A STUDY OF PERMANENT SECOND AND THIRD MOLARS IN DETERMINING THE OPTIMAL TIME FOR ORTHODONTIC INTERVENTION AMONG MALAY POPULATION USING RADIOGRAPHS

KHALED Q. A. ALAWAJ

UNIVERSITI SAINS MALAYSIA

2013

A STUDY OF PERMANENT SECOND AND THIRD MOLARS IN DETERMINING THE OPTIMAL TIME FOR ORTHODONTIC INTERVENTION AMONG MALAY POPULATION USING RADIOGRAPHS

by

KHALED Q. A. ALAWAJ

Thesis submitted in fulfillment of the requirements for the degree of Master of Science (Dentistry)

April 2013

Dedication

To my Beloved Son & Family

ACKNOWLEDGMENT

It would not have been possible to write this master thesis without the greatest and the most merciful guidance and blessing from Allah S.W.T.

I would like to thank my supervisor Prof. Rozita Hassan for her guidance, support, correcting and giving advices throughout my research project. I would like to thank my co-supervisor Dr. Shani Mani for her personal support, great patience at all times and continued encouragement throughout my research project.

Heartfelt acknowledgement are expressed to my family especially my parents, wife, brothers and sister. Without them guidance, support, encouragement, advises and great patience at all times, I may never have overcome this long journey in my research project. I extend my deeply grateful to Dr. Kamrul Emran and dear Wan Arafah for their support and helping in data analysis. I would like to extend my appreciation to Dr. Ahmad Burhanuddin for assisting with the sample collection.

I also would like to thank all my friends that gives support and helping me for finishing the thesis. Their support and help always give motivation and energy for me to finish the thesis. My appreciation also extended to all academic and non-academic member of the Faculty of Dental Sciences for their warm heart co-operation during my stay in Universiti Sains Malysia (USM).

I also would like to thank to people that direct or indirectly help me in finishing the thesis.

Finally, I dedicate this thesis to my son, Waled, for giving me the motivation to finish this research project.

TABLES OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATION

OPG	Orthopantomogram
CVM	Cervical vertebral maturation stage.
FPMs	First permanent molars.
MIH	Molar-incisor hypomineralization.
Stage (E)	Formation of the interradicular bifurcation has begun. Root length is less than the crown length.
Stage (F)	Root length is at least as great as crown length. Root have funnel-shaped ending.
Stage (0)	Period when the bone crypt is visible without a dental germ inside.
SD	Standard deviation.
DA	Dental age.

KAJIAN MOLAR KEDUA DAN KETIGA DALAM MEMASTIKAN MASA OPTIMAL BAGI INTERVENSI ORTODONTIK DALAM KALANGAN POPULASI MELAYU MENGGUNAKAN RADIOGRAF

ABSTRAK

Latar belakang: Intervensi awal seperti pengekstrakan molar kekal pertama (FPMs) yang mempynyai prognosis yang tidak baik pada masa optimal dan rawatan dengan alatan yang berfungsi adalah penting dalam pengurusan ortodontik.

Sasaran: Untuk menentukan anggaran umur ideal untuk pengekstrakan prognosis tidak baik molar kekal dan puncak pertumbuhan mandibular menggunakan OPG dalam kalangan populasi Melayu. Kajian ini juga membuat perbandingan umur kronologikal pada tahap perkembangan krip pada setiap tiga molar di antara jantina, rahang atas dan bawah kanan dan kiri pada setiap rahang.

Kaedah: Kajian keratan retrospektif ini dijalankan ke atas 641 subjek Melayu, 289 lelaki dan 352 perempuan, berusia daripada umur 7 hingga 16 tahun. Kematangan gigi pada molar kedua mandibular kanan dan molar ketiga kekal dinilai daripada radiograf ortopantomogram dengan menggunakan tahap kalsifikasi dengan kaedah Demirjian et al., (1973), manakala kematangan tulang rangka dinilai daripada sefalogram lateral oleh tahap CVM kaedah Baccetti et al., (2005). Statistik deskriptif didapati dengan mengira purata dan sisihan piawai umur kronologikal bagi tahap-tahap krip oleh molar ketiga (tahap 0) molar mandibular kedua kanan kekal perkembangan tahap E dan tahap-tahap CVMK. Pekali korelasi urutan tahap Spearman digunakan untuk menilai perkaitan antara CVM dan tahap molar mandibular kekal kedua.

Keputusan: Umur purata kalsifikasi pada tahap 0 untuk molar atas dan bawah adalah 10.48 dan 11.88 tahun manakala molar bawah ketiga adalah 9.78 dan 10.85

tahun bagi wanita dan lelaki. Umur purata kalsifikasi pada tahap E untuk molar mandibular kekal kedua adalah 10.50 dan 10.67 tahun bagi lelaki dan wanita. Purata dan sisihan piawai umur kronologikal dalam tahun bagi tahap kematangan vertebral servikal daripada CSI kepada CS6 adalah 9.70 (SD 1.87), 10.61 (SD 1.92), 11.09 (SD 1.51), 12.78 (SD 1.53), 13.29 (SD 1.46) dan 14.73 (SD 0.77) untuk lelaki dan 9.83 (SD 1.66), 9.38 (SD 1.31), 10.94 (SD 1.36), 12.69 (SD 1.41), 13.38 (SD 1.25) dan 13.87 (SD 1.25) untuk wanita. Pekali korelasi antara molar kedua dan tahap CVM adalah 0.661 dan 0.625 untuk wanita dan lelaki.

Kesimpulan: Umur ideal untuk pengekstrakan prognosis bawah tidak baik FPM adalah di antara 9.78 – 10.50 tahun dan 10.67 – 10.85 tahun masing- masing bagi lelaki dan wanita Melayu. Pada lengkungan atas, umur ideal untuk pengekstrakan adalah di antara 10.5 – 12 tahun bagi kedua-dua jantina. Terdapat perkaitan kukuh di antara molar kedua dan tahap kematangan vertebral servikal. Pakar pergigian boleh mengagak tempoh masa puncak pertumbuhan mandibular pada pengikut pertama pertumbuhan molar mandibular kedua bifurkasi akar dan apabila formasi ‘crown’ adalah sama. Perbezaan umur krip di antara jantina adalah signifikan bagi semua molar ketiga yang dikaji kecuali molar ketiga kanan. Perbezaan umur perkembangan tahap krip di antara rahang atas dan bawah adalah signifikan, manakala perbezaan umur untuk kanan dan kiri adalah tidak signifikan.

A STUDY OF PERMANENT SECOND AND THIRD MOLARS IN DETERMINING THE OPTIMAL TIME FOR ORTHODONTIC INTERVENTION AMONG MALAY POPULATION USING RADIOGRAPHS

ABSTRACT

Background: Early intervention such as extraction of poor prognosis first permanent molars (FPMs) during the optimal time and treatment with functional appliances are essential in orthodontic management.

Aim: To determine the ideal age range for extraction of poor prognosis FPMs and peak mandibular growth using orthopantomogram radiographs (OPG) in Malay population. This study also compared the chronological age of crypt stage developmental of each third molar between genders, upper and lower jaw, right and left in each jaw.

Methods: This retrospective cross-sectional study was done on 641 Malay subjects, 289 males and 352 females, ranging from 7 to 16 years of age. Dental maturity of the permanent mandibular second molar and third molars were assessed from OPG radiographs by using calcification stages of Demirjian et al., (1973) method, whereas skeletal maturity was evaluated from lateral cephalogram by cervical vertebral maturation (CVM) stages of Baccetti et al., (2005) method. Descriptive statistic was obtained by calculating the mean and standard deviations of the chronological age for the crypt stages of third molars (stage 0), right permanent mandibular second molar (stage E) development and stages of CVM. Spearman rank order correlation coefficient was used to assess the relationship between CVM and permanent mandibular second molar stages.

Results: The mean age of calcification at stage 0 for upper third molar was 10.48 and 11.88 years while, lower third molar was 9.78 and 10.85 years for male and female respectively. The mean age of calcification at stage E for permanent mandibular second molar was 10.50 years and 10.67 years in males and females respectively. The mean and standard deviation of the chronological age in years for cervical vertebral maturation stages from CS1 to CS6 were, 9.70 (SD 1.87), 10.61 (SD 1.92), 11.09 (SD 1.51), 12.78 (SD 1.53), 13.29 (SD 1.46) and 14.73 (SD 0.77) respectively for males, and 9.83 (SD 1.66), 9.38 (SD 1.31), 10.94 (SD 1.36), 12.69 (SD 1.41), 13.38 (SD 1.25) and 13.87 (SD 1.25) respectively for females. The correlation coefficients between second molar and CVM stages were 0.625 and 0.661 for males and females respectively.

Conclusion: The ideal age range for extraction of poor prognosis lower FPM was between 9.78 - 10.50 years and 10.67 - 10.85 years for Malay males and females respectively. In upper arch, the ideal age for extraction was between 10.5 - 12 years for both genders. There is a strong association between second molar and cervical vertebral maturation stages. The clinician may estimate timing of the peak in mandibular growth is during the first appearance of permanent mandibular second molar root bifurcation and when the crown formation are equal to the root formation. Age difference of crypt stage developmental between genders was significant in all third molar studied teeth except for the lower left third molar. Age difference of crypt stage developmental between upper and lower jaw was significant, on other hand age difference for right and left was not significant.

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

More than 50% of children worldwide who are over 11 years old have experienced caries in the permanent dentition (Ong and Bleakley, 2010). In Malaysia, the prevalence of dental caries in 12-year-old children comprises 60.9%, and that of decayed, missing, and filled teeth (DMFT) comprises 1.9% (M.O.H, 1997). These statistics exceed the WHO global oral health goal of less than 1.5% DMFT in 2020 for 12-year-old children (Petersen, 2008). The first permanent molar (FPM) usually erupts at age six. At this age, the growth of the FPM exposes a child to the risk of caries onset on the tooth surface (Noronha et al., 1999; Mejare et al., 2000; Luca et al., 2003; Pitts et al., 2006; Skeie et al., 2006). Improvements in restorative techniques and high parental expectations motivate dentists to consider the restoration of FPMs with extensive caries and pulpal symptoms during the mixed-dentition stage (Mejàre et al., 2000; Raducanu et al., 2009). However, heavily restored teeth enter the restorative cycle and may need to be extracted in later life (Al-Emran, 1990; Ong and Bleakley, 2010).

Another condition that affects FPMs is the molar-incisor hypomineralization (MIH). MIH affects 3.6% to 25% of children in European countries (Weerheijm and Mejare, 2003). This term, which was first used by Weerheijm et al. (2000), denotes the enamel defects in FPMs and permanent incisors, which range from distinct, isolated, white, and cream-colored markings to large-scale ill structuring (Weerheijm et al., 2000). FPM extraction in severe MIH is a good treatment alternative (Sandler et al., 2000; Gill et al., 2001; Jalevik and Klingberg, 2002).

Hence, the most frequently extracted teeth are the FPMs because of caries, endodontic problems and MIH; mandibular FPMs have a particularly high incidence at an early age in some populations (Al-Emran, 1990; Weerheijm and Mejare, 2003; Albadri et al., 2007; Ong and Bleakley, 2010). Similarly, FPMs may be chosen for orthodontic extraction in preference to premolars for a number of reasons, including gross caries, large restorations, root-filled teeth, anterior open bite malocclusion, and significant hypoplasia (Sandler et al., 2000; Al-Emran, 2001; Davies et al., 2001).

The timing of FPM extraction plays a vital role in occlusion development (Davies et al., 2001). The presence and eruption path of other teeth, especially the third molar, should be assessed before extracting the poor prognosis FPMs because they will form part of the functional dentition (Conway and Petrucci, 2005). Earlier extraction may cause a mandibular second premolar to drift distally and shift dental midline to the extraction side (Caglaroglu et al., 2008). However, delayed extraction results in less bodily movement and more tilting of the second molar (Gill et al., 2001).

Favorable spontaneous space reduction and development of permanent dentition positioning can be expected without intervention in most cases, if extractions are done prior to the eruption of the second permanent molars, and when the second permanent molars show crown completion with the initial development of the bifurcation (Sandler et al., 2000; Gill et al., 2001). Hence, extraction of the poor prognosis FPM at the ideal time can save time, effort, cost, and discomfort to the patient (Jalevik and Klingberg, 2002; Jalevik and Moller, 2007).

Orthodontists should have knowledge of the growth and developmental status of the patient. Timing is also important in orthodontic diagnosis, including treatment planning and the use of extraoral traction, the use of functional appliances, performing extraction or nonextraction, the selection and execution of orthodontic retention, and the timing of orthognathic surgery (Krailassiri et al., 2002).

Skeletal maturation staging through radiographic analysis is a widely used approach to predict the timing of pubertal growth, and estimate growth velocity and the amount of remaining growth (Baccetti et al., 2002). Recently, modifications in the size and shape of the cervical vertebrae of growing subjects as a biological indicator of individual skeletal maturity have gained increasing interest (Baccetti et al., 2005). This process is referred to as cervical vertebral maturation (CVM). Dental maturity from orthopantomogram (OPG) has also been used to evaluate skeletal maturity (Demirjian et al., 1973). Dental maturation from orthopantomograms (OPG) has been strongly correlated with skeletal maturity (Engstrom et al., 1983).

If a strong association exists between CVM stages and dental calcification stages, the stages of dental calcification could be used as a first-level diagnostic tool for estimating the timing of the adolescent growth spurt (Chen et al., 2010; Rozylo-kalinowskal et al., 2011). Periapical radiographs and orthopantomograms (OPG) are taken more frequently in routine examination and diagnosis; hence, these x-rays could serve a dual advantage if they can be simultaneously used to assess skeletal maturity. We hypothesized that it would be clinically useful to study the developmental stages of one tooth and its relation to CVM. Among all the studied teeth, the second permanent molar has the best correlation with peak mandibular growth (Basaran et al., 2007; Nassar, 2008; Rai and Anand, 2008; Chen et al., 2010). Racial variations notably play a role in the relationship between dental and skeletal maturation (Krailassiri et al., 2002). Unfortunately, little is known of this relationship among Malay subjects. Therefore, the current study determines the ideal age of extraction of poor prognosis FPMs and the peak mandibular growth in mixed dentition using OPG in Malay population.

1.2 Statement of the problem

The most caries-prone tooth in the permanent dentition, probably as a result of its early exposure to the oral environment is the first permanent molar. Early extraction of FPMs before the age of 8 years may result in distal drifting, tilting and rotation of the unerupted second premolar, especially in a spaced dentition (Telli and Aytan, 1989). If extraction of FPMs is delayed during or after eruption of the second permanent molars, space closure is usually unsatisfactory resulting in mesial tilting and lingual rolling of the second permanent molar, over eruption of the opposing FPM, plaque stagnation, distal drifting and tilting of the second premolar, and atrophy of the alveolar bone (Gill *et al.*, 2001). Thus, predicting the age for extraction of the FPMs in the mixed dentition stage is important in order to prevent or minimize the amount of orthodontic intervention (Shugars *et al.*, 2000).

Numerous x-ray exposures to the patient during routine diagnosis are detrimental to the growth of the child. Thus, predicting the correlation between cervical vertebral maturation (CVM) and dental maturity by using OPG is an important in the orthodontic field, which allows the orthodontist to predict the mandibular growth from a single x-ray reducing x-ray exposure for the patient.

1.3 Justification of the study

Treatment at the proper time reduces complex fixed orthodontic and eliminates orthognathic treatment. Predicting the age for extraction of the FPMs in the mixed dentition stage is an important aspect of early orthodontic diagnosis and treatment planning. The accurate age for extraction the poor prognosis FPMs allows patient to obtain good occlusion and proper growth and facial development. Determining the proper age for extraction the poor prognosis FPMs in the mixed dentition stage requires accurately predicting the age of development the unerupted permanent second and third molar in the concerned population.

The cervical vertebra maturation method of Baccetti *et al.*, (2005) is not only provides a convenient method for staging skeletal maturation, it also provides a method for estimating when peak mandibular growth will occur. However, using the tooth calcification stages as an indicator for the peak in mandibular growth can minimize the x-ray exposure allowing the clinicians to assess the optimal time for starting orthodontic treatment without extra radiation to the patient. The age of development of the permanent teeth varies between different ethnic groups and no such study has been done previously in the Malay population.

1.4 Objectives

1.4.1 General Objective

To determine the ideal age for extraction of first permanent molar with poor prognosis based on developmental stages of second and third permanent molar and correlate the stages of second permanent molar development to peak mandibular growth in Malay population.

1.4.2 Specific Objectives

1) To determine the chronological age of crypt stage (stage 0) development of lower and upper third molars for male and female among Malay population.

2) To determine the chronological age at which the lower second permanent molar shows crown completion and initial development of the bifurcation (stage E), among Malay male and female.

3) To compare the chronological age of stage 0 developmental of each third molars and stage E of lower second permanent molar between male and female.

4) To compare the chronological age of stage 0 developmental of third molar between upper and lower jaw.

5) To compare the chronological age of stage 0 developmental of third molar between right and left side in each jaw.

6) To determine chronological age of CVM stages among Malay male and female.

7) To investigate the correlation between stages of CVM and stages of development of second permanent molar among Malay male and female.

1.4.3 Research Hypothesis

1) There is a significant difference in the chronological age of crypt stage development of third molars while, no significant difference in the chronological age of stage E of lower second permanent molar between male and female Malay population.

2) There is a significant difference in the chronological age of crypt stage development of third molars between upper and lower jaw while, no significant difference between right and left side of Malay population.

3) There is a correlation between stages of CVM and stages development of second permanent molar among Malay male and female.

CHAPTER TWO

LITERATURE REVIEW

The literature review is discussed in two broad categories, which are related to the timing of FPM extraction and the timing of CVM, mandibular growth, and tooth development.

2.1 Causes that affect the prognosis for FPM

2.1.1 Dental caries

Fifty percent of six-year-old children in Malaysia require extraction of the lower first permanent molar. Moreover, 39.4% and 36.2% require restoration in the right and left lower first permanent molar, respectively (M.O.H, 2009).

A survey of dental extraction among French children showed a total of 14,621 extractions. Overall, caries was the most frequent cause for extraction (49%). The most frequently extracted tooth due to caries was the molar (40.95%). Taken together, the first and second molars comprised 29.6% of the total extractions (Cahen et al., 1985).

A cross-sectional retrospective study in Romania revealed that 44 patients (5%) had first permanent molar extractions. Eight hundred five (805) of patients (40.9%) without previous first molar extraction have caries of the first permanent molars. Majority of first permanent molar extractions among children and adolescents occurred after the age of 11, which is considered as too late for spontaneous space closure (Raducanu et al., 2009).

Vehkalahti et al. (1991) reported that first permanent molars in Finnish children aged 7 to 9 years has caries were found on the occlusal surfaces. Whereas children aged between 12 and 13 years has caries on the proximal surfaces.

An association between caries experience on the mesial surface of first permanent molars and the adjacent surface was reported in two studies (Mejare et al., 2000; Mejare et al., 2001). Mejare et al. (2000) showed that the rate of progression from the inner half of the enamel to the outer half of the dentin on the mesial surface of the first permanent molar was almost four times faster in a young age group (6 to 12 years) than in an older group (12 to 22 years). A retrospective study in children aged 6 to 12 years revealed that the caries rate for the mesial surface of the FPM depended on the status of distal surface of the second primary molar. This rate increased 15 times if the distal surface of the second primary molar had enamel/enamel-dentin border caries compared with a sound distal surface of the second primary molar (Mejare et al., 2001).

Parents have little knowledge about the FPM. They frequently consider the FPM as a deciduous tooth. Parents usually bring young children to the dentist for acute pain, either in the primary teeth or in the FPMs (Luca et al., 2003). In either case, FPMs may already bear massive crown destruction through caries. Treatment is extraction, large restoration or root canal treatment. Both later treatments will provide a questionable long-term prognosis of FPM. Therefore, extraction of poor prognosis FPM in the ideal time when the spontaneous space closure can be achieved is advisable.

2.1.2 Molar-incisor hypomineralization (MIH)

Most of the prevalence studies on MIH have been conducted in European countries, and data from Asian populations are lacking (Jalevik et al., 2001; Leppaniemi et al., 2001; Weerheijm and Mejare, 2003; Gomez et al., 2011).

Study in Sweden using the Development Defects of Enamel (DDE) index reported a prevalence of 18.4% demarcated opacities among children. The authors defined the presence of demarcated opacity on molar and incisor as MIH (Jalevik et al., 2001).

A study on a sample size of 505 Spanish children aged 6 to 14 years was conducted to establish the prevalence of MIH. The study, which employed transillumination (Gomez et al., 2011), showed that 90 patients (17.85%) had MIH. Among these patients, 45 were girls (50%) and 45 were boys (50%). Sixteen percent of the children had more than one affected FPM (81 children), and only 1.85% had one affected FPM (9 children).

Weerheijm and Mejare, (2003) reported that the prevalence of enamel defects in FPMs were 6.4% in Switzerland and 25% in Finland.

A total of 488 children aged between 7 and 13 years took part in a study in Finland (Leppaniemi et al., 2001). The defects on the permanent first molar were recorded on the three categories described by Alaluusua et al. (1996). The prevalence of children with hypomineralized permanent first molar was 19.3%, in which 8.4%

had severe defects, 1.4% had lesions with rough, broken enamel, and 9.5% had color changes only.

A total of 2,635 records on Chinese children with mean age of 12 years were reviewed and 73 cases (2.8%) of MIH were identified. A total of 192 teeth were affected. The most commonly affected teeth were permanent maxillary first molars, followed by mandibular first molars and maxillary central incisors (Cho et al., 2008).

Children with severe enamel hypomineralization on their first molars experienced a considerable amount of dental treatment compared with other children (Leppaniemi et al., 2001). These teeth create problems for patients and dentists. Children often report shooting pains when eating ice cream or even breathing cold air shortly after the eruption of the affected teeth (Weerheijm et al., 2001). Treatments can be painful due to anesthetic difficulties resulting from a subclinical inflammation of the pulpal cells. This condition may be caused by the porosity of the enamel as dentists frequently report loss of fillings and continuing disintegration of porous enamel (William et al., 2006). Therefore, the affected teeth often require repeated treatment (Jalevik and Noren, 2000), which affect the behavior of children causing them to exhibit fear and anxiety during dental treatment (Jalevik and Klingberg, 2002). The extraction of permanent first molars that are severely affected by MIH is a good treatment alternative for early malocclusion intervention (Sandler et al., 2000; Jalevik and Klingberg, 2002; William et al., 2006).

2.2 Methods of assessment of dental maturity

Radiographic methods are more reliable indicators of dental age (DA) than tooth emergence. Tooth emergence is affected by oral factors, such as infection, pathology, trauma, and malnutrition. Various methods have been used to assess dental maturation based on the stages of tooth calcification using radiographs (Garn et al., 1958; Nolla, 1960; Moorrees et al., 1963; Demirjian et al., 1973).

2.2.1 Nolla method (1960)

Nolla, (1960) studied the average teeth development among male and female American children aged between 5 and 18 years. Author developed tables for estimating chronological age based on the degree of observed dental development. These developmental stages were examined longitudinally for the maxillary and mandibular teeth in 25 boys and 25 girls. A total of 1,656 and 1,746 lateral oblique radiographs were obtained for males and females respectively.

Nolla’s study assessed the teeth on the right and left sides. A score of 1 to 10 was assigned to each stage shown in Figure 2.1, starting from the appearance of the uncalcified dental germ to the complete apical closure. Stage 0 was added to designate the total absence of tooth formation. The description of the stages is based on tooth length criteria, and is likely to be subjective (Nolla, 1960).

Figure 2.1 Stages of tooth calcification according to Nolla (1960)

2.2.2 Demirjian method 1973

Demirjian et al. (1973) developed a method of estimating DA based on the stages of dental development seen in radiographs. The authors divided the developmental stage of the tooth to eight from A to H (four for crown development and four for root development). Stage 0 indicated calcification non-appearance. The lower seven left side teeth were recorded.

Their study was based on the method described by Tanner in relation to skeletal age. To indicate DA, each tooth was assigned a score numerical value (weight score) depending on its stage. The scores of all teeth were added to obtain the total maturity score (MS), which could be converted into DA using the appropriate table of standards. Boys and girls were given a different system of scores. The Demirjian method is advantageous over other dental developmental methods because the development stages are based on the shapes of teeth, which are easily recognizable, and not on absolute length (Demirjian et al., 1973).

2.3 Timing of FPM extraction

2.3.1 Third molar crypt formation

The development of the third molar is remarkably diversified among different ethnic groups; thus, the crypt formation stage of the third molar varies from population to population (Garn et al., 1962).

A study on the crypt formation of the third molar on the radiodontographic of 1,000 Denver orthodontic patients indicated that the age at which the third molar crypt formation may appear is 5 years to as late as 14 years. The study also reported that the greatest numbers of crypts are formed at age 8 years (42 children). Variation may also occur in the degree of calcification of third molars in the same mouth. Positive evidence of the congenital absence of the third molar crypt formation may not manifest until 14 years of age (Banks, 1934).

A group of 35 children, consisting of 14 males and 21 females at the age of 10 years, was studied. Third molar development was classified using the system adapted by Bjork and Helm, (1967) that devised by Gleiser and Hunt, (1955) for first molar (Richardson, 1980). The size of the third molar was measured on the last radiograph of each series using a Perspex scale measured at the widest mesiodestal diameter. Richardson (1980) concluded that a 50% probability of agenesis exists for all four third molars if the third molar does not appear by the age of 10. Third molar genesis may occur up to the age of 16, and genesis probability may be reduced after the age of 12 years. No significant difference in the size between the early and late development of third molar was observed.

Panoramic radiographs of 500 Mexican children and young people between the ages of 7 to 18 were studied; crypt formation of third molar was found between 9 and 11 years old (Larena and Nuno, 1990).

Two studies were conducted among the Turkish population to predict the crypt formation of the third molar (Uzamis et al., 2000; Orhan et al., 2007). These studies employed the method of Demirjian et al. (1973), but with a modified sample size. One study examined 400 panoramic radiographs of Turkish children and adolescents, comprising 188 female and 212 male subjects (Uzamis et al., 2000). The earliest age for maxillary third molar crypt formation was 8 years, whereas mandibular third molars could be seen radiographically as early as 7 years. The second study on 1,134 panoramic radiographs of Turkish Caucasians (524 males and 610 females) revealed that third-molar crypt formation is observable as early as 7 years in both the mandible and the maxilla (Orhan et al., 2007). This difference may be attributed to the smaller sample size compared with that of Uzamis et al. (2000).

A study evaluated the third molar development in 786 Spanish children aged from 4 to 20 (Bolanos et al., 2003). The stages proposed by Nolla, (1960) were used to determine the development of the mandibular third molar. The onset of the mandibular third-molar crypt formation was observed at very variable ages in this series, which ranged from 5.86 to 14.66 years. The authors concluded that the first developmental stages of maxillary third molars are not usually radiographically visible, which can lead to an incorrect diagnosis of agenesis.

Another study examined 2,795 radiographs of 1,970 ethnic Finns (966 males and 1,004 females) aged from the birth to 25 years. The study was based on the method of Demirjian et al. (1973) (Nystrom et al., 2007). The crypt formation stage (0) was recorded at the period when the bone crypt is visible without an interior dental germ. The study concluded that the third-molar crypt formation for boys ranged from 7.4 to 12.2 years, whereas that for girls was more advanced at 7.1 to 11.3 years. The timing of third-molar crypt formation was similar to several other populations.

Panoramic radiographs of white and Bangladeshi children from London and black African and Cape colored children from South Africa in the age range of 5 to 24 years were studied (Liversidge, 2008). The mandibular third molar was staged according to Moorrees et al. (1963) with some additional descriptive criteria. The study concluded that the average age of third molar entering initial mineralization ranged from 7.9 to 9.7 years.

The panoramic radiographs of 979 subjects in Croatia aged from 5.7 to 14.6 years were examined to determine the development of the mandibular third molar based on the method proposed by Nolla, (1960) (Legovi et al., 2010). Results indicated that the age range of the right and left mandibular third molar crypt formation was between 6 and 12 years. A considerable increase in the number of subjects with initial mineralization only occurred after the 8 and 9 year.

A longitudinal study was conducted on the mandibular third molar based on the serial, oblique, jaw, and lateral head radiographs of 140 Ohio-born children (Garn et al., 1962). The development of the mandibular third molar was staged according to Garn et al. (1960). The authors reported that the mean age of small crypt formation was 8.7 and 8.6 years, and that of full size crypt formation was at 9.2 and 9.1 years, for males and females, respectively.

The panoramic radiographs of 1,700 subjects in the Czech Republic aged between 5 and 21 years were examined to determine the development of third molar based on the method proposed by Kominek and Rozkovcova et al., (1975) (Rozkovcova et al., 2004). Results suggested that the age range of crypt formation was from 6 to 18 years in the upper and lower jaw for males and females.

2.3.2 Second molar development

The loss of the mandibular FPM ideally occurs before the eruption of the second permanent molar, usually at a chronological age of 8 to 9 years (Gill et al., 2001). The second molar may erupt early, and a good contact area relationship can finally be established with the second premolar.

A cross-sectional study was conducted on Malay school children in the district of Kota Bharu, Kelantan. The study used a sample size of 1,386 school children in the age range of 5 to 19 years (908 females and 478 males). The age of tooth emergence was investigated in the study (Hussin et al., 2007). A tooth emerged if any part of the crown was visible through the gingiva. The maxillary and mandibular second molars appeared at about 0.27 years earlier in females than in males. The mandibular and maxillary second molars in females emerged at 11.2 and

12.2 years, respectively. The mandibular second molar in males emerged at the age of 11.5 years, followed by the appearance of its maxillary counterpart 0.9 years later.

A study was conducted on 33 children with 1 to 4 extracted FPMs due to severe MIH and poor prognosis. The subjects were eligible for a follow-up evaluation (Jalevik and Moller, 2007). The median age at the time of extraction for 27 children was 8.2 years (age range of 5.6 to 12.7 years). A total of 15 children demonstrated favorable bite development without any orthodontic intervention. The remaining 12 children were subjected to orthodontic treatment for other reasons, such as crowding, crossbites, and distal bites. The criteria for good or favorable bite development were spontaneous space reduction, absence of teeth tilting that could make oral hygiene more difficult, absence of teeth elongation in the opposite jaw, and patient satisfaction. The authors concluded that extractions should be planned with an orthodontist before the eruption of the second permanent molar.

The timing of the developmental stages of the permanent mandibular teeth of Finns from birth to age 25 years were investigated based on the method proposed by Demirjian et al. (1973) (Nystrom et al., 2007). The age when the second molar's crown was completed and the bifurcation became visible (stage E) ranged from 8.5 to 9.5 years for boys and 8.5 to 9.1 years for girls.

Ong and Bleakley, (2010) stated that the ideal time to extract the upper FPM was when the upper second permanent molar was unerupted at the time of the procedure. In particular, a highly favorable space closure can be achieved if the upper second permanent molar is located above the cemento-enamel junction of the FPM to be extracted, whereas in the lower arch, the crown of the lower second permanent molar is complete and the bifurcation of its roots is visible. Thus, the ideal time for extraction of the lower FPM has been reported to be approximately at 8 to 9 years old, but generally around 10 years old. When a lower FPM is extracted at the ideal stage, a maximum amount of spontaneous mesial movement of the unerupted second permanent molar can be expected.

Sandler et al. (2000) pointed out that the timing of the extraction of the first permanent molar in the lower arch was critical. It is unlikely that the lower second molars will completely replace the lower first molars after their extraction given that they have a much more vertical eruption path. If little or no space is required in the lower arch for correction of the malocclusion, extracting the lower first molars early, when the bifurcation on the second molars is calcifying and the roots are about half-formed, is advisable. Doing so will maximize spontaneous space closure in the lower arch, thus minimizing the retraction of the lower labial segment, which is an unwanted side effect observed during space closure. In the upper arch, the extraction of the permanent first molar is not as crucial as in the case of the lower arch mentioned previously. The reason is that the favorable mesial drift movement of the upper second permanent molar is achieved earlier compared with that of the lower one if extraction is done prior to the eruption of the upper second molar.

2.4 Timing of CVM, mandibular growth, and tooth development

2.4.1 Assessment method of skeletal maturity

2.4.1.1 Cervical vertebral maturation methods

According to Lamparski, (1972) and O’Reilly and Yanniello, (1988), a system for skeletal assessment based on morphological changes in the cervical vertebrae was created. The method analyzed the size and shape changes in the bodies of five cervical vertebrae from the second to the sixth vertebrae, as shown in Figure 2.2. This method included the following stages:

Stage 1 (Cvs 1): The inferior borders of the bodies of all cervical vertebrae are flat. The superior borders are tapered from posterior to anterior.

Stage 2 (Cvs 2): A concavity develops in the inferior border of the second vertebra. The anterior vertical height of the bodies increases.

Stage 3 (Cvs 3): A concavity develops in the inferior border of the third vertebra.

Stage 4 (Cvs 4): A concavity develops in the inferior border of the fourth vertebra. Concavities in the lower borders of the fifth and the sixth vertebrae begin to form. The bodies of all cervical vertebrae are rectangular.

Stage 5 (Cvs 5): Concavities are well defined in the lower borders of the bodies of all the five cervical vertebrae. The bodies are nearly square in shape, and the spaces between the bodies are reduced.

Stage 6 (Cvs 6): All concavities have deepened. The bodies are now higher than they are wide.

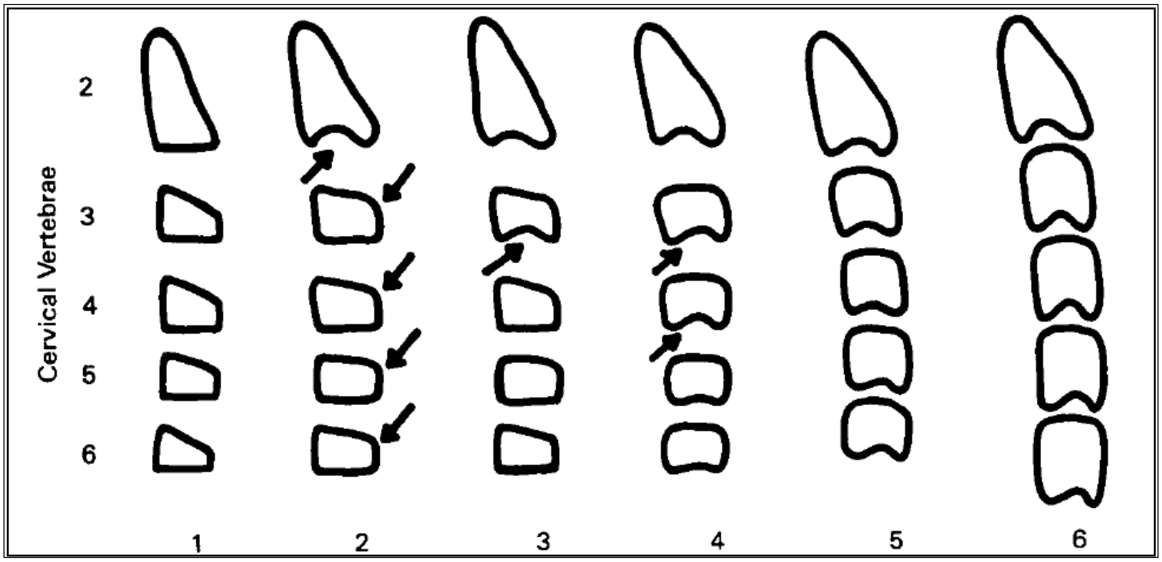

Figure 2.2 Developmental stages of cervical vertebrae (O'Reilly and Yanniello, 1988)

Hassel and Farman, (1995) developed cervical vertebrae maturation indicators (CVMI) using C3 as a guide. The sample size consisted of 11 groups of 10 males and 10 females (220 subjects) aged from 8 to 18 years, from the Bolton-Brush Growth Study Center at Case Western Reserve University. The researchers used the system developed by Fishman (1986) to determine the skeletal maturation indicator (SMI) based on a hand-wrist radiograph evaluation of each subject. Once skeletal maturation was assessed from the hand-wrist radiograph, the lateral cephalograms of the second, third, and fourth cervical vertebrae were taken on the same date. The CVMI readings were then evaluated against the previously determined SMI reading to determine the existing correlations. The 11 SMI groupings were condensed into six CVMI categories. The following observations were made for each category (see Figure 2.3):

Category 1: Initiation, corresponding to a combination of SMI 1 and SMI 2. At this stage, adolescent growth begins, and 80% to 100% of adolescent growth is expected. The inferior borders of C2, C3, and C4 are flat at this stage. The vertebrae are wedge-shaped, and the superior vertebral borders are tapered from posterior to anterior.

Category 2: Acceleration, corresponding to a combination of SMI 3 and SMI 4. Growth acceleration begins at this stage, with 65% to 85% of adolescent growth expected. Concavities develop in the inferior borders of C2 and C3. The inferior border of C4 is flat. The bodies of C3 and C4 are nearly rectangular in shape.

Category 3: Transition, corresponding to a combination of SMI 5 and SMI 6. Adolescent growth is still accelerating at this stage toward peak height velocity, with 25% to 65% of adolescent growth expected. Distinct concavities are seen in the inferior borders of C2 and C3. A concavity begins to develop in the inferior border of C4. The bodies of C3 and C4 are rectangular in shape.

Category 4: Deceleration, corresponding to a combination of SMI 7 and SMI 8. Adolescent growth begins to decelerate dramatically at this stage, with 10% to 25% of adolescent growth expected. Distinct concavities are seen in the inferior borders of C2, C3, and C4. The vertebral bodies of C3 and C4 become more square in shape.

Category 5: Maturation, corresponding to a combination of SMI 9 and SMI 10. Final maturation of the vertebrae takes place at this stage, with 5% to 10% of adolescent growth expected. More accentuated concavities are seen in the inferior borders of C2, C3, and C4. The bodies of C3 and C4 are nearly square to completely square in shape.

Category 6: Completion, corresponding to SMI 11. Growth is considered to be complete at this stage. Little or no adolescent growth is expected. Deep concavities are seen in the inferior borders of C2, C3, and C4. The bodies of C3 and C4 are square or greater in vertical dimension than in horizontal dimension.

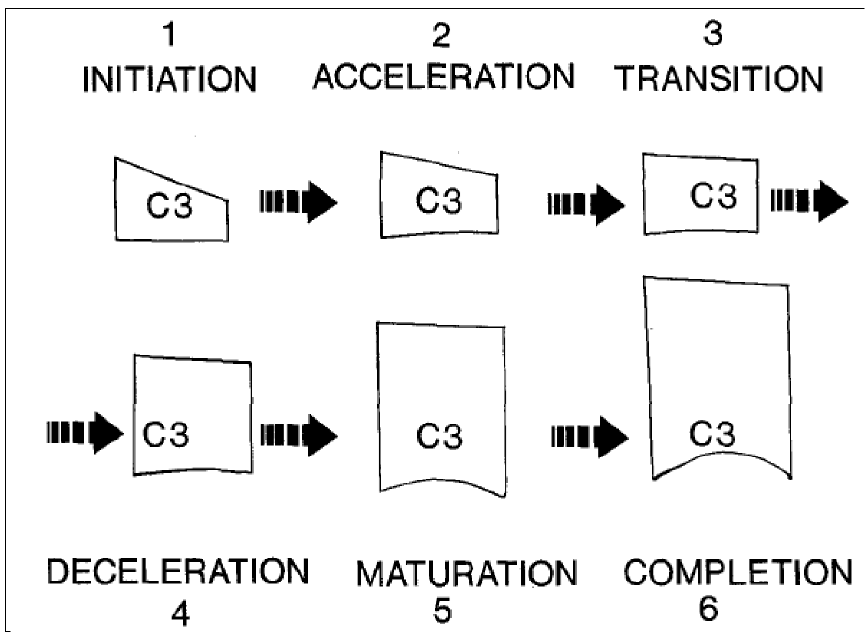

Figure 2.3 Cervical vertebrae maturation indicators using C3 as guide (Hassel and Farman, 1995)

Another study presented an improved version of the CVM method to detect the peak in mandibular growth in a single lateral cephalogram (Baccetti et al., 2002). The researchers examined 30 subjects (18 boys and 12 girls) from the University of Michigan elementary and secondary school growth study. The morphology of the bodies of the second (C2), third (C3), and fourth (C4) cervical vertebrae were analyzed in six consecutive cephalometric observations (T1 through T6), two during