-	-	-	-	-	7.50	11.40	12.54	
5	6.79	7.48	***	-	7.17	7.48	13.52	12.39	
6	7.60	7.62	-	-	7.68	7.98	14.32	14.02	
7	9.04	10.08	-	-	9.42	10.25	11.13	14.23	
8	10.27	11.03	-	6.78	10.64	11.34	16.33	14.78	
9	11.08	11.63	7.26	7.72	11.75	11.94	18.96	17.28	
10	12.68	12.88	8.15	8.31	13.27	13.81	-	-	
11	17.09	17.15	15.06	14.69	18.17	18.42	23.26	21.93	
*(p < .001) ** (p < .01) ***(p < .05)									

Table 18. Cronbach's Alpha for maxillary teeth.

*Reliability																
Cronbach's Alpha								Cronbach's Alpha Based on Standardized Items								
0,982								0,991								
Inter-Item Correlation Matrix																
	T18	T17	T16	T15	T14	T13	T12	T11	T21	T22	T23	T24	T25	T26	T27	T28
T18	1,000	,850	,583	,829	,807	,777	,589	,584	,584	,591	,788	,807	,815	,596	,852	,989
T17	,850	1,000	,707	,915	,909	,902	,716	,712	,709	,708	,904	,909	,905	,709	,975	,859
T16	,583	,707	1,000	,729	,759	,790	,813	,872	,855	,788	,782	,769	,743	,953	,713	,577
T15	,829	,915	,729	1,000	,972	,939	,734	,743	,740	,736	,948	,967	,982	,727	,926	,829
T14	,807	,909	,759	,972	1,000	,950	,780	,779	,776	,780	,957	,983	,972	,765	,925	,803
T13	,777	,902	,790	,939	,950	1,000	,788	,803	,798	,782	,981	,962	,946	,801	,912	,780
T12	,589	,716	,813	,734	,780	,788	1,000	,840	,832	,989	,779	,783	,739	,838	,719	,584
T11	,584	,712	,872	,743	,779	,803	,840	1,000	,996	,847	,795	,777	,742	,876	,721	,580
T21	,584	,709	,855	,740	,776	,798	,832	,996	1,000	,848	,794	,775	,739	,870	,721	,580
T22	,591	,708	,788	,736	,780	,782	,989	,847	,848	1,000	,779	,785	,739	,827	,717	,586
T23	,788	,904	,782	,948	,957	,981	,779	,795	,794	,779	1,000	,967	,954	,792	,919	,788
T24	,807	,909	,769	,967	,983	,962	,783	,777	,775	,785	,967	1,000	,975	,781	,926	,804
T25	,815	,905	,743	,982	,972	,946	,739	,742	,739	,739	,954	,975	1,000	,746	,919	,813
T26	,596	,709	,953	,727	,765	,801	,838	,876	,870	,827	,792	,781	,746	1,000	,724	,590
T27	,852	,975	,713	,926	,925	,912	,719	,721	,721	,717	,919	,926	,919	,724	1,000	,862
T28	,989	,859	,577	,829	,803	,780	,584	,580	,580	,586	,788	,804	,813	,590	,862	1,000
T48	,947	,835	,545	,793	,764	,753	,545	,541	,541	,547	,759	,765	,781	,551	,835	,956
T47	,837	,932	,731	,897	,891	,913	,712	,730	,728	,708	,907	,893	,899	,733	,937	,844
T46	,578	,700	,911	,716	,753	,784	,820	,890	,883	,810	,788	,758	,729	,926	,718	,575
T45	,822	,920	,734	,957	,943	,928	,732	,746	,742	,734	,938	,947	,958	,736	,936	,824
T44	,798	,894	,766	,949	,953	,941	,771	,783	,785	,778	,957	,949	,949	,772	,910	,797
T43	,766	,889	,785	,924	,935	,955	,799	,799	,794	,792	,957	,933	,932	,791	,897	,767
T42	,536	,673	,840	,681	,727	,738	,783	,870	,862	,785	,735	,734	,695	,825	,686	,530
T41	,413	,544	,747	,557	,599	,616	,644	,739	,726	,639	,595	,609	,557	,724	,546	,410
T31	,402	,530	,748	,543	,584	,603	,635	,724	,711	,623	,584	,593	,542	,725	,536	,399
T32	,533	,665	,852	,684	,725	,743	,791	,873	,865	,788	,740	,732	,693	,837	,687	,528
T33	,766	,892	,793	,914	,933	,952	,806	,806	,803	,800	,955	,935	,927	,808	,899	,765
T34	,802	,895	,778	,956	,963	,960	,800	,796	,795	,803	,963	,962	,955	,791	,911	,799
T35	,824	,923	,749	,965	,949	,939	,752	,772	,772	,759	,944	,951	,966	,757	,943	,825
T36	,576	,695	,901	,711	,747	,781	,820	,889	,883	,809	,785	,752	,724	,917	,715	,573
T37	,844	,944	,761	,918	,915	,927	,736	,752	,750	,734	,929	,915	,921	,762	,957	,852
T38	,952	,828	,544	,784	,756	,745	,545	,542	,542	,547	,752	,758	,769	,551	,825	,960

Table 19. Cronbach's Alpha for mandibular teeth teeth.

*Reliability																
Cronbach's Alpha								Cronbach's Alpha Based on Standardized Items								
0,982								0,991								
	T48	T47	T46	T45	T44	T43	T42	T41	T31	T32	T33	T34	T35	T36	T37	T38
T18	,947	,837	,578	,822	,798	,766	,536	,413	,402	,533	,766	,802	,824	,576	,844	,952
T17	,835	,932	,700	,920	,894	,889	,673	,544	,530	,665	,892	,895	,923	,695	,944	,828
T16	,545	,731	,911	,734	,766	,785	,840	,747	,748	,852	,793	,778	,749	,901	,761	,544
T15	,793	,897	,716	,957	,949	,924	,681	,557	,543	,684	,914	,956	,965	,711	,918	,784
T14	,764	,891	,753	,943	,953	,935	,727	,599	,584	,725	,933	,963	,949	,747	,915	,756
T13	,753	,913	,784	,928	,941	,955	,738	,616	,603	,743	,952	,960	,939	,781	,927	,745
T12	,545	,712	,820	,732	,771	,799	,783	,644	,635	,791	,806	,800	,752	,820	,736	,545
T11	,541	,730	,890	,746	,783	,799	,870	,739	,724	,873	,806	,796	,772	,889	,752	,542
T21	,541	,728	,883	,742	,785	,794	,862	,726	,711	,865	,803	,795	,772	,883	,750	,542
T22	,547	,708	,810	,734	,778	,792	,785	,639	,623	,788	,800	,803	,759	,809	,734	,547
T23	,759	,907	,788	,938	,957	,957	,735	,595	,584	,740	,955	,963	,944	,785	,929	,752
T24	,765	,893	,758	,947	,949	,933	,734	,609	,593	,732	,935	,962	,951	,752	,915	,758
T25	,781	,899	,729	,958	,949	,932	,695	,557	,542	,693	,927	,955	,966	,724	,921	,769
T26	,551	,733	,926	,736	,772	,791	,825	,724	,725	,837	,808	,791	,757	,917	,762	,551
T27	,835	,937	,718	,936	,910	,897	,686	,546	,536	,687	,899	,911	,943	,715	,957	,825
T28	,956	,844	,575	,824	,797	,767	,530	,410	,399	,528	,765	,799	,825	,573	,852	,960
T48	1,000	,821	,533	,805	,757	,737	,495	,380	,370	,494	,734	,754	,796	,530	,827	,988
T47	,821	1,000	,738	,915	,889	,870	,692	,563	,554	,696	,874	,895	,919	,738	,980	,818
T46	,533	,738	1,000	,730	,766	,770	,873	,743	,741	,871	,786	,779	,759	,993	,776	,535
T45	,805	,915	,730	1,000	,953	,915	,713	,576	,560	,710	,911	,947	,983	,726	,942	,795
T44	,757	,889	,766	,953	1,000	,962	,741	,586	,572	,744	,952	,983	,964	,760	,928	,750
T43	,737	,870	,770	,915	,962	1,000	,743	,600	,590	,755	,985	,962	,928	,765	,904	,726
T42	,495	,692	,873	,713	,741	,743	1,000	,859	,843	,985	,758	,752	,738	,881	,723	,494
T41	,380	,563	,743	,576	,586	,600	,859	1,000	,993	,861	,621	,616	,591	,759	,581	,381
T31	,370	,554	,741	,560	,572	,590	,843	,993	1,000	,857	,612	,601	,573	,757	,571	,371
T32	,494	,696	,871	,710	,744	,755	,985	,861	,857	1,000	,759	,751	,731	,879	,726	,493
T33	,734	,874	,786	,911	,952	,985	,758	,621	,612	,759	1,000	,962	,926	,788	,903	,720
T34	,754	,895	,779	,947	,983	,962	,752	,616	,601	,751	,962	1,000	,966	,778	,926	,750
T35	,796	,919	,759	,983	,964	,928	,738	,591	,573	,731	,926	,966	1,000	,756	,949	,787
T36	,530	,738	,993	,726	,760	,765	,881	,759	,757	,879	,788	,778	,756	1,000	,771	,533
T37	,827	,980	,776	,942	,928	,904	,723	,581	,571	,726	,903	,926	,949	,771	1,000	,828
T38	,988	,818	,535	,795	,750	,726	,494	,381	,371	,493	,720	,750	,787	,533	,828	1,000

Table 20. Intra-rater reliability, Pearson's r, all values significant to 0.001

Tooth no.	r	Tooth no.	r
18	0.993	48	0.992
17	0.987	47	0.943
16	0.870	46	0.857
15	0.987	45	0.974
14	0.974	44	0.981
13	0.965	43	0.945
12	0.946	42	0.881
11	0.973	41	0.912
21	0.980	31	0.912
22	0.967	32	0.923
23	0.978	33	0.953
24	0.963	34	0.978
25	0.964	35	0.982
26	0.847	36	0.967
27	0.956	37	0.974
28	0.978	38	0.990

Table 21. Reliability and correlation test for the total score for intra-rater reliability test.

Cronbach's Alpha		Cronbach's Alpha Based on Standardized Items			Cronbach's Alpha		Cronbach's Alpha Based on Standardized Items		
0.981		0.992			0.981		0.991		
Reliability and correlation for total score for Pilot 1					Reliability and correlation for total score for Pilot 2				
	Scale mean if item is deleted	Scale variance if item is deleted	Corrected item-total correlation	Cronbach's Alpha if item is deleted		Scale mean if item is deleted	Scale variance if item is deleted	Corrected item-total correlation	Cronbach's Alpha if item is deleted
18	294.24	1836.304	0.867	0.981	18	296.56	1827.802	0.864	0.981
17	289.82	1953.868	0.959	0.980	17	292.22	1952.257	0.957	0.980
16	288.35	2067.433	0.751	0.981	16	290.86	2059.551	0.786	0.981
15	289.59	1950.407	0.946	0.980	15	291.98	1948.673	0.945	0.980
14	289.49	1963.495	0.944	0.980	14	291.86	1956.164	0.950	0.980
13	289.29	1977.492	0.954	0.980	13	291.72	1969.961	0.955	0.980
12	288.65	2024.273	0.823	0.981	12	291.18	2006.110	0.849	0.980
11	288.45	2048.893	0.760	0.981	11	291.00	2033.714	0.805	0.981
21	288.45	2048.893	0.760	0.981	21	290.98	2036.632	0.813	0.981
22	288.67	2022.267	0.844	0.981	22	291.16	2007.402	0.849	0.980
23	289.31	1976.100	0.953	0.980	23	291.68	1975.283	0.958	0.980
24	289.49	1951.135	0.950	0.980	24	291.86	1950.939	0.939	0.980
25	289.61	1943.443	0.939	0.980	25	291.92	1945.871	0.949	0.980
26	288.39	2060.803	0.768	0.981	26	290.98	2040.102	0.769	0.981
27	289.82	1953.308	0.956	0.980	27	292.16	1958.749	0.906	0.98
28	294.25	1828.874	0.885	0.981	28	296.40	1842.204	0.835	0.981
48	295.04	1858.158	0.822	0.982	48	297.34	1856.025	0.824	0.981
47	290.00	1924.120	0.971	0.980	47	292.60	1908.163	0.905	0.980
46	288.41	2060.527	0.846	0.981	46	291.00	2037.510	0.799	0.981
45	289.86	1937.401	0.946	0.980	45	292.20	1946.898	0.907	0.980
44	289.47	1960.014	0.962	0.980	44	291.92	1952.606	0.962	0.980
43	289.22	1984.173	0.933	0.980	43	291.58	1978.861	0.944	0.980
42	288.51	2049.855	0.839	0.981	42	290.96	2043.182	0.802	0.981
41	288.29	2075.772	0.677	0.982	41	290.78	2072.502	0.635	0.981
31	288.29	2075.772	0.677	0.982	31	290.78	2071.767	0.651	0.981
32	288.47	2052.934	0.801	0.981	32	290.88	2055.781	0.724	0.981
33	289.20	1985.441	0.956	0.980	33	291.54	1988.213	0.919	0.980
34	289.37	1969.878	0.952	0.980	34	291.82	1955.375	0.960	0.980
35	289.76	1940.624	0.958	0.980	35	292.12	1940.393	0.977	0.980
36	288.41	2060.527	0.846	0.981	36	290.92	2050.851	0.864	0.981
37	290.02	1923.660	0.975	0.980	37	292.46	1919.723	0.970	0.980
38	295.04	1853.278	0.829	0.982	38	297.42	1856.412	0.819	0.981

Table 22. Mean age and SD in stage 10, for all teeth, girls and boys, lined up by age.

Tooth/Boys	mean	SD
38	n/v	n/v
28	18,27	n/v
18	18,00	0,67
48	17,63	1,05
37	13,81	1,00
47	13,61	1,15
27	13,51	0,57
17	13,27	1,19
25	13,22	1,30
35	12,88	1,21
45	12,85	1,42
15	12,50	1,23
24	12,21	0,82
44	12,11	1,26
23	12,07	1,22
14	11,90	1,11
34	11,87	1,07
13	11,84	1,23
33	11,84	0,81
43	11,69	0,99
22	10,37	1,29
21	9,80	1,80
12	9,34	1,04
11	8,79	1,02
32	8,74	1,84
42	8,48	1,33
26	8,430	0,99
46	8,40	0,80
36	8,31	0,73
16	8,26	0,95
41	7,53	0,60
31	7,50	0,45

Tooth/Girls	mean	SD
38	n/v	n/v
48	18,47	1,26
28	17,91	n/v
18	17,81	1,26
37	13,27	1,14
17	13,14	1,69
47	13,08	1,13
35	12,68	0,62
27	12,41	1,70
45	11,94	1,22
15	11,78	1,11
44	11,64	1,20
25	11,45	1,18
13	11,42	1,03
14	11,38	0,93
23	11,16	1,23
34	11,09	0,34
33	10,99	0,70
24	10,86	0,86
43	10,61	0,81
12	9,21	0,74
22	9,04	0,94
32	8,99	1,14
11	8,63	0,97
21	8,59	0,75
42	8,55	1,00
26	8,15	0,67
36	8,15	0,56
16	8,12	1,15
46	8,10	0,95
31	7,37	0,90
41	7,30	0,73

Table 23. Mean age and SD of teeth on the right side that have reached stage 10.

Tooth	Girls	SD	Boys	SD
18	17.81	1.26	18.17	0.67
17	13.14	1.69	13.27	1.19
16	8.12	1.15	8.26	0.95
15	11.78	1.11	12.50	1.23
14	11.38	0.93	11.90	1.11
13	11.42	1.03	11.84	1.23
12	9.21	0.74	9.34	1.04
11	8.63	0.97	8.79	1.02
48	18.47	1.26	17.63	1.05
47	13.08	1.13	13.61	1.15
46	8.10	0.95	8.40	0.80
45	11.94	1.22	12.85	1.42
44	11.64	1.20	12.11	1.26
43	10.61	0.81	11.69	0.99
42	8.55	1.00	8.48	1.33
41	7.33	0.73	7.53	0.60