Mandibular Canine Calcification Stages as an Indicator of Skeletal Maturity

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INTRODUCTION

The emphasis of orthodontics has undergone a major shift in the past 60 years. Our profession now recognizes that a face-conscious society needs more than merely looking at the molars and moving the teeth in front of them to achieve optimal results. Orthodontic speciality has widened to a spectrum wherein the correction of skeletal malrelationship is also incorporated.

Maturational stage of individual has significant influence on orthodontic treatment modalities and outcome. Major clinical decisions such as those regarding use of extraoral or myofunctional forces, extraction or nonextraction treatment are at least, in part, founded on growth status of individual. Growth prediction has been a controversial topic ever since it was advocated by Ricketts. Occasionally, when a precise evaluation of adolescent growth status is needed, a radiograph of the hand and wrist showing the patient’s age of bone ossification has been traditionally recommended.

One area of craniofacial growth, which is of considerable interest to dentist, is the development of the dentition and associated structures. But our knowledge of the relationship between the skeletal and dental maturation is limited. Studies have generally shown low correlations between dental development and other parameters of physical development. However, likelihood of significant correlation between stages of canine development and pubertal growth spurt is higher when compared to any other dental parameter. So the stages of calcification of mandibular canine can be used as a tool to estimate growth status of individual. Unfortunately, racial and
ethnic variations exist in the timing of calcification of this tooth like other parameters of development. May be changed to - as with any parameter of development, racial and ethnic variations do exist in the calcification of canine. The purpose of this study was to ascertain whether the stages of calcification of mandibular canine correlate with skeletal maturity in Malabar population using panoramic radiograph and handwrist X-rays, respectively.

**MATERIALS AND METHODS**

This particular study was conducted in the Department of Orthodontics, Sree Anjaneya Dental College, Calicut. Study was based on the comparison of handwrist radiograph and orthopantomographs (OPGs) of the children of both sexes. The sample consisted of 50 males and 50 females aged between 8 and 15 years [Tables 1-3]. The study subjects were randomly selected from the patients visiting the Department of Orthodontics and Pedodontics, mainly seeking orthodontic treatment and some already undergoing orthodontic treatment.

Two radiographs namely OPG and handwrist radiograph were required for this study. Majority of the samples were taken from the already-existing diagnostic records. For fresh samples, consent form signed by the parents of patient was obtained prior to the study. Ethics committee approval was also obtained prior to the commencement of the study.

Handwrist X-rays taken from the left hand of the selected patients. During this procedure, hands are placed in a palm down manner. Patients were asked to slightly separate the fingers, and to place the axis of the handwrist and forearm in a straight line. All the X-rays were taken using the same machine (Planmeca 2002 CC Proline, 25 Haoren st. Haifa Israel, Israel) in the Department of Oral Medicine and Radiology, Sree Anjaneya Dental College, Calicut under standardized procedure. Exposure parameters were 72 kVp, 10 mA, and 1.2s. High-quality good contrast radiographs were used.

The records with subjects name, age, and sex were first evaluated by the author using X-ray viewer as per the methods detailed below.

Skeletal age was determined from handwrist radiographs based on the method introduced by Fishman,[1] The system was introduced in 1982. This system used only four-stage skeletal maturation; all can be found at six anatomical sites in handwrist X-ray. The sites are on the thumb, third fingers, fifth fingers, and radius. The sequence of four ossification stages progresses in the following manner: epiphyseal widening on selected phalanges, followed by the ossification of adductor sesamoid of thumb, which is followed by the capping of selected epiphysis over their diaphysis and then the fusion of the same. Widening of epiphyses relative to diaphysis is a progressive process. The epiphysis first appears as a small ossification center centrally located in the diaphysis. When it has developed laterally to the width of diaphysis, it is considered applicable as a skeletal maturational indicator in this system. Capping occurs in the transition between initial widening and fusion of epiphyses and diaphysis. It is the stage in which the round lateral margin of epiphyses begins to flatten and point toward the diaphysis, with an acute angle on the side facing the diaphysis. The time of first appearance of capping is applicable as skeletal maturity indicator (SMI).

Fusion between epiphysis and diaphysis follows capping. It also begins centrally and progresses laterally until the two formally separate bones become one. The time of completion of this fusion with a smooth continuity of the surface of the junction area is applicable as SMI.

Ossification of adductor sesamoid of the thumb first appears as a small relatively round center of ossification medial to the junction of epiphysis and diaphysis of the proximal phalanx. It then becomes progressively larger and denser. It is the first observation of the existence of

| Table 1: Frequency table-Sex |
|-----------------------------|
|                      | Frequency | Percent | Valid percent | Cumulative percent |
| F                     | 50        | 50.0    | 50.0          | 50.0               |
| M                     | 50        | 50.0    | 50.0          | 100.0              |
| Total                 | 100       | 100.0   | 100.0         |                    |

| Table 2: Frequency table-Age |
|-----------------------------|
|                      | Frequency | Percent | Valid percent | Cumulative percent |
| 8.00                  | 3         | 3.0     | 3.0           | 3.0                 |
| 9.00                  | 8         | 8.0     | 8.0           | 11.0                |
| 10.00                 | 5         | 5.0     | 5.0           | 16.0                |
| 11.00                 | 15        | 15.0    | 15.0          | 31.0                |
| 12.00                 | 18        | 18.0    | 18.0          | 49.0                |
| 13.00                 | 31        | 31.0    | 31.0          | 80.0                |
| 14.00                 | 16        | 16.0    | 16.0          | 96.0                |
| 15.00                 | 4         | 4.0     | 4.0           | 100.0               |
| Total                 | 100       | 100.0   | 100.0         |                    |

| Table 3: Group statistics |
|---------------------------|
| Sex | N  | Mean | Std. deviation | Std. error mean |
|-----|----|------|----------------|-----------------|
| Age |    |      |                |                 |
| male| 50 | 12.2800 | 1.61675         | .22864          |
| female| 50 | 12.0000 | 1.77281         | .25071          |
this bone that is considered applicable as an SMI. This occurs after the SMIs based on epiphyseal widening, but before those based on capping. The individual maturity indicators are listed below in chronological order [Figure 1].

SMI 1: Third finger proximal phalanx—epiphysis and diaphysis equal width
SMI 2: Third finger middle phalanx—epiphysis and diaphysis equal width
SMI 3: Middle phalanx of fifth finger—epiphysis and diaphysis equal width
SMI 4: Appearance of adductor sesamoid of the thumb.
SMI 5: Distal phalanx of third finger—capping of epiphysis
SMI 6: Middle phalanx of third finger—capping of epiphysis
SMI 7: Middle phalanx of fifth finger—capping of epiphysis
SMI 8: Distal phalanx of third finger—fusion of epiphysis and diaphysis
SMI 9: Proximal phalanx of third finger—fusion of epiphysis and diaphysis.

The mean of the skeletal age assigned to each maturity indicator was then calculated and this value was the skeletal age assigned to that film. Two other orthodontists also assess the skeletal maturity to reduce the observer bias. The development of mandibular canine was assessed according to Demirjian’s stages of Dental Calcification. The stages ascribed to teeth in this study ranged from C to H. Each of these stages may be recognized by the following criteria [Figure 2]:

Stage C: Enamel formation has been completed at the occlusal surface and dentine formation has commenced. Also the pulp chamber is curved and no pulp horns are visible.

Stage D: Crown formation has been completed to the level of amilocemental junction. Root formation has commenced. The pulp horns are beginning to
differentiate. But the walls of pulp chamber remain curved.

Stage E: The root length remains shorter than the crown height. The walls of pulp chamber are straight, and the pulp horns have become more differentiated than in the previous stage.

Stage F: The walls of the pulp chamber now form an isosceles triangle and the root length is equal to or greater than the crown height.

Stage G: The walls of the root canal are now parallel, but the apical end is partially opened.

Stage H: The root apex is completely closed.

**Statistical analysis**

The relationship between canine calcification stages and skeletal maturity index were assessed using chi-square.

**Statistical software**

Data were analyzed using statistical software SAS 9.2, SPSS 15.0, Armonk, New York, Stata 10.1, MedCalc 9.0.1, Armonk, New York, SYSTAT 12.0, Armonk, New York, and R Environment version 2.11.1, Armonk, New York. Graphs and tables were generated using Microsoft Office Word and Excel, Redmond, Washington.

**Results**

[Table 4] shows tabulation between calcification of canine stages and skeletal maturity index as the number of canine stages valid was only 5, with such a sample size it was not possible to compare with 11 handwrist stages. So handwrist stages were divided into three groups.

1–3: in this group, epiphysis shows equal width of diaphysis—it signifies the prepubertal stage.

4–6: in this group, initial calcification of adductor sesamoid and capping of diaphysis with epiphysis occurs—it signifies the pubertal acceleration.

7–11: in this group, epiphysis fuses with diaphysis—it signifies deceleration of growth. All of these stages showed statistically significant correlation ($P < 0.001$).

Table 5 shows cross-tabulation between calcification of canine stages and skeletal maturity index for males.

**Table 4: Cross-tabulation between calcification of canine stages and skeletal maturity index**

| Canine stage | Handwrist | Total |
|--------------|-----------|-------|
|              | 1–3 | 4–6 | 7–11 | 100 |
| Canine stage D count | 1 | 0 | 0 | 1 |
| % within canine stage | 100.0% | 0.0% | 0.0% | 100.0% |
| % within handwrist | 3.0% | 0.0% | 0.0% | 1.0% |
| % of total | 1.0% | 0.0% | 0.0% | 1.0% |
| Canine stage E count | 10 | 0 | 0 | 10 |
| % within canine stage | 100.0% | 0.0% | 0.0% | 100.0% |
| % within handwrist | 30.3% | 0.0% | 0.0% | 10.0% |
| % of total | 10.0% | 0.0% | 0.0% | 10.0% |
| Canine stage F count | 22 | 10 | 0 | 32 |
| % within canine stage | 68.8% | 31.3% | 0.0% | 100.0% |
| % within handwrist | 66.7% | 27.8% | 0.0% | 32.0% |
| % of total | 22.0% | 10.0% | 0.0% | 32.0% |
| Canine stage G count | 0 | 25 | 4 | 29 |
| % within canine stage | 0.0% | 86.2% | 13.8% | 100.0% |
| % within handwrist | 0.0% | 69.4% | 12.9% | 29.0% |
| % of total | 0.0% | 25.0% | 4.0% | 29.0% |
| Canine stage H count | 0 | 1 | 27 | 28 |
| % within canine stage | 0.0% | 3.6% | 96.4% | 100.0% |
| % within handwrist | 0.0% | 2.8% | 87.1% | 28.0% |
| % of total | 0.0% | 1.0% | 27.0% | 28.0% |
| Total count | 33 | 36 | 31 | 100 |
| % within canine stage | 33.0% | 36.0% | 31.0% | 100.0% |
| % within handwrist | 100.0% | 100.0% | 100.0% | 100.0% |
| % of total | 33.0% | 36.0% | 31.0% | 100.0% |

**Chi-square test**

| Value | df | Asymp. Sig (two sided) |
|-------|----|------------------------|
| Pearson chi-square N of valid cases | 133.578 | 8 | $P < .001$ |
Table 5: Cross-tabulation between calcification of canine stages and skeletal maturity index for males

| Canine stage D count | Handwrist | Total |
|----------------------|-----------|-------|
| % within canine stage | 100.0%    | 0.0%  | 0.0%  | 100.0% |
| % within handwrist   | 4.2%      | 0.0%  | 0.0%  | 2.0%   |
| % of total           | 2.0%      | 0.0%  | 0.0%  | 2.0%   |

| Canine stage E count | Handwrist | Total |
|----------------------|-----------|-------|
| % within canine stage | 100.0%    | 0.0%  | 0.0%  | 100.0% |
| % within handwrist   | 16.7%     | 0.0%  | 0.0%  | 8.0%   |
| % of total           | 8.0%      | 0.0%  | 0.0%  | 8.0%   |

| Canine stage F count | Handwrist | Total |
|----------------------|-----------|-------|
| % within canine stage | 73.1%     | 26.9% | 0.0%  | 100.0% |
| % within handwrist   | 79.2%     | 35.0% | 0.0%  | 52.0%  |
| % of total           | 38.0%     | 14.0% | 0.0%  | 52.0%  |

| Canine stage G count | Handwrist | Total |
|----------------------|-----------|-------|
| % within canine stage | 0.0%      | 92.9% | 7.1%  | 100.0% |
| % within handwrist   | 0.0%      | 65.0% | 16.7% | 28.0%  |
| % of total           | 0.0%      | 26.0% | 2.0%  | 28.0%  |

| Total count          | Handwrist | Total |
|----------------------|-----------|-------|
| % within canine stage | 48.0%     | 40.0% | 12.0% | 100.0% |
| % within handwrist   | 100.0%    | 100.0%| 100.0%| 100.0% |
| % of total           | 48.0%     | 40.0% | 12.0% | 100.0% |

Chi-square test

| Pearson chi-square N of valid cases | Value | df | Asymp. sig (two sided) |
|-------------------------------------|-------|----|------------------------|
|                                     | 66.495| 8  | P < .001               |

Table 6: Cross-tabulation between calcification of canine stages and skeletal maturity index for females

| Canine stage E count | Handwrist | Total |
|----------------------|-----------|-------|
| % within canine stage | 100.0%    | 0.0%  | 0.0%  | 100.0% |
| % within handwrist   | 66.7%     | 0.0%  | 0.0%  | 12.0%  |
| % of total           | 12.0%     | 0.0%  | 0.0%  | 12.0%  |

| Canine stage F count | Handwrist | Total |
|----------------------|-----------|-------|
| % within canine stage | 50.0%     | 50.0% | 0.0%  | 100.0% |
| % within handwrist   | 33.3%     | 18.8% | 0.0%  | 12.0%  |
| % of total           | 6.0%      | 6.0%  | 0.0%  | 12.0%  |

| Canine stage G count | Handwrist | Total |
|----------------------|-----------|-------|
| % within canine stage | 0.0%      | 80.0% | 20.0% | 100.0% |
| % within handwrist   | 0.0%      | 75.0% | 12.0% | 30.0%  |
| % of total           | 0.0%      | 24.0% | 6.0%  | 30.0%  |

| Canine stage H count | Handwrist | Total |
|----------------------|-----------|-------|
| % within canine stage | 0.0%      | 4.3%  | 95.7% | 100.0% |
| % within handwrist   | 0%        | 6.3%  | 88.0% | 46.0%  |
| % of total           | 0%        | 2.0%  | 44.0% | 46.0%  |

| Total count          | Handwrist | Total |
|----------------------|-----------|-------|
| % within canine stage | 18.0%     | 32.0% | 50.0% | 100.0% |
| % within handwrist   | 100.0%    | 100.0%| 100.0%|
| % of total           | 18.0%     | 32.0% | 50.0% | 100.0% |

Chi-square test

| Pearson chi-square N of valid cases | Value | df | Asymp. sig (two sided) |
|-------------------------------------|-------|----|------------------------|
|                                     | 69.777a| 6  | P < .001               |
Table 6 shows cross-tabulation between calcification of canine stages and skeletal maturity index for females.

Table 7 shows comparison between mandibular canine calcification stages and individual anatomic sites for males.

Table 8 shows comparison between mandibular canine calcification stages and individual anatomic sites for females.

**Males**

Adductor sesamoid—except in stage F similarity is 100%, and for F it is 73%.

Third proximal phalanx—all stages show 100% similarity.

Third middle phalanx—stage E shows 75%, stage F 53.8%, stage G 92.8%, and stage H 80% similarity of occurrence.

Third distal phalanx—stages D, H, and E show 100% similarity and stage G shows 92.8% similarity.

Fifth middle phalanx—stages D and H show 100% similarity and stage F shows 96% similarity but stage G shows only 50% similarity.

**Females**

Adductor sesamoid—stages E, G, and H show 100% similarity, whereas stage F shows only 50% similarity.

Third proximal phalanx—stages E and F show 100%, stage G 93.3%, and stage H 82.6% similarity of occurrence.

Third middle phalanx—stage E shows 83.3%, stage F 50%, stage G 93.3%, and stage H 69.5% similarity of occurrence.

Third distal phalanx—stages D and E show 100%, stage F 50%, stage G 80%, and stage H 69.5% similarity of occurrence.

Fifth middle phalanx—stage F shows 83.3%, stage G 93.3%, and stage H 100% similarity of occurrence.

**DISCUSSION**

Evaluation of growth potential and determination of maturation are critical factors in orthodontic practice. In certain situations, the entire treatment plan may depend on the growth potential of individual patient. In adolescent patient with skeletal deviations, growth evaluation has paramount importance.

As a result of American Association of Orthodontists (AAO)’s current recommendation[2] for first orthodontic consultation at 7 years of age and the amount of interest professionals and public have on early treatment, orthodontists will have to see a large number of young patients. Chronological age is of little value when
compared with indicators of developmental age as far as growth potential of individual in concerned. Four systems are commonly used to determine physiological maturity. They are morphological age, skeletal age, dental age, and secondary sexual characters.

Bone age has been traditionally used to determine growth status of individuals. In orthodontic practice, evaluation of bone age necessitates an additional radiograph known as handwrist radiograph. A significant number of literatures showing correlation between dental maturity and bone age have been reported. However, dental age that is influenced by environmental factors is of limited value as a maturity indicator.

Interestingly, correlation between calcification stages of individual teeth and skeletal maturity have also been previously reported. Garn et al. showed only weak correlation between skeletal development and third molar calcification. When relationship between stages of mineralization various teeth and skeletal maturity compared, mandibular canine appears to tops the list. The contemporary paradigm of evidence-based clinical practice mandates research to bolster clinical protocols.

This study was conducted to verify the relationships between mandibular canine calcification stages and skeletal maturity. In current situation, panoramic radiograph is considered as essential diagnostic aid and lateral cephalogram is considered only when necessary. Limited standardization of panoramic radiograph as used in this study is still an inherent lacunae. But in our study we use Demirjian's index, which focuses the objective criteria rather than the absolute length and proportions. In this study, the radiograph of the handwrist has been used the reason being that many centers are available in this part of skeleton and they undergo changes at different times and rates, so it is considered as the gold standard of the skeletal maturity evaluation.

In this study, author was not able to follow uniform distribution of ages due to limited sample size. The maximum number of samples belonged to age 13 and minimum age 8. The reason for this uneven distribution is that most of the radiographs were taken from already-existing records where in lower age group samples were comparatively less, as our society does not seek orthodontic treatment much early.

For females, the canine stage E shows 100% similarity to first group (prepubertal) period. But canine stage F shows only limited reliability, for canine stage G there is >80% reliability and canine stage H shows >95% reliability to completion of puberty. In the studies conducted by Chertkow, Coutinho et al., Vijayalakshmi and Sathiasekar, almost all stages showed positive correlation. In the Chertkow’s study, the similarity in prepubertal period was 100%, in circumpubertal period 78%, and in declaration stages >90%. This study was altogether in agreement with our study.

Similarly for males, canine stages D and E show 100% similarity to prepubertal period. For canine stage F, it shows 73% similarity, which is higher than females. Canine stages G and H show similarity in the range of 93% and 100%, respectively. This was in agreement with the study conducted by Coutinho et al. In the Chertkow’s study, the similarity in prepubertal period was 100%, in circumpubertal period 77%, and in deceleration stages >90%. This study was altogether in agreement with our study.

Even among the studies, which reported low correlation between dental maturity and skeletal maturity, calcification stages of mandibular canines appear to be more closely related to peak high velocity (PHV) than any other teeth. The higher association found in this particular study may therefore be attributed to the use of mandibular canine instead of composite dental units. From this study, it becomes clear that the relationship between tooth calcification stages of mandibular canine and the SMIs is strong and this probably gives the opportunity for clinician to use easily available panoramic radiograph, which is a must in orthodontist diagnostic tool for identifying the stages of pubertal growth period. Evaluation of tooth root area will be more expedient for a dental clinician than epiphysis diaphysis area. The unequivocally identifiable dental developmental stages together with ubiquitous availability of intraoral or panoramic radiographs in most orthodontic or pediatric dental practice are good reasons for attempting to gauge physiologic maturity using mandibular canine calcification stages.

**Conclusion**

On analyzing the result, the following conclusions were drawn:

Calcification stages of mandibular canine can be used as a method for skeletal maturity assessment. The correlations of mandibular canine calcification to initiation and deceleration stages were very strong. But in circumpubertal period it was relatively less, but still it was statistically significant. The canine stages D and E correlate well with initiation. Occurrences of stage G coincide with the capping of the third, middle, and proximal phalanxes and ossification of adductor sesamoid (it is indicative of PHV). Stage H correlates
well with deceleration. Stage F shows only limited correlation. Mandibular canine calcification stages can be recommended as a supplemental diagnostic aid. Similar studies may be conducted in different population to rule out any possible racial and regional influences on growth characteristics.

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Conflicts of interest
There are no conflicts of interest.

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