"COMPARISON OF DENTAL MINERALIZATION STAGES USING ORTHOPANTAMOGRAM (OPG) AND SKELETAL MATURATION USING HAND WRIST RADIOGRAPHS DURING PUBERTAL GROWTH PERIOD"

Dissertation submitted to

THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY

In partial fulfilment for the Degree of

MASTER OF DENTAL SURGERY

BRANCH V

ORTHODONTICS AND DENTOFACIAL ORTHOPEDICS

2015 – 2018

CERTIFICATE

This is to certify that **Dr.G.Dinesh Nandakumar**, Post graduate student (2015-2018) from the Department of Orthodontics and Dentofacial Orthopedics J.K.K. Nattraja Dental college, Komarapalayam, Namakkal District-638183,Tamilnadu has done the dissertation titled **COMPARISON OF DENTAL MINERALIZATION STAGES USING ORTHOPANTAMOGRAM(OPG) AND SKELETAL MATURATION USING HAND WRIST RADIOGRAPHS DURING PUBERTAL GROWTH PERIOD** under my direct guidance and supervision in the partial fulfilment, for the degree of Master of Dental surgery awarded by THE TAMILNADU Dr.M.G.R MEDICAL UNIVERSITY, CHENNAI in the Branch-V ORTHODONTICS AND DENTOFACIAL ORTHOPEDICS.

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ACKNOWLEDGEMENT

CERTIFICATE II

This is to certify that this dissertation work titled **COMPARISON OF DENTAL MINERALIZATION STAGES USING ORTHOPANTAMOGRAM(OPG) AND SKELETAL MATURATION USING HAND WRIST RADIOGRAPHS DURING PUBERTAL GROWTH PERIOD** of the candidate **G.DINESH NANDAKUMAR** with registration number **241519102** for the award of **MASTER OF DENTAL SURGERY** in the branch of **ORTHODONTICS AND DENTOFACIAL ORTHOPEDICS** . I personally verified the urkund.com website for the purpose of plagiarism check. I found that the uploaded thesis file contains from introduction to conclusion pages and result shows 1 percentage of plagiarism in the dissertation.

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ABSTRACT

The present study was conducted on 294 males and 306 females from outpatients reporting to J.K.K. Nattraja Dental college, Komarapalayam, Namakkal. The skeletal maturation was assessed using Hand wrist radiograph using the method proposed by Grave and Brown classifying the ossification into fourteen events and three stages. Dental maturation stages were analysed from Orthopantamogram(OPG) using the method proposed by Demirjian et al in which maturation is classified into eight stages from A-H. The data was subjected to statistical analysis, and the following conclusions were drawn from the results.

In males, mandibular canine and mandibular second molar were statistically significant with higher correlation observed in relation to stage F for onset of pubertal growth period, stage G coincided for peak of the pubertal growth period and stage H coincided for end of the pubertal growth period.

In females, mandibular canine and mandibular first premolar were statistically significant and higher correlation was observed in relation to stage F for the onset of pubertal growth period, stage G coincided with the peak of the pubertal growth period and stage H coincided with the end of the pubertal growth period.

There is a correlation between dental maturation and skeletal maturation stages in determining the pubertal growth period. On comparison of chronological age the females preceded males in all three stages of skeletal maturation by approximately 1.6 years.

Change is the law of nature and human beings are no exception to change. During their lifetime, they change in size, appearance and even psychologically. This change differs from individual to individual. However, the fundamental underlying patterns of growth are all the same. The various processes by which a germinating seed or conceived organism is turned into a mature plant or full-fledged human is collectively termed growth and development. Growth is usually measured by physical appearances such as height, weight; all of which are pre-determined by the genetic backup of the individual, which he or she receives from the parents and that which is encoded into their DNA. Growth does not occur at the same pace and at same time for all, it varies based on the influence of environmental factors. In daily life one can witness the variations from lean and undernourished to obese and overnourished individuals. This variations in growth suggest that growth rate is not always common for all individuals it varies from one to another. Growth has its own periods of up's and down's where the rate of growth is faster and times where the growth is almost negligible.

The knowledge of growth is important for any clinician to differentiate normal growth from growth abnormalities and to understand the underlying reason. Most of the growth is encoded into the genetic backup of the individual, undergoing change based on the influence of environmental factors. The knowledge of the individual's growth rate and the amount of growth yet to be completed can be useful for planning any growth modification treatment.

Any modification in the growth of an individual to correct the underlying malocclusion should be undertaken during the period of growth spurts. Period of accelerated growth is called growth spurts, but there is difference in the age observed between females and males. Females mature earlier than males[1,2].

Growth spurts occurs at various periods in life just before birth ,one year after birth, during the mixed dentition period and pre-pubertal age. Pre-pubertal growth spurt brings about multitude of changes in the human body and is ideal for correction of malocclusion using growth modification like myofunctional appliance.

Though the chronological age of an individual gives an overall status of growth, it is not a reliable indicator of maturation[3]. To understand the individual skeletal maturation, to know the ideal time for growth modification and to determine the amount of growth remaining we need methods of growth prediction.

Growth prediction methods have been classified into measurement approaches and experimental approaches. Measurement approaches are Implant radiology[4] and vital staining whereas experimental approaches are Craniometry, Anthropometry, Cephalometric radiology and Three-dimensional imaging .

The use of the above methods though helpful had a increased level of invasiveness causing discomfort to the patient and is time consuming, to overcome these disadvantages the use of X-rays proved useful .

X-rays invented in 1900's by W. C. Roentgen has been a boon to the field of medicine owing to its minimal invasiveness; it also brought a detailed insight into the underlying pathology. X-rays in the field of dentistry have found their use ranging from Intra Oral Periapical radiography(IOPA) to the most complex MRI, CT and CBCT.

X-rays used in orthodontics are mostly Orthopantamogram (OPG) and Lateral Cephalogram which give an insight into the underlying dental and skeletal conditions of

malocclusion and to some extent the skeletal maturation of the individual through cervical vertebral maturation.

Dental OPG one of the routine diagnostic aids in orthodontics is used to determine the position of the teeth, however it also provides details about the dental maturation of the tooth and thereby facilitate the determination of the dental age.

Demirjian[5], Nolla's[6] have proposed their methods to study the dental maturation of an individual by studying the individual tooth maturation and determine the dental age. Demirjian A, et al[5] conducted a study on fifty subjects from the French-Canadian population to determine the dental maturation stages using OPG. The tooth were scored based on the developmental criteria like shape change of the pulp chamber and dentinal deposition. The teeth on the left side of the mandible from the central incisor to the second molar teeth were considered. The dental maturation was calculated by measuring the individual tooth score for each stage and the summed scores of all seven teeth gives the dental age.

Skeletal maturation is assessed from the analysis of cervical vertebral maturation using lateral cephalograms and analysis of bones in the Hand and wrist regions using hand wrist radiographs. Hand wrist radiograph is commonly used due to the ease in taking radiograph and the wide region available for assessment and reliability.

Hand wrist radiographs have been used to detect skeletal maturation stages by analysing the small bones of the hand and wrist region. Researchers like Fishmann[7], Grave and Brown[8], have proposed their methods of assessment of the bones in the hand and wrist region.

A.Bjork[9] and S.Helm conducted a study on Danish children and concluded that there was a close relationship between ossifcation of the ulnar sesamoid of the thumb.

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Leonard S. Fishman[7] conducted a study to evaluate a new system for evaluation of the skeletal maturation by assessment of hand wrist radiographs and concluded that hand wrist radiographs can be used to determine the skeletal maturation of the individual.

In the present study Grave and Brown[8] method has been used to determine the skeletal maturation. The method was chosen due to its versatility and reliability. The changes that are studied are classified into epiphyseal changes and individual bone changes. These changes are broadly classified into fourteen stages and three stages of growth.

But the disadvantage pertaining to hand wrist radiograph is unwanted exposure of the patient to radiation. To overcome this disadvantage correlation between skeletal maturation and dental maturation stages to determine the pubertal growth period was considered.

Seymour chertkow[10], Christer Engstrom[11], Goyal et al[12], have suggested the possibility of using tooth maturation as a indicator of the pubertal growth period. Christer Engstrom[11] conducted a study on the lower molar development in relation to the skeletal maturity and found a strong correlation between third molar development and skeletal age and concluded that third molar can be used as a reliable tool for determination of skeletal maturation.

The present study used the method proposed by Demirjian[5] et al to determine the dental maturation stages and, Grave and brown[8] method for skeletal maturation assessment.

The present study aims to determine the correlation between dental mineralisation stages and skeletal maturation in determining the pubertal growth period by studying OPG and hand wrist of 600 samples in South Indian population.

AIM: To compare the dental mineralization stages using OPG and skeletal maturation stages using Hand wrist radiographs during the pubertal growth period.

OBJECTIVES:

1. To determine the dental mineralization stages using OPG.

2. To determine the skeletal maturation stages using hand-wrist radiograph.

3. To determine the correlation between dental mineralization stages and pubertal growth spurt using OPG and Hand wrist radiograph.

Roy M.Acheson (1954)[13] conducted a study to assess the skeletal maturity for both sexes from radiographs by assessing every round bone and epiphysis in hand and knee region using Oxford Maturity units. He concluded that this method of skeletal maturity assessment can be applied to hand and knee till five years of life and it can also be applied to other parts of the body, throughout the developmental period.

Arthur Demisch and Peter Wartmann (1956)[14] studied the calcification of mandibular third molar and its relationship to chronological and skeletal age on American population. They concluded from the study that there was a high positive correlation between degree of mandibular third molar calcification, skeletal and chronological ages.

Frank.F.Lamos and Stephen W.Gray (1958)[15] conducted a study on the Atlanta population to determine the relationship between the tooth eruption age, skeletal developmental age and chronological age. They found that the development of teeth and hand may be independent and there was a correlation of the hand wrist and dental maturation in two or more ages. They concluded that hand wrist can be used as a prediction method but not as an absolute index of development.

Lewis and Garn (1960)[16] conducted a study on Ohio population to determine the relationship between the tooth formation and other maturational factors by studying the dental calcification and tooth movement stages and correlated them with height, weight, stature, bone age, menarche in females and epiphyseal union in tibia in both sexes. They

found that during childhood there was a positive, low and rarely significant relationship between tooth mineralisation and other factors, but as adolescence approached there was an increasing association between maturational status like menarche in girls and tooth formation, and in males epiphyseal union of proximal epiphysis in tibia. They concluded that the use of tooth mineralisation to determine the general maturation needs more extensive research.

Larry.J.Green(1961)[17] conducted a study on Caucasian population to determine the nature of inter-relationship between height, weight, chronological age, dental and skeletal development and he found that there was a moderate correlation between dental, skeletal, and chronological ages, and chronological age was more highly correlated to the dental age when compared to other variables.

Marjorie M. C.Lee (1971)[18] studied the maturation disparity between Hand-wrist Bones in Chinese children. The study analysed the maturation status of the bone groups, and the overall skeletal age was obtained as a arithmetic mean of all the centres. The study results showed that there was a general retardation in boys and it was concluded that the ossification was significantly delayed**.**

Chapman (1972)[19] conducted an longitudinal and cross sectional studies on subjects from New South Wales to relate the ossification of the ulnar sesamoid, developmental status of the thumb and increase in height and to show the occurrence of sesamoid ossifcation in children. He concluded that the adductor sesamoid appears with the development of the metacarpophalaengeal joint, and ossification of the adductor sesamoid occurs at the time of increase in height during adolescent growth spurt and maximum height increment was seen

after the ossification of the adductor sesamoid, and the epiphyseal and diaphyseal fusion of the proximal phalanx of the thumb marks the completion of two maturational events.

A.Demirjian et al (1973)[5] conducted a study on French-Canadian population to determine a new method for estimation of the dental maturity considering the radiological appearances of the seven teeth on the left side of the mandibular arch. The dental maturity was assessed using developmental criteria like dentinal deposit, shape change in the pulp chamber. The stages are designated from A-H; the tooth are scored individually and the sum of the scores gives the dental age. They concluded that the method is applicable from three to seventeen years of age.

Marshall W.A.(1974)[20] conducted a study on British subjects from the Harpenden study group to analyse the relationship between the skeletal age and sexual maturation by analysing the radiograph of the hand wrist and photograph. He concluded that the appearance of the secondary sexual characters were independent of mechanism that regulated skeletal maturation but can be modified by the action of gonadal hormones.

K.C.Grave and T.Brown (1976)[8] conducted a study on eighty eight children of aboriginal population from Australia to determine the skeletal ossification and the adolescent growth spurt by analysing the serial hand and wrist films and the ossification events were studied. The changes were broadly classified to ossification of the individual bones and epiphyseal changes. Individual bone changes include the initiation of pisiform calcification and hooking of the hamate, appearance of the ulnar sesamoid. Epiphyseal changes are

recorded in the first second and third fingers and the radius. They concluded that this method of skeletal maturation assessment from hand wrist was accurate and reliable.

Seymour Chertkow and Paul Fatti (1979)[21] studied Caucasian subjects to analyse the relationship between the tooth mineralisation and early radiographic evidence of Ulnar sesamoid. They concluded that the calcification of adductor sesamoid was closely related to the completion of root mineralisation of the mandibular canine tooth prior to apical closure and it can be used as an indicator of pubertal growth spurt without any sex differences but however racial differences may exist and care must be taken on applying this study to other groups.

A.Demirjian and G.Y.Levesque (1980)[22] conducted a study on genetically homogenous French-Canadian population to analyse the sexual differences in dental development and prediction of tooth emergence. The results suggested that there was no difference in the timing of crown formation and chronology of dental calcification between the sexes till five years of age, but in older ages there was an advancement in girls dental development compared to males. They concluded that there was a pattern of sexual dimorphism predominant in the mandibular canine.

W.J.B.Houston (EJO 1980)[23] conducted a study on the Harpenden study group to analyse the roles of ossification events, bone stages and bone ages in the prediction of the timing of pubertal growth spurts. Data was collected on a scheduled basis every three months. He concluded that important information can be obtained from hand wrist

radiograph but limited to the time of peak height velocity of the growth spurt and can only be useful when the child approaches pubertal spurt.

Urban Hagg and John Taranger (1982)[3] conducted a prospective study on Swedish population and analysed the maturational indicators for pubertal growth spurt from birth to adulthood. Analysis was based on the Standing height, Tooth emergence , Pubertal development , Radiographs of the right hand wrist ,Voice change and menarche. They found that there was a 2 year sex difference in age at beginning and peak of the pubertal growth in standing height . Dental development was faster in boys than girls. Skeletal growth was faster in girls at the beginning and peak of pubertal growth spurt, whereas at the end of

pubertal growth spurt boys had faster growth. They concluded that the peak and the end, but not the beginning, of the pubertal growth spurt could be determined by means of indicators taken from the skeletal development of the hand.

Urban Hagg and Lars Mattson (1985)[24] conducted a study on Swedish children to estimate the accuracy and precision among Liliequest and Lundberg method, Demirijian method and Gustafson and Koch method for chronological age estimation. The subjects were divided into sub-groups based on sex and age. They concluded that Demirjian et al method was comparatively highly accurate and precise for all age groups.

Demirjian et al (1985)[25] conducted a study on French- Canadian girls to assess the interrelationships of the five measures of Maturity such as Menarche, Peak height velocity,

75% percent of skeletal maturation, appearance of the ulnar sesamoid and 90% dental development. From the study it was understood that the menarche preceded the peak height velocity by approximately one year. Maturity of the canines appeared to be closely related to peak   height   velocity. They concluded that the dental development is independent of somatic and Sexual maturity.

Marjatta Nystrom (1986)[26] conducted a study on the Finnish population to determine the dental maturity using the developmental stages of seven mandibular permanent teeth and to compare the dental maturity with Demirjian Standards of French Canadian population. The results revealed that there was a significant advancement in dental maturation in Finnish population. They concluded that Demirjian et al method is not applicable to Finnish population.

Mark S.Mappes (1992)[27] conducted a cross sectional study on the samples from Mid-west and Mid south regions of the United states and analysed the samples for regional

 variation in the tempos of tooth mineralisation and hand wrist radiographs. Mineralisation stages   of canines and premolars, second and third molars were analysed. The results showed that the maxillary premolars had advanced development when compared to   the   mandibular   counterparts. He concluded that the Mid west population was comparably one and half years advanced by the Mid-South population and there was an unexpected independence of the dental and osseous systems.

H.M.Liversidge et al (1999)[28] conducted a cross sectional retrospective study to determine whether the dental maturation standards of Demirjian method was applicable to British Population and it was found that there was an advancement in dental maturation in both sexes when compared with the Demirjian standards. It was concluded that the Demirjian standards cannot be applied to British population.

Sandra Coutinho et al (1993)[29] conducted a cross sectional study on American population to analyse the mandibular canine calcification and skeletal maturity indicators to study the pubertal growth spurt. The results obtained showed that there was an one year advancement of growth in girls and the growth indicators were consistently higher in girls than   boys   in   all   skeletal   maturity   indicators. Mandibular canine calcification was highly related to the middle phalanx of the third finger for both the sexes. They concluded that the mandibular canine calcification stages can be used as maturity indicator.

Serene Koshy and Shobha Tandon (1998)[30] conducted a study to analyse the Dental age and assess the applicability of Demirjian method in South Indian population. They found

 that Dental age is dependent on the racial group and the Demirjian method was not applicable to the South Indian population, and concluded that the applicability of Demirjian method is to be done after extensive research if it is to be applied to South Indian population.

C.S.Farah et al (1999)[31] studied the dental maturity of children in Australian population using Demirjian method and its application in forensic age estimation. The results suggested that the dental maturation was more advanced in girls when compared to boys and

dental age has a significant correlation to chronological age. They concluded that Demirjian et al method can be applied to Perth population but differences exist between various population groups.

Guy Willems et al (2001)[32] conducted a study on Belgian Caucasian population to analyse the accuracy of Demirjian dental estimation method and to adapt the scoring system method if over estimation was reported. The results revealed that there was an significant over estimation of the chronological age in subjects. The alternate method of using scoring system which expressed the age in years had a higher accuracy compared to the original method. They concluded that there was a significant over estimation of the dental age in Belgian population which was attributed to the different rates of dental development in different populations using Demirjian method.

Sood and Hegde R.J.(2002)[33]et al conducted a study on Belgaum population to determine the dental age using Demirjian method and to check its applicability to the population. They found that there was a higher correlation between chronological and dental age in both the sexes. They concluded that Demirjian method showed higher level of accuracy and it can be applied to Belgaum population**.**

Krailassiri et al(2002)[34] conducted a study on Thai individuals to determine the relationship between the stages of tooth calcification and skeletal maturation. Results revealed that there was an advanced dental development seen in males when compared to females whereas the skeletal maturation seems to have a higher pace in females. It was

reported that the third molar calcification had a poor correlation with the skeletal maturity and strong correlation was noted between premolars and second molars. They finally concluded that the dental mineralisation can be used as a stable indicator of maturity.

Prabhakar et al (2002)[35] studied the applicability of Demirjian method of dental age estimation to Davangere population and assessed the relationship between the dental and skeletal age .The results showed that there was an significant overestimation of age in Demirjian method and they concluded that Demirjian method cannot be applied to Davangere children.

R.M.R.Eid et al (2002)[36] conducted a retrospective study on the Brazilian population to check the applicability of Demirjian method and to obtain dental maturity curves for each sex, and assessed if there was any significant correlation to body mass index and dental maturity. The study results showed that there was a significant advancement of age in both females and males. They concluded that no correlation existed between dental maturity and body mass index**.**

Tancan Uysal et al (2004)[37] studied the relationship between stages of calcification in dental panoramic radiography and hand wrist radiograph of Turkish Population by studying the mandibular canine, premolars and mandibular second and third molars. The results showed that there was a consistent earlier appearance of tooth mineralisation stages in females than males. The second molar was seen to have high correlation in both females and males, The mandibular third molars had a lower correlation for both the sexes. They finally

concluded that the completion of mandibular canine root formation can be used to identify the pubertal growth period.

Flores-Mir (2004)[38] et al conducted a study to review the predictive value of the hand-wrist radiograph for assessment of skeletal maturity for estimating facial growth timing and velocity. They study was performed using articles collected from the Cochrane database library and Pubmed, Embase, Web of Science, Lilacs. On complete analysis of the articles, they found that overall horizontal and vertical facial growth velocity is related to skeletal maturity indicators from hand wrist radiographs and the chronological age in an individual is not a standard for reference of skeletal maturity. They concluded that the Skeletal maturity analysis of hand-wrist used for prediction of facial growth velocity should include the bone staging and ossification events.

Iguma et al(2005)[39] conducted a study on cleft lip and palate children to analyse the usefulness of Martins and Sakima method, and Grave and Brown method in predicting the pubertal growth spurt. It was found that the there was a similarity in estimation of pubertal growth spurt in both the methods. They have concluded that there is a equal amount of correlation seen in both methods and both methods are efficient in studying the pubertal growth spurt.

Leurs et al (2005)[40] conducted a study on the Dutch population to assess the dental age using Demirjian's method . The children were grouped based on their age. The results revealed that there was significant difference in chronological and dental age. Dutch children

were advanced in growth when compared to the French-Canadian population of demirjian method. They have concluded that the Demirjian method cannot be applied to the Dutch population.

Nuray Oksuz Kanbur et al (2006)[41] studied the relationship between dental age and bone age on Turkish adolescents with constitutional delay in growth and compared them with healthy individuals. The results suggested that there was statistically significant difference seen in between the dental age and bone age; and chronological age and bone age in individuals with constitutional delay in growth.It was concluded that the Demirjian method can be applied to the Turkish population and the dental maturation was appropriate for the chronological age, but not for the bone age.

Liversidge et al (2006)[42] conducted a meta-analysis study on subjects from eight countries to determine the timing of individual tooth formation stages using Demirjian et al method. They concluded that there was no major differences in timing of the tooth formation stages between sexes.

Rai and Anand(2007)[43] conducted a study on Indian population to investigate the relationship between stages of calcification and skeletal maturity among individuals. From this study it was found that there was advancement in dental development in males compared to females and they also found that the second molar had a higher correlation. They concluded that the tooth calcification stages can be used as a maturation indicator to determine the pubertal growth period.

Mani et al (2008)[44] conducted a study on the Malay population to compare the applicability of two dental age estimation methods. From the study it was found that both the methods showed significant overestimation of the ages, with the Demirjian method significantly higher than Willems method. They have concluded that the applicability of the two methods in the Malay population needs extensive research and modification.

S.Mittal et al (2009)[45] conducted a study on the relationship between the skeletal maturity and dental development in individuals using cervical maturation and dental mineralisation stages in Indian population. From the study they found that the skeletal maturation was comparably advanced in females than male. Lower correlation was seen with the third molar followed by canine, first premolar, second premolar and higher correlation was seen in second molar. The Stage F and G of the Demirjian method has the highest correlation to the peak of the pubertal growth spurt. They concluded that the tooth calcification stages from panoramic radiographs can be used for the maturity indicators of skeletal growth.

Muawia.A.Qudeimat and Faraj Behbehani (2009)[46] studied the Demirjian method and its applicability on Kuwaiti children . The study results revealed that there was a significant differences in the dental maturation of the Kuwaiti children when compared to the French Canadian population. They concluded that there was a significant delay in the dental maturation of the Kuwaiti children, and Demirjian et al method is not applicable for Kuwaiti Population.

Niucha P.S. Vasconcelos et al (2009)[47] studied the dental maturity assessment in children with acute lymphoblastic leukemia after cancer treatment. The subjects were divided into study group which comprised of children who underwent treatment for acute lymphobalstic leukemia and control group of healthy children and it was found that there was a significant difference in chronological age and dental maturity in subjects who underwent anti-neoplastic therapy. They concluded that anti-neoplastic therapy can interfere with the dental maturity by interfering with root formation and dental development.

Mario Legovic et al (2010)[48] conducted a study on Croatian population to analyse the relationship between the dental development of mandibular third molar and chronological age. It was concluded that the dental mineralisation and its relation to chronological age was proved and can be applied to Croatian population**.**

Chen et al (2010)[49] conducted a study on the Western Chinese population to evaluate the applicability of Demirjian et al method. From this study they found that the Dental age was significantly advanced in western Chinese children when compared with the French-Canadian population and in western Chinese population dental ages were significantly higher in females than males. They concluded that the Demirjian et al method cannot be applied to Western Chinese children and further research is needed to evaluate the a new set of standard values should be developed for its applicability in Chinese population.

Chaudary et al (2010)[50] conducted a study on females from the Meerut population to assess whether any differences exsisted between Urban and rural female children. The study

showed that there was a higher correlation between dental age and skeletal age in total and strong correlation between skeletal dental and chronological age. They concluded that there existed no significant difference between rural and urban female children.

Reshma Nayak et al(2010)[51] conducted a study on the South Indian population to assess the growth using mandibular canine calcification stages and its correlation with modified MP3 stages by analysing the periapical radiographs. The study showed high statistical significant correlation in male and female but no statistical significance was observed between mandibular canine calcification and MP 3 stages. They concluded that the Mandibular canine calcification can be used as a reliable indicator for assessment of skeletal maturation.

A.Bagherpour et al (2010)[52] conducted a cross-sectional study on the Iranian population to assess the dental age using Demirjian method. The study results showed that the Demirjian method had over estimated the ages in boys and it was in a decreasing pace for girls and it showed increase in pace for the younger age group. They concluded that the results were appropriate for age estimation in age group from 9-13 years but in younger ages further studies are needed.

Nik Noriah Nik-Hussein et al (2011)[53] conducted a study on the applicability of two methods of dental age estimation in Malayasian population and the results suggested over estimation of age in both methods. They concluded that Willems method is found to be more applicable in Malaysian population when compared to Demirjian method.

Ashith B. Acharya (2011)[54] conducted a study on Indian population to assess the success of the formulas of the Demirjian method in determining the age of the individual. The results suggested that there was a significant under estimation of age seen in Indian population when compared to the original study of Demirjian on French-Canadian population.It was concluded that an Indian-specific formulas need to be developed for the applicability in Indian population.

Diz et al (2011)[55] conducted a study on Spanish subjects with prevalent congenital or peri-natally occurring physical and mental disabilities and compared them with a control group to assess the differences in dental age. They found that there was no significant differences between the dental and chronological age in boys but significant delay in dental age compared to chronological age was observed in girls.

Asab et al (2011)[56] studied the accuracy of Demirjian method in estimating the chronological age on Kelantanese Malay children and established a new dental age (DA). The results showed that Demirjian method over estimated the chronological age (CA) for boys, and for girls and it was less accurate. It was concluded that the Demirjian method tends to be less accurate in estimating the chronological age in Malay children.

Ingrid et al (2011)[57] conducted a study on polish population to analyse the relationship between the Demirjian method and improved Cervical maturation method by studying the panoramic and lateral cephalograms. The results suggested that there was a overall higher level correlation between the chronologic and dental age in females and the

second premolars showed higher correlation in females and in males the canines showed higher correlation. It was concluded that there was a varied level of correlation for each tooth. The dental maturation stages can be used as a simple method to determine the skeletal maturity.

Ali Bagherian and Mostafa Sadeghi (2011)[58] studied the dental maturity of Iranian population using Demirjian et al method. The results showed that there was significant over-estimation of chronological age in individuals, in both the sexes and it was concluded that the Demirjian method can be applied to the Iranian population.

Kanu Priya Gupta et al (2011)[59] conducted a study to evaluate the interrelationship between the chronological age, cervical vertebrae maturational stage and dental calcification stages to determine the timing of the pubertal growth spurt. On analysis the results showed that there was a correlation between the second molar calcification stage E and the circumpubertal phase in females and mandibular first premolar stage E in males. It was concluded that there was a strong correlation between the skeletal maturity and dental calcification in females compared to males and dental calcification can be used as a indicator for pubertal growth spurt assessment.

Vinod Kumar et al (2011)[60] conducted a study on 60 children from Mangalore population aged between 8 to 14 years to determine the relationship between dental age,bone age and chronological age. The study results revealed that there was a delay in the bone age and dental age when compared with the chronological age and statistically

significant correlation seen in females. They concluded that there was a delay in the skeletal and dental age in short-statured children.

Malik et al (2012)[61] conducted a study on the appliacability of Demirjian method to North Indian population. The results showed that there was a higher correlation between the chronological and dental age in Indian population and it was concluded that Demirjian method can be applied to the North Indian Population.

Pooja Malik et a (2012)[62] conducted a study to determine the skeletal age and establish a relationship between the mandibular canine calcification and skeletal age. The results suggested that there was stronger correlation between mandibular canine calcification stage F and Stage G. They concluded that the mandibular canine calcification stages can be used as a maturity indicator to determine the skeletal age.

Grover et al (2012)[63] conducted a study on North Indian population to estimate the dental age and compare it with chronological age by using two methods Williems and Demirjian method. The study showed that there was a strong correlation between the dental age and chronological age in those two methods and it was concluded that there was a over estimation of age in both methods. Comparable accuracy was observed in Williems method which showed a stronger relationship to chronological age, and hence can be used for forensic studies.

Gottimukkala et al (2012)[64] conducted a study on South Indian population with extreme facial patterns to compare the chronological age with the skeletal age and the dental age to evaluate the growth status of the children. The study results showed a statistically significant difference between dental ages in horizontal and vertical growth patterns and it was concluded that the vertical growth pattern showed an earlier dental maturity than the horizontal growers. They concluded that there was an advanced dental and skeletal maturity seen in vertical growers in both the sexes and delayed dental and skeletal maturity in horizontal growers; thus indicating the need for early start of treatment in vertical growers compared to horizontal growers.

Sushil kumar et al (2012)[65] conducted a study on the relationship between the second molar calcification stages and skeletal maturity, and to check the applicability of second molar calcification for assessment of skeletal maturity. And it was found that the Stage E of the Demirjian et al method coincides with the pre-pubertal growth period and Stages F and G coincide with the Peak of Pubertal growth spurt and Stage H was associated with the End of pubertal growth spurt. They concluded that there existed a significant correlation between the dental calcification and cervical maturation indicators, and mandibular second molars can be used as a reliable indicator for skeletal maturity assessment.

Ahamed O Rizig et al (2013)[66] conducted a study to estimate age and dental maturity in Sudanese children using Demirjian et al method. It was observed that there was an overall under-estimation of age by the Demirjian et al method. They concluded that the application of Demirjian method on this particular ethnic group needs a new set of standard values other than the values obtained by studying French-Canadian population.

Shilpa PH et al (2013)[67] conducted a study on 250 Bangalore south school going children to estimate and compare the dental, skeletal and chronological age. The children were divided into 10 groups based on their ages and the results suggested that there was a correlation seen between dental age and chronological age among males in group 1 and 5 and among females in group 3 and 7.Skeletal age showed a correlation to chronological age in groups 3,5,9,10 for males and 1,2,5,9,10 for females.From the study it was concluded that Demirjian method can be applied only to specific age groups of the Bangalore school going children

Vinod kumar et al (2013)[68] conducted a study on underweight children to determine the dental age, bone age and to compare the both with chronological age. It was found that there existed a correlation between dental and skeletal age and there existed a delay in their relation to the chronological age in both females and males. They concluded that dental age and bone age is comparably delayed with respect to the chronological age in under-weight children.

Raghav et al(2014)[69] conducted a study on North indian subjects to compare the second molar calcification stages with the hand wrist maturity indicator and to evaluate the reliability of mandibular second molar as a skeletal maturity indicator. They found that there was a higher correlation between the second molar calcification and skeletal maturation assessment. The skeletal maturity stages appeared earlier in females compared to males and significant correlation was found between Demirjian index and Hand wrist. They concluded

that mandibular second molar can be used as a reliable indicator for skeletal maturity assessment.

Vijayashree et al (2014)[70] conducted a study to analyse the relationship between mandibular second molar calcification stages and compared it with the cervical vertebral stages. They also determined whether the second molar calcification can be used as a indicator of skeletal maturity.They found that Stage E of the dental age coincided with the Start of pubertal growth period, and Stage F and Stage G coincides with the Peak of pubertal growth period and peak of the mandibular growth within a year; Stage H coincided with the end of Pubertal growth spurt. They concluded that there exists a higher level of correlation between mandibular second molar calcification and skeletal maturity hence mandibular second molar calcification can be used as a reliable indicator of skeletal maturity.

Kamble et al (2014)[71] conducted a study to evaluate and compare the skeletal and dental maturity indicators in individuals with different growth patterns. It was concluded that there was a delay in dental maturation in horizontal growers compared to the vertical growers and females were growing ahead of the males in dental maturation.

Sharmila Surendaran et al (2014)[72] conducted a study to determine whether dental calcification can be used to assess the skeletal maturity. The study results showed that the dental mineralisation of canine and first and second premolars were useful to determine the pre-pubertal growth phase and they concluded that the dental mineralisation can be used to determine the pre-pubertal and post-pubertal growth phase .

Vinothkumar et al (2014)[73] studied the relationship between the dental, skeletal and chronological age in children. Chronologic age was assessed by date of birth and dental age was assessed using Orthopantamogram and skeletal age using Hand-wrist radiograph. They found that the dental age was reduced compared to chronological age in females and males, and there was a delay in dental and skeletal age compared to the chronologic age in both females and males. They finally concluded that the dental age, bone age and chronological age can be used as a reliable indicator to understand the overall maturation of the individual.

Goyal et al(2014)[12] assessed the skeletal maturity by studying the calcification stages of permanent mandibular canine and compared them with cervical vertebral maturation to determine whether mandibular canine can be used as a skeletal maturity indicator and they concluded that the mandibular canine calcification can be used as a pubertal maturity indicator but useful only during onset and acceleration stages of pubertal growth period.

Purv S.Patel et al (2015)[74] conducted a study on Gujarathi population to determine the accuracy of two dental and one skeletal maturation method. The results suggested that Williems method of dental age estimation was accurate for the population. The study concluded that predicting the age accurately for males was higher in Demirjian method and for females in Williems method.

Neha gandhi et al (2015)[75] conducted a study on Gujarathis populations to assess the reliability of third molar development for age estimation. The results showed that there was an significant under estimation of ages in both the sexes, and females achieved dental

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maturation earlier than males. They concluded that greater accuracy can be obtained if the population specific values for the Indian population is devised.

Shabil Musthafa et al (2015)[76] conducted a study on Karnataka population to assess the usefulness of panoramic radiography as a tool to estimate growth and use tooth calcification stages as an indicator of maturity. They concluded that the panoramic radiography can be used as a reliable tool for growth estimation in boys, but extensive research on a much larger sample is needed for assessment in girls.

Yunus et al (2016)[77] conducted a study on the differences in chronological and dental age in individuals ; aged between four years to nine years. They concluded that method proposed by Demirjian et al is a reliable method and can be used to determine the chronological age of an individual .

Vildana Dzemidzic et al (2016)[78] studied the skeletal maturity assessment using mandibular canine calcification stages. The study results showed that there was a significant correlation between mandibular canine calcification and skeletal maturity. They concluded that the mandibular canine calcification can be used to assess the skeletal maturity during the pre-pubertal phase.

Maria Melo et al (2016)[79] studied the accuracy of dental age estimation in comparison with the chronological age on a Spanish population using two methods. This study results showed that there was an under estimation of age with nolla's method and over-

estimation of age with Demirjian method compared to the Nolla's method. They concluded that combining the two methods can give a more accurate predictive capacity of the chronological age.

Savaliya Bhoomiben Aravindbhai et al (2016)[80] conducted a study on western Maharashtra population to assess the skeletal maturation using maxillary canine and mandibular second molar calcification stages. The results suggested that the maxillary canine and mandibular second molar stages-D correlate with the pre-peak of the puberty and stages E,F and G correlate with the pre-peak and post peak of the pubertal period. They concluded that the maxillary canine and mandibular second molar calcification can be used as reliable indicator of skeletal pubertal growth.

Pawan C.Motaghare et al (2016)[81] conducted a study on Indian population to determine the correlation of calcification of permanent mandibular canine and mandibular first and second premolars and first and second molars to skeletal maturation. The results showed that there was a higher correlation of second molars and skeletal maturation; and first molars showed the lowest correlation for males and females. The study concluded that the dental mineralisation stages can be used as a tool to determine the pubertal growth period.

Abdrhamn M.Azzawi et al (2016)[82] conducted a study on children from Tanta city of Egypt to determine the dental age. The results showed that there was an advancement in dental age for both males and females and it was concluded that the Demirjian method cannot be applied to the Egyptian population. New set of standards for the Egyptian population needs to be developed.

George Listas and Alessandra Lucchese (2016)[83] conducted a study on Greek population to determine the relationship between dental ,chronological and cervical vertebral maturation in determining the peak growth period and to determine the association between them. The study results revealed that the chronological age showed higher correlation to dental age for both genders and the second molars had a higher correlation to CVM stages. They concluded that dental age was more advanced than the chronological age in both genders and second molars showed the highest correlation with canines showing the least correlation.

Lecca Morales et al (2017)[84] studied the relationships between the dental calcification stages and skeletal maturation in Peruvian population. The results revealed that there was a positive correlation between tooth mineralisation and skeletal maturation stages using cervical maturation and hand-wrist radiographs. They concluded that the mandibular second molar had the highest correlation with hand wrist and cervical vertebral maturation.

Alejandra et al (2017)[85] conducted a study to determine whether dental maturation can be used to assess the skeletal maturation. The results showed that there was a correlation between cervical and dental maturation stages in females and males. They concluded that dental maturation can be used to determine the pubertal growth period in individuals.

Pratyusha et al (2017)[86] conducted a study on the western Godavari population to determine the applicability of three methods of dental age estimation. The samples were divided into three groups and were analysed. They concluded that out of the three methods, the Modified Cameriere's population specific regression equation method was comparably accurate for age determination in South-Indian population.

Antoine Saade et al(2017)[87] conducted a study on Lebanese children to determine the dental and skeletal age by using two skeletal maturation methods and two dental age estimation methods. The samples were divided into four groups each. The results suggested that the skeletal age by Greulich and Pyle method showed non-significant difference in males and significant difference was observed in females between skeletal and chronological age.They concluded that Greulich and Pyle method was accurate in males and only in one group of females and the Williems method was more accurate for both the genders compared to the Demirjian method.

Ayman A Al-Dharrab et al(2017)[88] conducted a retrospective cross sectional study on Saudi children to evaluate the dental age maturation as an indicator of chronological age. The results suggested that there was a significant difference in chronological age and dental age and significant overestimation of age in males and underestimation in females. The study concluded that Demirjian et al method could be applied to the Saudi population.

Sources of the samples :

The samples were selected from the out patients visiting the J.K.K.Nattraja Dental college, Komarapalayam. A total of 600 samples were selected in the age group between 7 to 17 years. OPG(Fig-2) and Hand-wrist radiographs(Fig-3) were taken using SIRONA Orthophos XG 5 DS/Ceph (Fig-1) for all the samples the skeletal maturation and dental mineralization stages were analysed. Institutional ethical committee reviewed and approved the study. Informed consent was obtained from the parents or guardians of the children.

Inclusion criteria:

1.Patients within the age group of 7 years to 17 years.

2.Patients with no previous history of orthodontic therapy

3.OPG and Hand-wrist radiographs to be taken at the same time

Exclusion criteria:

1.Patients with congenitally missing teeth.

2.Patients with history of any previous orthodontic therapy.

3.Patients with cleft lip or palate.

4.Patients with debilitating diseases.

5.Patients with poor periodontal condition .

Method of Assessment:

OPG and Hand-wrist radiographs were obtained from all the samples selected and the radiographs were assessed on **HP-Pavilion 15 Notebook PC** with a Screen size of **15.6 inches** and with a resolution of **1366*768** using **Windows Photo Viewer** software and the investigator was permitted to use zoom tool and change the contrast if needed. The panoramic radiograph and the hand-wrist radiograph were analysed separately.

Dental calcification :

Dental calcification stages were studied by using Orthopantamogram (OPG) analysing the teeth present on the left side of the mandibular arch and assessed using Demirjian et al[8] method. Tooth calcification stages were designated from stage A to stage H based on the development criteria like dentinal deposition, shape change of the pulp chamber; calcification of tooth from single occlusal points to root apical closure were analysed. The values for each stage were calculated separately and were summed up to give the dental maturity score of the individual which gives the dental age of the individual. The present study was performed with a slight modification on the original method proposed by Demirjian et al. The study was performed on mandibular canine, mandibular first premolar, mandibular second premolar and mandibular second molar to determine the dental mineralisation stages. The tooth with the highest correlation to skeletal maturation was identified.

Skeletal maturation:

Skeletal maturation was assessed from hand-wrist radiograph using Grave and Brown method[9]. This method studied skeletal maturation using the left hand of the individual and classified it into fourteen stages of bone ossification categorizing them into three growth periods; Onset, Peak and End of pubertal growth spurt. Stages were designated on the basis of the ossification events occurring at various points in the hand wrist. Epiphyseal events like epiphysis as wide as the diaphysis , epiphysis capping and union of the epiphysis and diaphysis are studied on the first, second, third fingers and radius. Other events studied included the hooking of the hamate and appearance of the pisiform. The onset, peak and end of the pubertal growth spurt were studied by using the indicators like appearance of the pisiform for onset of puberty, Epiphysis capping the diaphysis in radius bone for peak of the pubertal period, and fusion of the epiphysis and diaphysis of the radius bone for the completion of the pubertal growth period.

The measured data obtained from the analysis of the Orthopantamograms and hand wrist radiographs were measured and tabulated separately and evaluated statistically. Statistical calculations were done using   SPSS (Statistical Package for Social Sciences) 21.0 software.

The means of the chronologic ages for both the sexes in three periods of skeletal maturation was analysed by 2-way analysis of variance (ANOVA) and post hoc tukey test. And the analysis of ordinal multinomial logistic regression to evaluate the which teeth had the mineralization association to skeletal maturation.

Table i: Chronologic age of males and females based on skeletal maturation

Maturation Event	Number of subjects		Chronologic age, mean (SD)	
	Male	Female	Male	Female
Onset	118	68	11.09 (2.19)	9.57 (1.93)
Peak	99	59	13.03 (1.58)	11.31 (2.12)
End	77	179	15.10 (1.94)	13.41 (2.28)

Table ii: Results of ordinal multinomial logistic regression analysis for male

Variable	Estimate	SE	Wald chi-square	P value	OR	95% CI
Canine	1.403	0.491	8.171	0.004	4.069	1.554-6.649
First Premolar	0.772	0.648	1.423	0.233	2.165	0.608-7.702
Second Premolar	0.244	0.526	0.215	0.643	1.276	0.455-3.577
Second Molar	0.908	0.352	6.659	0.010	2.481	1.244-4.946

Table iii: Results of ordinal multinomial logistic regression analysis for female

Variable	Estimate	SE	Wald chi-square	P value	OR	95% CI
Canine	0.547	0.358	2.344	0.012	1.729	0.858-3.483
First Premolar	0.539	0.457	1.390	0.023	1.715	0.700-4.203
Second Premolar	0.67	0.42	2.539	0.111	1.954	0.857-4.454
Second Molar	0.334	0.309	1.170	0.279	1.397	0.762-2.560

Table iv: Distribution of mineralization stages of teeth at the Onset of Pubertal growth period

Dental Maturation Stages	Canine		First Premolar		Second Premolar		Second Molar	
	Male	Female	Male	Female	Male	Female	Male	Female
C				3.20%		2.20%	5.20%	6.10%
D	1.00%	4.50%	9.20%	10.10%	11.30%	14.60%	21.60%	27.00%
E	10.30%	15.70%	20.60%	24.60%	25.80%	21.30%	9.30%	9.00%
F	36.00%	37.60%	22.70%	36.00%	26.80%	23.70%	44.30%	34.30%
G	32.00%	22.50%	35.10%	15.70%	27.90%	30.30%	18.60%	18.00%
H	20.70%	19.70%	12.40%	10.40%	8.20%	7.90%	1.00%	5.60%

Table v: Distribution of mineralization stages of teeth at the Peak of Pubertal growth period

Dental Maturation Stages	Canine		First Premolar		Second Premolar		Second Molar	
	Male	Female	Male	Female	Male	Female	Male	Female
D						2.70%	1.20%	5.00%
E	1.30%	1.20%	4.80%	5.30%	4.70%	7.10%	5.30%	9.60%
F	8.00%	9.60%	12.50%	13.30%	17.30%	20.00%	21.70%	26.70%
G	60.00%	56.70%	33.30%	44.10%	35.30%	33.90%	54.50%	45.40%
H	30.70%	32.50%	49.40%	37.30%	42.70%	36.30%	17.30%	13.30%

Table vi: Distribution of mineralization stages of teeth at the End of Pubertal growth period

Dental Maturation Stages	Canine		First Premolar		Second Premolar		Second Molar	
	Male	Female	Male	Female	Male	Female	Male	Female
F		1.50%		4.40%	3.30%	8.20%	13.10%	18.60%
G	8.20%	13.40%	16.40%	17.20%	18.90%	17.90%	28.70%	29.90%
H	91.80%	85.10%	83.60%	78.40%	77.80%	73.90%	58.20%	51.50%

RESULTS:

Table i The means of the chronologic ages for both the sexes in three periods of skeletal maturation was compared by 2-way analysis of variance (ANOVA) and the post hoc tukey test.

The results showed differences between the sexes of the sample (P <0.05) and between the skeletal maturation periods(P <0.05).

A consistent early occurrence of each skeletal maturation stages were observed in girls when compared to boys. The mean chronologic age for girls was approximately 1.6 years (range 1.5-1.7 years) younger than the boys.

The ordinal multinomial logistic regression analyses between the skeletal and dental mineralization stages of the teeth are presented for males in **Table ii** and for girls in **Table iii**;

The analysis of ordinal multinomial logistic regression predicts the Odds ratio of the tooth to predict the pubertal growth period by the mineralization stages.

The results reveal mandibular canine and mandibular second molar were statistically significant predictors for males (P <0.05), the odds ratio was 4.069 (P value-0.004) for mandibular canine suggesting that mineralization of the tooth can predict the skeletal maturation four times more than any other tooth.

The other tooth with statistically significant correlation was seen in mandibular second molar; Odds ratio of 2.481 (P value- 0.010), suggesting that the second molar is 2.5 times more reliable for prediction of skeletal maturation than other teeth.

Similarly the statistically significant correlation was observed in relation to mandibular canine and mandibular first premolar for females.

The results suggest that mandibular canine odds ratio 1.729 and for mandibular first premolar odds ratio was at 1.715.

Tables iv to vi shows the percentage of distribution of each tooth in the 3 skeletal maturation stages.

Table iv gives the percentage distribution of the mineralization stages at the onset period;
 There was a wide range of distribution of the mineralization stages in all teeth for both the sexes. The dental maturation stages with most reliable predictor was observed in stage F of the mandibular canine and mandibular second molar for boys.

For girls stage F of the mandibular canine and first premolar was seen as a reliable predictor of maturation.

Table v at the peak of the maturation period teeth were identified in the stages G of the dental maturation,

For boys the stages were seen in mandibular canine stage G and second molars.

For girls the stage G were seen in mandibular canine and first premolar, other teeth with higher percentage of distribution was seen in mandibular second molar but as the tooth was not statistically significant it was neglected.

Table vi gives the percentage distribution at the end of the pubertal growth period for boys and girls.

For boys stages H of the mandibular canine and the second molar had higher percentage of distribution.

For girls higher distribution was observed in stage H of mandibular canine and first premolar.

Correction of skeletal malocclusion during growth period can be achieved by growth modification. Growth modification using myofunctional appliance and orthopaedic appliances is mainly dependent on the timing of the pubertal growth spurt. It is during the pubertal growth period that an individual exhibits highest growth potential, but the timing varies between individuals. Chronologic age though a common indicator of the maturation, does not provide accurate information due to influence of factors like climate, ethnic origin, nutrition, genetic and environmental factors, hence it would be useful to understand the developmental age[45]

Maturation status of an individual is analysed using various ossification centres in the body. Most commonly used centres of ossification are ankle, foot, hip, cervical vertebra, hand and wrist regions[31]. Hand wrist radiographs are extensively used because of the ease of obtainment and extensive bone area that are suitable for study.

Fishmann[7]and Grave and Brown[8] have proposed various methods of determination of skeletal maturation by analysing the ossification centres of the hand and wrist region.

Skeletal maturation in the present study was assessed using Grave and Brown method[8]. This method is used because even small radiographic changes are detectable and also it provides a reliable description of the events.

Ossification events are broadly classified into three stages namely onset, peak, and end of the growth containing fourteen events. Changes are two types epiphyseal changes and individual bone changes. Epiphyseal changes are studied on the first, second, third fingers and radius bone. Individual bone changes include the appearance of the Pisiform, Hooking of the hamate, appearance of the sesamoid bone.

Hand wrist radiograph though useful has a disadvantage of additional radiographic exposure to the patient.

Dental maturation is studied using the method proposed by Demirjian et al[5] of analysing OPG. This method utilizes the maturation status of the seven teeth of the mandible on the left side from the central incisor to second molar and maturation stages are designated from stage A- H. Demirjian method was performed on the French-Canadian population. This method is chosen because it shows higher accuracy even when applied to north-Indian population[63] and is also reliable as it uses distinct changes in the shape and proportion of root length .

In the current study dental maturation is assessed with a slight modification of the Demirjian method[5]. Dental maturation is analysed from four mandibular teeth the canine, first and second premolar and second molar.

To overcome the disadvantage of hand wrist radiograph and reduce the radiation exposure to the patient it is advisable to use dental mineralisation to determine the skeletal maturation.

Many researchers like Sandra coutinho[29], Engstrom[11] have reported high correlations between tooth calcification and skeletal maturity indicators which helps the practitioner to determine the pubertal growth from panoramic radiographs.

Arthur Demisch and Peter Wartmann[14] found a positive straight line correlation between mandibular third molar calcification, and skeletal or chronological age and concluded there exisisted a correlation between maturation of various systems.

On the contrary Arthur B.Lewis et al[16] has found little relation between dental maturation and skeletal maturation stages. Arthur B.Lewis et al[16] found a positive but less significant correlation between the tooth formation and general growth and development between tooth formation timings and maturational status.

The present study is conducted on six hundred samples from the south Indian population to determine the pubertal growth period by studying the correlation between dental maturation stages studied from panoramic radiographs and skeletal maturation stages from hand-wrist radiographs.

The mean chronological age for each skeletal maturation level is given in Table-i; it indicates that in each stage of development females preceded males.

A.Bjork[7] reported that the maximum pubertal growth in girls preceded males by approximately eighteen months, the appearance of the ulnar sesamoid also was seen advanced in females by twenty one months. Chapman[19] also reported that ossification of the adductor sesamoid appeared in females approximately one year earlier than males.

S.Mittal et al[45] reported that females maturation was consistently earlier than males in all stages of maturation.

Results of the ordinal multinomial logistic regression test calculated to determine the correlation between the skeletal maturation and dental maturation stages are given in Table-ii for males and Table- iii for females; Highest correlation was observed in mandibular canine (Pvalue-0.004<0.05 for males and 0.012<0.05 for females) for both the sexes in south Indian population. This result is in accordance with the works done by B.Rai et al[43], Uysal et al[37], Seymour Chertkow[10], Chertkow and Paul Fatti[21].

Seymour Chertkow[10] from his study concluded that the calcification of the mandibular canine can be used as reliable tool for assessment of skeletal maturation. Reshma Nayak[51] found that a high correlation existed between mandibular canine calcification and MP3 stage.

Other tooth with significant correlation were the second molars in males and first premolars in females.The first premolars(Pvalue-0.023<0.05) in girls Table-ii also showed significant correlation in females, results are in accordance with the results given by Sharmila surendran[72] they found stage E of the first premolars showed correlation to pre-pubertal growth period and second molar had highest correlation to post-pubertal growth period.

The second molar(Pvalue-0.010<0.05) Table-ii showed a significant correlation in boys, the results are in accordance with the results of Sushil kumar et al[51] study on Indian population and Krailassiri et al[34] study on Thai population. Vijayashree et al[70] found that there was a high positive correlation between the mandibular second molar calcification and skeletal maturation and suggested that mandibular second molar can be used as a reliable tool for skeletal maturation assessment.

Tooth mineralisation relative to the stages of skeletal maturation is considered separately for both sexes for determination of the pubertal growth period. Hagg[3] and Bjork[9] found ossification of the adductor sesamoid in relation to the onset of the pubertal growth period.

Seymour Chertkow[10] found the relationship between mandibular canine calcification prior to apical closure and appearance of the ulnar sesamoid which indicated the circumpubertal growth period.

Tooth mineralisation stages that have correlation to skeletal maturation was observed in stage F for mandibular canine(36.00%) and mandibular second molar(44.30%) in Table-iv for males the results are in accordance with Reshma nayak et al[51] and Sandra Coutinho et al[29] whose results show that stage F of the canine had higher correlation to onset of the pubertal growth period.

Pubertal growth period is observed with relation to stage G(60.00%) in Table-v in mandibular canine and second molars(54.50%) in Table V which are in accordance with the results published by Sushil kumar et al[65] and B.Rai et al[43] which suggested stage G of the canine coincided with the pubertal peak period.

The end of the pubertal growth period was found in relation to stage H of mandibular canine(91.80%) in Table-vi and mandibular second molar(58.20%) in Table-vi similar results were obtained from the studies done by Vijayashree et al[70] who found that stage H of the second molar coincided with end of the pubertal growth period. Reshma nayak et al[51] found that stage H of the canine coincided with end of the pubertal growth period.

For females the onset of the pubertal growth period was correlated to Stage F of the mandibular canine and first premolar in Table-iv, which is in accordance with the results of the study by Perinetti et al[85] on Italian population which suggested stage E to be correlated to the onset of the pubertal onset the difference in stages may be attributed to the environmental and local factors.

During peak of the pubertal growth the stages G of the canine(56.70%)in table-v and first premolar(44.10%) in Table-v are statistically significant, they are in close relation to the results of Vijayta Yadav et al[86] which suggested Stage G of the first premolar to the peak of the pubertal growth.

End of the Pubertal growth was significant with stages H of the mandibular canine(85.10%) in Table-vi and mandibular first premolar(78.40%) Table-vi.

The current study results suggest that there exists a relationship between dental maturation and skeletal maturation stages. It also found that dental maturation stages can be used as a reliable tool for identification of skeletal maturation in individuals, but one must also consider the racial variations and environmental changes.

The study results reveal that skeletal maturation of females was advanced than males by an average of 1.6 years in all three stages of skeletal maturation.

These results also suggest that any growth modification therapy like myofunctional appliances, orthopaedic appliances must be initiated for females at a younger age when compared with males.

The study results suggest that dental maturation stages can be used as a reliable tool for identification of pubertal growth period.

SUMMARY AND CONCLUSION:

The present study was conducted on 294 males and 306 females from outpatients reporting to J.K.K. Nattraja Dental college, Komarapalayam, Namakkal. The skeletal maturation was assessed using Hand wrist radiograph using the method proposed by Grave and Brown classifying the ossification into fourteen events and three stages. Dental maturation stages were analysed from Orthopantamogram(OPG) using the method proposed by Demirjian et al in which maturation is classified into eight stages from A-H. The data was subjected to statistical analysis, and the following conclusions were drawn from the results.

In males, mandibular canine and mandibular second molar were statistically significant with higher correlation observed in relation to stage F for onset of pubertal growth period, stage G coincided for peak of the pubertal growth period and stage H coincided for end of the pubertal growth period.

In females, mandibular canine and mandibular first premolar were statistically significant and higher correlation was observed in relation to stage F for the onset of pubertal growth period, stage G coincided with the peak of the pubertal growth period and stage H coincided with the end of the pubertal growth period.

There is a correlation between dental maturation and skeletal maturation stages in determining the pubertal growth period. On comparison of chronological age the females preceded males in all three stages of skeletal maturation by approximately 1.6 years.

From the study it is concluded that dental mineralization stages studied from Orthopantamogram(OPG) a routine diagnostic tool can be used to determine the skeletal maturation of the individual thereby reducing the additional radiation exposure to the patient.

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ANNEXURES (TABLES)

Table- i	Chronologic age of males and females based on skeletal maturation
Table- ii	Results of ordinal multinomial logistic regression analysis for male
Table- iii	Results of ordinal multinomial logistic regression analysis for female
Table-iv	Distribution of mineralization stages of teeth at the onset of pubertal growth period
Table-v	Distribution of mineralization stages of teeth at the peak of pubertal growth period
Table-vi	Distribution of mineralization stages of teeth at the end of pubertal growth period

LIST OF ABBREVATIONS

1. OPG- Orthopantamogram.