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Assessment of Growth Using Mandibular Canine Calcification Stages and Its Correlationwith Modified MP3 Stages and Cervical Vertebrae Maturation Stages

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Abstract

Aim and objectives: To correlate the developmental stages of the mandibular canine withthat of known methods like skeletal developmental stages of MP3 and cervical vertebral maturation stages (CVM) and to find out if the developmental stages of the mandibular canine alone can be used as a reliable indicator for assessment of skeletal maturity.

Methods: The study includes 160 subjects (80 males and 80 females). A total 160 lateral cephalograms were taken to analyse CVM stages as given by Hassel and Farman and 160 periapical radiographs of mandibular right canine and right MP3 region were taken and assessed according to Demirjian's stages and R. Rajagopal's modified MP3 stages respectively.

Results: The correlation between the canine was compared with developmental stages of MP3 and CVM stages and a high statistical significant values were obtained ($p = 0.001$) in males and females, whereas these parameters were not significantly related tochronological age in males and females ($p>0.05$)

Conclusion: The correlation between developmental stages of the mandibular canine with the developmental stages of MP3 and cervical vertebral maturation stages was found to be significant. The developmental stages of mandibular canine can be used reliably as asole maturity indicator for assessment of skeletal maturity.

Keywords: Mandibular canine calcification, modified MP3, CVM stages, skeletalmaturity, and

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growth prediction.

INTRODUCTION

Growing individuals differ in the timing of the maturational events and also in the sequence of these events.[1] Assessing maturational status to know whether the pubertal growth spurt of the patient has been reached or completed can have a considerable influence on the diagnosis, treatment goals, treatment planning, and the eventual outcome of orthodontic treatment.[2] There are many parameters to assess the developmental status of a child such as height, weight, chronological age, skeletal age, dental age and secondary sexual characteristics. The key issue with any of these growth assessment methods is the reliability.[3]

Skeletal age has been considered the most reliable method to assess the developmental status from a long time.[1] The hand-wrist radiographs or the cervical vertebrae on lateral cephalograms are commonly used for the assessment of skeletal development. The developmental changes which occur in the middle phalanx of 3rd finger (MP3) have been used to study the skeletal maturity development as they follow the pubertal growth spurt from the onset to end. [4] Many studies have shown that the middle phalanx of the third finger alone can be used as an indicator for determining skeletal maturity.[1, 3, 6, and 8]

Dental age estimation is mainly based upon the rate of development, progressivesequence of their eruption in the oral cavity and calcification of tooth buds.[1] Dental development is a useful indicator of maturation because of its high reliability, a low coefficient of variation, and resistance to the effects caused by environment.[5] Studies have shown that the relationships between the stages of tooth mineralization of the mandibular canine appear to correlate better with the skeletal maturity indicators than the other teeth.[6] There are several methods that have been developed to assess the dental age according to the degree of calcification observed in permanent teeth.[1] Of all the methods currently, the most common method for children is the Demirjian's method.[5]

Radiology plays an indispensable role in the determination of human age.[7] The clarity of the periapical radiographs, feasibility, and the ease with which the developmental stages can be interpreted, the simplicity of the method, low cost and significantly low patient radiation exposure highly recommends it as a practical and a sensitive technique which will meet the requirement of the clinician in our field.[8] The technology of digital dental radiovisiography (RVG) is another method which provides the highest quality and greatest flexibility for producing digitized radiographic images with high clarity and with less radiation exposure. It is also much faster and easier than the conventional radiographs.

The current study is designed to correlate the developmental stages of the mandibular canine with that of known methods like skeletal developmental stages of MP3 and cervical vertebral maturation stages. Also to assess if mandibular canine development stages alone can beused as a reliable indicator of skeletal maturity.

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METHODOLOGY

The study includes 160 subjects. The subjects were divided into two groups group 1 containing 80 males, group 2 containing 80 females. Each group is again subdivided into 4 subgroups (n=20) based on age (8-10 years, 10-12 years, 12-14 years,14- 16years).

Selection criteria include:

a. Well-nourished subjects with no history of known serious illness

b. Not undergone previous orthodontic treatment

c. Not undergone extraction of any permanent teeth

d. With no major malalignment of the teeth

e. No previous history of trauma or injury to the neck and the hand and wristregions.

Procedure:

i. Intra oral periapical radiographs: A total of 160 periapical radiographs of the mandibular right canines is taken using Radio Visuographic unit (70 kVp, 8mA, 0.4s) (Figure 1).

ii. Radiographs of MP3: In this study standard periapical radiographs are used in assessment of MP3 stages as an indicator of skeletal maturity. A total of 160 periapical radiographs of the MP3 region. Instruct the subject to place the right hand with the palm downward ona flat table middle finger being centered on a RVG sensor with the radiographic grid (Figure 3). The sensor was stabilized by using a plaster model with radiographic grid over it (Figure 2). The finger lies parallel to the long axis of the sensor and the cone of the dentalRVG machine positioned in slight contact with the middle phalanx, perpendicular to the film (Figure 4).

Specifications of RVG unit: voltage is 70kvp, current is 8mA and exposure time is 0.4s

iii. Lateral cephalograms: Digital cephalograms of 160 subjects were taken with functional head positioners (70 kVp, 8mA, 1.8s).(Figure 4)

Then all the radiographs are interpreted:

Cervical vertebrae maturation was assessed according to the 6 stages given by Hassel and Farman (1995).[9]

The development of the MP3 stages of the hand were evaluated using R. Rajagopal's observational scheme which is an modification of Hagg and Taranger's observational scheme.[10] development of mandibular canine was assessed according to Demirjian's stages of dental calcification.[11]

The data was subjected to statistical analysis:

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i. Mean and standard deviation

ii. Co-relation coefficient

iii. Mann Whitney U test

iv. Student's t test

v. Unpaired t test

Figure 1: Radio Visuographic unit (RVG)

Figure 2: Radiograph of right mandibular canine

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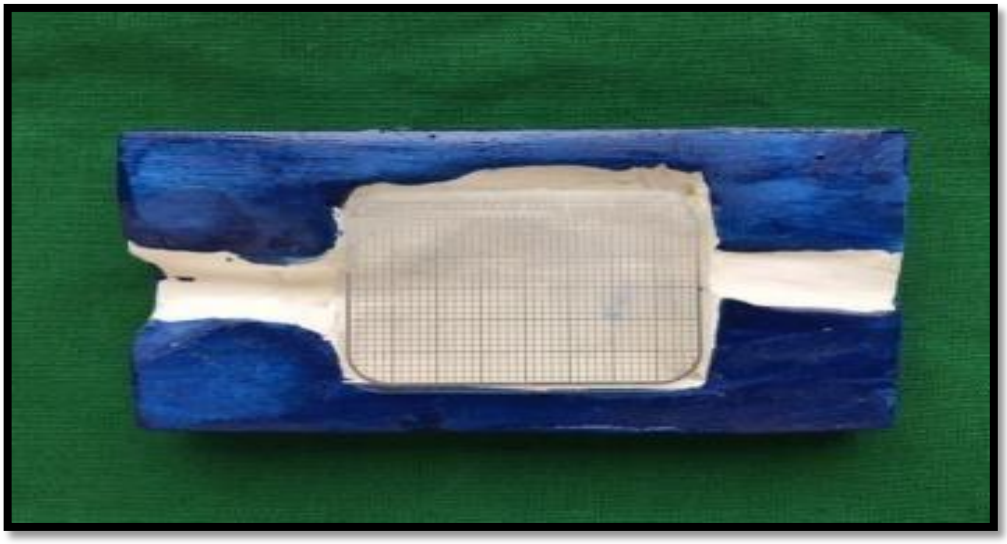

Figure 3: Plaster model for stabilization of sensor

Figure 4: Position of middle phalynx of third finger

Figure 5: position of RVG sensor and x-ray cone

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Figure 6: Digital cephalostat with functional head positioners

Figure 7: Position of patient to take lateral cephalogram

Results

On comparing the cervical vertebrae maturation stages and the chronological age in males and females (Table 1):

In males, the correlation was found to be not significant ($P > 0.05$) in the group (8-10 years) and (10-12 years), it was highly significant ($P < 0.01$) in the group (12-14 years) and very highly significant in the group (14-16 years).

In females, the correlation was found to be not significant ($P > 0.05$) in the group (8-10 years) and (14 -16 years) it was highly significant ($P < 0.01$) in the group (10-12 years) and (12-14 years).

On comparing the developmental stages of chronological age and mandibular right canine in males and females (Table 1):

In males, the correlation was found to be not significant ($P > 0.05$) in the group (8-10 years) and (10-12 years), it was significant ($P < 0.05$) in the group (12-14 years) and very highly significant ($P< 0.01$) in the group (14-16 years).

In females, the correlation was found to be not significant ($P > 0.05$) in the group (8-10 years), (12-14 years) and (14-16 years), it was highly significant ($P < 0.05$) in the group (10-12 years).

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On comparing the developmental stages of MP3 and the chronological age in males and females (Table 1):

In males, the correlation was found to be not significant ($P > 0.05$) in the group (8-10 years) and (10-12 years), it was highly significant ($P < 0.01$) in the group (12-14 years) and very highly significant in the group (14-16 years).

In females, the correlation was found to be very highly significant ($P > 0.001$) in the group(8-10 years) it was significant ($P < 0.05$) in the group (10-12 years), no significant in thegroup (12-14 years) and (14-16 years).

On comparing the CVM stages and the canine in males and females:

In males the correlation was found to be significant in (8-10 years), (10-12 years) and (14-16 years), it was found to be very highly significant in (12-14) years.

In females the correlation was found to be significant in (8-10 years) and (10-12 years), highly significantin (14-16 years), it was found to be very highly significant in (12-14) years.

On comparing the CVM stages and the MP3 stages in males and females (Table 2):

In males the correlation was found to be very highly significant in (8-10 years), (10-12 years) and (12-14 years), it was found to be significant in (14-16) years.

In females the correlation was found to be very highly significant in (8-10 years) and (10-12 years), highly significant in (12-14 years), it was significant in (14-16) years.

On comparing the canine stages and the MP3 stages in males and females (Table 3):

In males the correlation was found to be very highly significant in (8-10 years), (10-12years) and (12-14 years), it was found to be highly significant in (14-16) years

In females the correlation was found to be very highly significant in (8-10 years) and (10-12 years), highly significant in (12-14) and (14-16 years).

The relationship between CVM stages and canine stages were also highly significant when analyzed statistically (Table 4).

For males the stage 1 of CVM showed correlation with stage E of canine and, the stage2 showed the maximum correlation with the F and G stages of canine, whereas the stage 3 and 4 showed maximum correlation with G stage. In the stages 5 and 6 of, the H stage of mandibular canine development showed to have a high correlation.

For females the stage 2 and 3 of CVM showed correlation with stage F of canine and, the stage 4 showed the maximum correlation with the G stages of canine, whereas the stage5 showed maximum correlation with H stage. In the stages 6, the H stage of mandibular canine development showed to have a high correlation.

The relationship between CVM stages and MP3 stages were also highly significant when analyzed statistically (Table 5).

For males the stage 1 of CVM showed correlation with MP3 F and MP3 FG stages, the stage 2 showed the maximum correlation with the MP3-FG stage, whereas the stage 3 and 4 showed maximum correlation with MP3 G and MP3 H stages , the G stage a high correlation was seen with the MP3-G stage. In the stages 5 and 6 of, the MP3-HI and MP3-I stage was observed to have a high correlation.

For females. Stage 2 and 3 of CVM showed correlation with MP3 FG stage, the stage 4 showed the

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maximum correlation with the MP3-H stage, whereas the stage 5 showed maximum correlations with MP3 I stage, in the stages 6, the MP3-I stage was observed to have a high correlation.

The relationship between canine stages and MP3 stages were highly significant when analyzed statistically (Table 6) (Graph 1).

For males the D stage of canine calcification showed correlation with MP3 F stage, the E stage showed the maximum correlation with the MP3-F stage, whereas the stage F showed maximum correlation with MP3 FG stage, while in the G stage a high correlation was seen with the MP3-G stage. In the H stage of mandibular canine calcification, the MP3-I stage was observed to have a high correlation.

For females, the D stage of mandibular canine calcification had no subjects from the samples; the E stages showed maximum correlation with the MP3-F stage and F stage was correlating to MP3 FG stage. The G stage seemed to show a high correlation with the MP3-G stage and the H stage closely related with the MP3-I stage.

Table 1: Correlation between CVM stages with canine developmental stages in male and females

Age groups	Gender	Variables	p-value
8--10	Male	CVM stages vs canine stages	0.0239*
	Female	CVM stages vs canine stages	0.017*
10--12	Male	CVM stages vs canine stages	0.0205*
	Female	CVM stages vs canine stages	0.0104*
12--14	Male	CVM stages vs canine stages	0.0008*
	Female	CVM stages vs canine stages	0.001*
14--16	Male	CVM stages vs canine stages	0.0248*
	Female	CVM stages vs canine stages	0.001*
Total	Male	CVM stages vs canine stages	0.0001*
	Female	CVM stages vs canine stages	0.0001*

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Table 2: Correlation between canine stages and MP3 stages in male and females

Age groups	Gender	Variables	p-value
8--10	Male	Canine stages vs MP3 stages	0.0001*
	Female	Canine stages vs MP3 stages	0.001*
10--12	Male	Canine stages vs MP3 stages	0.0004*
	Female	Canine stages vs MP3 stages	0.0001*
12--14	Male	Canine stages vs MP3 stages	0.0014*
	Female	Canine stages vs MP3 stages	0.0914
14--16	Male	Canine stages vs MP3 stages	0.0453*
	Female	Canine stages vs MP3 stages	0.6861
Total	Male	Canine stages vs MP3 stages	0.0001*
	Female	Canine stages vs MP3 stages	0.0001*

Table 3: Association between CVM stages and developmental stages of MP3 in malesand females

Gender	CVM stages	MP3 F	MP3 FG	MP3 G	MP3 H	MP3 HI
Male	1	10	2	-	-	-
	2	3	17	5	-	-
	3	-	-	13	3	-
	4	-	-	-	7	-
	5	-	-	-	-	8
	6	-	-	-	-	3
Female	1	-	-	-	-	-
	2	3	9	4	-	-

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	3	-	3	4	4	-
	4	-	-	-	9	5
	5	-	-	-	1	4
	6	-	-	-	-	4

Table 4: Association between CVM stages and developmental stages of mandibular caninein males

Gender	**CVM stages**	**D**	**E**	**F**	**G**	**H**
Male	1	-	7	5	-	-
	2	1	8	10	6	-
	3	-	-	1	14	1
	4	-	-	-	2	5
	5	-	-	-	4	6
	6	-	-	-	-	10
Female	1	-	-	-	-	-
	2	-	4	11	1	-
	3	-	-	4	7	-
	4	-	-	-	9	5
	5	-	-	-	2	10
	6	-	-	-	2	25

Table 5: Association between canine stages with MP3 stages in males.

Canine Stages	MP3F	%	MP3G	%	MP3G	%	MP3H	%	MP3HI	%	MP3I	%	Total
D	1	100	-	-	-	-	-	-	-	-	-	-	1
E	8	53.3	7	46.7	-	-	-	-	-	-	-	-	15
F	4	25	10	62.5	2	12.5	-	-	-	-	-	-	16
G	-	-	2	7.7	16	61.5	4	15.4	4	15.4	-	-	26
H	-	-	-	-	-	-	6	27.3	7	31.8	9	40.9	22

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Table 6: Association between canine stages with MP3 stages in females.

Canine Stages	MP3F	%	MP3G	%	MP3G	%	MP3H	%	MP3HI	%	MP3I	%
D	-	-	-	-	-	-	-	-	-	-	-	-
E	3	75	1	25	-	-	-	-	-	-	-	-
F	-	-	8	53.3	7	46.7	-	-	-	-	-	-
G	-	-	3	14.3	1	4.8	13	61.9	2	9.5	2	9.5
H	-	-	-	-	-	-	1	2.5	8	20	31	77.5

Discussion

Growing individuals differ not only in the timing of the maturational events, but also inthe sequence of this events.[1]

Assessing maturational status, whether the pubertal growth spurt of the patient has beenreached or completed can have a considerable influence on interceptive diagnosis, treatment
goals, treatment planning, and the eventual outcome of orthodontic
treatment.2, 12, 13.

Stages of maturation can be identified by chronological age, sexual maturation characteristics, body height and weight, skeletal development, and dental development age 12, 4,14, 15, 16

Though there are various methods for the age determination, a universal system has not been achieved due to the varying differences in different ethnic populations.[17]

The purpose of the present study is to determine whether the stages of calcification of the mandibular canine could be correlated with the modified MP3 stages and cervical vertebrae maturation stages and also to know if this method of using the developmental stages of the mandibular canine using an intraoral periapical (IOPA) radiograph and standard X-ray machine alone could be used as a single reliable factor in assessing the skeletal maturity.

In the present study lateral cephalograms have been used as skeletal age has been considered the most reliable method to assess the developmental status.[1]

The CVM stages were interpreted according to Hassel and Farman[18] who have modified Lamparski's method and developed six stages of CVMI by using lateral profiles of 2nd, 3rd and 4th cervical vertebrae which significantly corresponded to 11 SMI values of Fishman.[19]

Another skeletal maturity indicator used in the present study is MP3 stages. Initially the hand wrist radiograph was considered to be the most standardized method of skeletal

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assessment.Assessment of skeletal maturation using hand wrist radiograph as an index based upon time and sequence of appearance of carpal bones and certain ossification events has been reported by many investigators.[10] The complete hand wrist radiograph involves 30 bones and assessment of these stages is one elaborate task which needs time and experience.[20] Hence, MP3 (Middle phalanx of third finger) stages, which is also as reliable as hand and wrist radiograph, have been used in this study to assess skeletal maturation or as an indicator of pubertal growth spurt according to Hagg and Taranger.[4]

Hagg and Taranger also stated that more information could be attained if maturation indicator is one of a series and of brief duration. Therefore, in the present study the development of the MP3 stages of the hand were evaluated using R. Rajagopal's observational scheme which is an modification of Hagg and Taranger's observational scheme[3] where they have added an additional bone stage between MP3 - H and MP3 - I, which they called the MP3 -HI stage.

But the disadvantages of using the routine methods to assess Mp3 stage by taking a hand wrist radiograph of skeletal maturity were that, they required elaborate equipments and the radiation exposure time(0.4sec) and dose were high(44 kVp, 45 mA)[20]. These conditions therefore put a question mark on ALARA principle.

Hence, simplified methods were used to record MP3 stages using standard size periapical radiographic films.

Later Abdel Kader (1998), stated that by using standard dental periapical radiograph anda standard dental x-ray machine a high degree clear radiograph is obtained by simple method which can be interpreted with ease and more importantly radiation exposure to child is also reduced(60kVp, 7 mA , exposure time: 0.25s).[8]

In the present study in order to further reduce the radiation exposure digital MP3 radiographs are used.

Tooth calcification is a more reliable indicator of dental maturity than eruption, that is the emergence of tooth from gingiva, because it is not affected by local factors such as loss of primary teeth, lack of space, malnutrition, dental decays, ankylosis, or orthodontic anomalies, and is instead much more genetically determined (Goldstein, 1973; Demirjian; Ogodescu et al., 2011; Shakuntala et al., 2011).

Many authors have developed scoring methods in order to asses dental age using dental calcification stages of permanent teeth but the most widely used dental maturity scaling system is the method developed by Demirjian in 1973 on a sample of French-Canadian children (Demirjian, Goldstein, 1973).[21] Due to its accuracy and feasibility in a developmental this method was chosen in the present study.[22]

Studies by Chertkow S and Coutinho S et al have shown that relationship between the stages of tooth mineralization of the mandibular canine appear to correlate better with pubertal growth spurt than the other teeth. So the stages of calcification of the mandibular canine might be used as a first level diagnostic tool to estimate the timing of the pubertal

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growth spurt.[23] So, due to the above mentioned reason the mandibular canine was used as the skeletal maturity indicator.

The results in the present study showed that there was an insignificant difference between chronological age and different skeletal maturity indicators used in this study in different age groups in both boys and girls. These results are in confirmation with the studies conducted by Shour and Masseler (1941)[25], Hunter (1966)[26], Bjork and Helm (1967)[27], Brown(1976)[28], Singer (1980)[29], Hagg and Taranger (1982)[4], Demirijian (1985)[24], Fishman(1994)[30], Kucukkelesand Acar (1999)[30]. Hence it can be inferred that chronological age cannot be used reliably for assessing skeletal maturity.

When CVM was compared with canine stages a high significant correlation was noticed.

These results are in confirmation with the study done by Sahar Taher (2001)[31]

When MP3 stages were compared with canine stages a high significant was noticed in all age groups in both males and females. These results are in confirmation with the studies done by It was also supported by Luterstein[32], Lewis and Garn[33], Sierra[34], Coutinho and Bushchang[35], Demirjian and Bushchang[36], Green[37].

Finally, the associations between CVM, MP3 and canine stages are obtained.

In boys, CVM stage 2 is associated with MP3 F and FG stage and canine stage E,F., CVM stage 3 is associated with MP3 G and H stage and canine stage G., CVM stage 5,6are associated with MP3 HI and I stage and canine stage H.

In girls, CVM stage 2 and 3 are associated with MP3 FG stage and canine stage F., CVM stage 4 is associated with MP3 H stage and canine stage G., CVM stage 5 is associated with MP3 H stage and canine stage H.

The stage E and stage F of mandibular canine calcification coincided with the MP3- F stage and CVM stage 2 indicating 65-80% of pubertal growth is remaining in the children. The stage G of mandibular canine calcification coincided with the MP3- G stage and CVM stage 3 indicating 25-65% of pubertal growth remaining in children. The stage H of mandibular canine calcification coincided with the MP3-I stage and CVM stage 6 indicating completion of pubertal growth spurt in children.

Conclusion

The correlation of canine calcification stages with MP3 stages and CVM stages is found to be of high statistical significance. The developmental stages of the mandibular canine could be used as a very reliable and as a sole indicator in assessing the skeletal maturity in children of Hyderabad population.

It was concluded that 65- 85% of pubertal growth remains in children with canine developmental stages E and F. 25-65% of pubertal growth remains in children with canine developmental stage G. Pubertal growth has been completed in children with the canine developmental stage H. And finally it can be concluded that the proposed method of assessing the skeletal maturity using digital radiography is a

simple, time saving, reliable as well as cost effective technique for the assessment of skeletal maturity at the same time reducing the radiation exposure to the child ensuring the safety.

REFERENCES:

1. Bala M, Pathak A, Jain RL. Assessment of Skeletal Age using MP3 and Hand-wrist Radiographs and its Correlation with Dental and Chronological Ages in Children. J IndianSoc Pedod Prevent Dent 2010; 28(2):95-9.
2. Krailassiri S, Anuwongnukroh N, Dechkunakorn S. Relationships between Dental Calcification Stages and Skeletal Maturity Indicators in Thai Individuals. Angle Orthod 2002; 72:155–166.
3. Rajagopal R, Kansal S. A Comparison of Modified MP3 Stages and the Cervical Vertebrae as Growth Indicators. J Clin Orthod 2002; 36: 398–406.
4. Hagg U, Taranger J. Maturation Indicators and the Pubertal Growth Spurt. Am J Orthod 1982; 82: 299-30.
5. Lee SS, Kim D, Lee S, Lee UY, Seo JS, Ahn YW. Validity of Demirjian's and modified Demirjian's Methods in age estimation for Korean juveniles and adolescents. Forensic Science International 2011; 211:41–6.
6. Nayak R, Nayak USK, Hegde G. Asessment of growth using mandibular canine calcification stages and its correlation with modified MP3 stages. Int J of Clin Pediatr Dent 2010; 3(1):27-33.
7. Panchbhai AS. Dental Radiographic Indicators, a Key to Age Estimation. Dento maxillofacial Radio 2011; 40:199–212.
8. Abdel-Kader HM**.** The Reliability of Dental X-ray Film in Assessment of MP3 Stages of Pubertal Growth Spurt. Am J Orthod Dentofacial Orthop 1998; 114:427–9.
9. Patel PS, Chaudhary AR, Dudhia BB, Bhatia PV, Soni NC, Jani YV. Accuracy of two dental and one skeletal age estimation methods in 6-16 year old Gujarati children. J Forensic Dent Sci. 2015 Jan-Apr;7(1):18-27.
10. Garcia FP, Torre H, Flores L, Rea J. The cervical vertebrae as maturational indicators. J Clin Orthod. 1998;32:221–5.
11. Mittal S, Singla A, Virdi M, Sharma R, Mittal B. Co-relation between determination of skeletal maturation using cervical vertebrae and dental calcification stages. J Forensic Sci 2011 Mar;4(1):1-8.
12. Hegde G, Hegde N, Kumar A, Keshavaraj. A new system for assessment of growth using mandibular canine Calcification stages and its correlation with modified MP3stages. JPharm Bioallied Sci. 2014 Jul;6(1):58-63
13. Pearson LE. Vertical control in treatment of patients having backward-rotational growthtendencies. Angle Orthod. 1978 Apr;48(2):132-40.
14. Singer J. Physiologic timing of orthodontic treatment. Angle Orthod. 1980 Oct;50(4):322-33.
15. Bjork A, Helm S. Prediction of the age of maximum pubertal growth in body height. Angle Orthod. 1967 Apr;37(2):134-43.
16. Demirjian A, Buschang PH, Tanguay R, Patterson DK. Interrelationships among measures of somatic, skeletal, dental, and sexual maturity. Am J Orthod. 1985 Nov;88(5):433-8.
17. Hegde DY, Baliga S, Yeluri R, Munshi AK. Digital radiograph of the middle phalanx of the third finger (MP3) region as a tool for skeletal maturity assessment.Indian J Dent Res.2012 Jul-Aug;23(4):447-53.
18. Hassel B**.** Skeletal maturation evaluation using cervical vertebrae. Am J Orthod. Dentofac Orthop. 1995 Jan;107(1):58-66.
19. Fishman LS. Radiographic evaluation of skeletal maturation. A clinically orientedmethod based on hand-wrist films. Angle Orthod.

1982 Apr;52(2):88-112.

20. Mahajan S. Evaluation of skeletal maturation by comparing the hand wrist radiograph and cervical vertebrae as seen in lateral cephalogram. Indian J Dent Res. 2011 Mar-Apr;22(2):309-16.

21. Demirjian A, Goldstein H, Tanner JM. A new system of dental age assessment. Hum Biol. 1973 May;45(2):211-27.

22. Anamaria J, Luminita L, Mariana P, Cristina B, Manuela C, Eugen B. Dental age assessment using Demirjian's method – a radiographic study. Eur Sci J. 2014 Dec;10(4):51-60.

23. Chertkow S, Fatti P. The relationship between tooth mineralization and early radiographic evidence of the ulnar sesamoid. Angle Orthod. 1979 Oct;49(4):282- 8.

24. Demirjian A, Goldstein H, Tanner JM. A new system of dental age assessment. Hum Biol. 1973 May;45(2):211-27.

25. Bhanat S, Patel D. Dental & skeletal maturity indicators of chronological age: radiographic evaluation amongst children in Gujarat, India. 2013 May-Jun;6(4):6- 12.

26. Litsas G, Ari-Demirkaya A. Growth indicators in orthodontic patients. Part 1:comparison of cervical vertebral maturation and hand-wrist skeletal maturation. Eur J Paediatr Dent. 2010 Dec;11(4):171-5.

27. Hunter CJ. The correlation of facial growth with body height and skeletal maturation at adolescence. Angle Orthod. 1966 Jan;36(1):44-54.

28. Grave KC, Brown T. Skeletal ossification and the adolescent growth spurt. Am JOrthod. 1976 Jun;69(6):611-9.

29. Lauterstein AM. A cross-sectional study in dental development and skeletal age. J Am Dent Assoc. 1961 feb;62:161-7.

30. Kamal M, Ragini, Goyal S. Comparative evaluation of handwrist radiographs with cervical vertebrae for skeletal maturation in 10-12 years old children. J IndianSoc Pedod Prev Dent. 2006 Sep;24(3):127-35.

31. Malik P, Rana V, Rehani U. To evaluate the relationship between mandibular canine calcification stages and skeletal age. Int J Clin Pediatr Dent. 2012 Jan;5(1):14-9.

32. Lewis AB. The relationship between tooth formation and other maturational factors. Am J Orthod Dentofac Orthop. 1960 Apr;30(2):70-7

33. Sierra AM. Assessment of dental and skeletal maturity. Am J Orthod Dentofac Orthop. 1987 Jul;57(3):194-208.

34. Larry JG**.** The interrelationships among height, weight and chronological, dental and skeletal ages. Am J Orthod Dentofacial Orthop. July 1961 Jul;31(3):189-93.

35. Baccetti T, Franchi L, McNamara JA. An improved version of the cervical vertebral maturation (CVM) method for the assessment of mandibular growth.Angle Orthod. 2002 Aug;72(4):316-23.

36. Gabriel DB, Southard KA, Qian F, Marshall SD, Franciscus RG, Southard TE. Cervical vertebrae maturation method: poor reproducibility. Am J Orthod Dentofacial Orthop. 2009 Oct;6(4):478-80.

37. Baccetti T, Franchi L, Toth LR, McNamara JA. Treatment timing for Twin blocktherapy. Am J Orthod Dentofacial Orthop. 2000 Aug;118(2):159-70.