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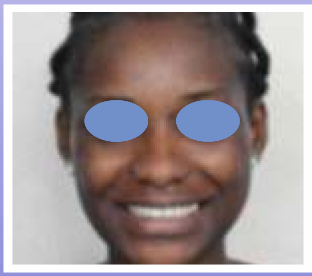

Dental calcification and cervical vertebrae maturation

Transverse occlusal discrepancy in Orthodontic patients

Psychological impact of malocclusion

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Relationship between Dental Calcification and Cervical Vertebrae Maturation in a Nigerian population

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Abstract

Background: This study aimed to determine the relationship between dental calcification and cervical vertebrae maturation in a Nigerian population.

Methods: The material consisted of lateral cephalometric and panoramic radiographs of 336 children aged 5 to 18 years (153 males and 183 females). Dental calcification stages were determined using panoramic radiographs according to the method described by Demirjian, while the stages of cervical vertebrae maturation were determined using lateral cephalometric radiographs and the method described by Baccetti et al.,(2005). Standard descriptive analyses were computed for chronological and dental ages concerning cervical vertebrae maturation stages. Spearman rank order correlations were performed to determine the associations between dental calcification stages and cervical vertebrae maturation stages.

Results: Good correlations ranging from 0.475 to 0.743 were observed between dental calcification stages and cervical vertebrae maturation stages. The tooth most highly correlated with cervical vertebrae maturation was the mandibular second molar in both genders. Females were more advanced in chronological age, dental age, and skeletal maturity than males.

Conclusion: This study suggests that dental calcification stages may be used as a preliminary measure in the determination of skeletal maturity.

ORIGINAL ARTICLE

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Introduction

Growth in humans is characterized by a significant variation in the rate of progress in different persons toward physiologic maturity.[1] It is one of the most variable events in nature playing an important role in the aetiology of malocclusion, evaluation, diagnosis, treatment plan, retention, and stability of any case.[1-4] Timing of treatment in orthodontics and dentofacial orthopaedics is as important as the selection of the specific treatment protocol.[5] It is therefore essential for the orthodontist to have an understanding of growth events to harness its potential advantages. During growth, all bones go through a sequence of changes, which can be seen radiographically.[4,6] This is referred to as skeletal maturity, which is the degree of ossification in bone. This sequence of changes is relatively constant for each given bone in each person.[4,6,7] Hassel and Farman[6] observed that though the timing of changes may vary as a result of each person's biologic clock, the events are mostly reproducible enough to allow a basis for comparison. Baccetti *et al*.[4] further stated that optimal timing for dentofacial orthopaedic treatment is connected to the identification of periods of accelerated growth. These periods of intense growth, identified as growth spurts, can contribute greatly to the correction of skeletal imbalances in individual patients.[4,8] Mandibular skeletal maturity has been assessed through various biologic indicators including an increase in body height, weight, skeletal development, dental development and eruption, chronological age, sexual maturation characteristics, and cervical vertebrae maturation.[6,9-19] The ability to evaluate skeletal maturation and predict mandibular growth peak from routinely obtained diagnostic lateral cephalometric radiographs through the assessment of cervical vertebrae maturation has the potential to eliminate the need for hand and wrist radiographs thus saving the patient the additional cost and exposure to radiation.[20] In addition the routine use of hand and wrist radiographs has lately been questioned from the radiation-hygiene-safety point of view.[21] Dental maturity on the other hand can be determined by the stage of tooth eruption or by the stage of tooth formation.[22,23] Various studies have however shown that tooth formation is a more reliable indicator of dental maturity than tooth eruption.[23-25] Knowledge of dental and skeletal age may be useful in determining treatment timing for orthodontic cases. In persons with delayed dental maturity, treatment may be deferred and commenced at a later stage resulting in shorter treatment time and more stable results.[26] The ease of recognition of dental developmental stages and the availability of periapical or panoramic radiographs in most orthodontic dental practices are practical reasons for attempting to assess dental maturity.[23] This is especially important in a developing continent where cost is a major consideration. The ability to determine ideal treatment timing from a panoramic radiograph would be of immense value to dental practitioners. The purpose therefore of the present study was to determine the correlation between dental calcification and cervical vertebrae maturation in a group of Nigerian orthodontic patients. If a strong correlation exists between cervical vertebrae maturation and dental calcification stages then the stages of dental calcification may be used as a first-level diagnostic tool in the estimation of the timing of the adolescent growth spurt and consequently ideal treatment time in Nigerian children.

Materials and Methods

The study was of a retrospective cross-sectional design and the material consisted of the panoramic and lateral cephalometric radiographs of 336 children (153 males and183 females) aged 5 to18 years. The data was taken from previous records of patients who had attended the Orthodontic Clinic of the Lagos University Teaching Hospital, Lagos from 2008 to 2013; six years. Inclusion criteria were the following: (1) All subjects of Nigerian ancestry; (2) all subjects aged between 5 and 18 years; (3) both lateral cephalometric and panoramic radiographs available with high clarity and good contrast, (4) all permanent teeth present on radiographs except for third molars and (5) no previous orthodontic treatment. Subjects with anomalies of the dentition and cervical vertebrae were excluded from the study. Chronological ages were computed by deducting the birth date of each subject from the date the radiograph was taken with the obtained value noted in years and decimal points. Utilizing the panoramic radiographs a single investigator (AA) determined the stages of dental maturity of the mandibular left seven permanent teeth for each subject using the method described by Demirjian.[14] Blinding to the ages of the subjects was done to eliminate bias. The eight-grade scale described by Demirjian was used to stage the teeth. Each tooth was assigned an appropriate numeric value representing the developmental stage using standard tables. These were then summed up giving the dental maturity score. This was used to determine the dental age as derived from standard tables for males and females respectively. On the lateral cephalometric radiographs cervical vertebrae C2, C3, and C4 were assessed (these are the vertebrae that can be seen when a patient has a protective thyroid collar on). Both visual and cephalometric analyses were performed as described by Baccetti *et al*.[5] and cervical vertebrae maturation stages were determined accordingly.

Statistical analysis

All statistical analyses were carried out using Epi-info version 7.1.0.6 (2012) software. Descriptive statistics (mean and standard deviations) of the chronological and dental ages of the subjects for the particular cervical stages of skeletal maturity were calculated, taking gender into consideration. Student's t-test was used to assess the differences in the mean between the two groups. Direct relationships between dental calcification stages and cervical vertebrae maturation stages were determined by computing the percentage distribution of dental development stages in subsequent cervical vertebrae maturation stages taking gender into account. Each tooth calcification stage was also correlated to the overall cervical vertebrae maturation stage. Spearman rank order correlation coefficients were run to measure the association between the cervical stages and dental calcification stages of all analyzed teeth. P values were calculated and $P<0.05$ was set as the level of statistical significance.

Results

Figure 1 shows the gender distribution and frequency of subjects in the different cervical vertebrae maturation (CVM) stages. CVM stage 1 was the most frequently occurring in both genders and was seen on average in over 40% of the subjects, at chronologic mean age group 9.1±2.0 years in females and 10.1 ±2.0 years in males (Table 1). Cervical stage 3, the stage where the pubertal growth spurt is expected to occur, was found on average in only 10% of the subjects (Figure 1) at chronologic age 11.4±2.1years in females and 11.9±2.0 years in males (Table 1).

The mean and standard deviations of both chronological and dental ages by CVM stage are shown in Table 1. Chronological and dental ages showed a high correlation in both males (r=0.863, P=0.00) and females (r=0.896, P=0.00) Table 2. Separate evaluations of the cervical stages showed that all correlations were statistically significant except in females at CVMS6 (P=0.496). This was also similar in males, where all correlations were statistically significant except in CVMS5 (P=0.957) and CVMS6 which could not be recorded (Table 3). The strongest correlation between chronologic and dental ages, in females, was observed in CVM stage 2 (r = 0.86) while for males the strongest correlation was recorded in CVM stage 1 (r = 0.86) both of which demonstrated the statistical significance of P=0.000. Conversely the lowest correlation was for CVMS6 in females (r=0.262, P=0.496) and CS5 (r=0.033, P=0.957) in males. The appearance of each CVM stage was consistently earlier in female subjects than in the male subjects using both chronological and dental ages. There was also a consistently earlier occurrence for each skeletal maturation stage in females (about 10 months). However, in males, no definite pattern was observed (Figure 2). All correlations between CVM stages and dental developmental stages of the teeth studied were statistically significant at $P < 0.05$ significance level using Spearman rank correlation coefficients (Table 4). The ranges for males and females were R = 0.186-0.485 and R =0.275-0.743 respectively. The tooth which showed the strongest relation to the CVM stage was the mandibular second molar in both males and females with R = 0.485 and R = 0.743 respectively. The teeth which showed the weakest correlations were the mandibular central incisor in females with R = 0.275 and the lateral incisor in males with R = 0.186.

The order of teeth as concerns increasing correlation with the CVM stage in males was the lateral incisor (R = 0.186), central incisor (R = 0.229), first molar (R = 0.239), canine (R = 0.423), first premolar (R = 0.456), second premolar (R= 0.477) and second molar (R = 0.485). The sequence varied marginally for females: central incisor (R = 0.275), lateral incisor (R = 0.395), first molar (R = 0.473), canine (R = 0.689), second premolar (R= 0.720), first premolar (R = 0.737) and the second molar (R = 0.743) (Table 4). The percentage distribution of dental developmental stages was calculated for the canines, first premolars, second premolars, and second molars (Table 5). The central incisors, lateral incisors, and first molars were excluded from the analysis as they showed the weakest correlation with CVM in this current study.

The most frequently observed dental development stage in CVM stage 1 was stage C in second molars (46.2%) in males and stage F in canines in both males (34.2%) and females (44.4%). In CVM stage 2 the most frequently observed stages in females were stages F for the canines (57.9%) and stages E for the second premolars (57.9%) and second molars (47.4%). In the males, stage E of the second premolar (38.9%) was the most predominant developmental stage. CVM stage 3 was accompanied by stages F for both the second premolar (58.8%) and the first premolar (52.9%) in females while 50% of the males exhibited stage H in both the canines and the first premolars indicating full development of these teeth. Stage H was the most predominant dental developmental stage in CVM stage 4, occurring in the first premolar in 68.8% of females and 59.1% of males, except in the second molars where stage G was most predominant with 45.5% in males and 43.8% in females. By CVM stage 5 most of the teeth assessed had achieved dental developmental stage H. All the male subjects studied exhibited stage H in the first premolar, second premolar, and second molar but only 60% of the canines had reached this stage. In females, 88.9% had achieved stage H in the canines at this stage but only 55.6% had achieved this stage in the second molar. In over 95% of the subjects studied, the final stage of dental development of the canines, first premolars, second premolars, and second molars had been accomplished by CVM stage 6. Stage G developmental stage of the second premolar was however still exhibited by 22.2% of the females.

Table 1: Mean chronological age and dental age by CVM stage

CVM Stage	Mean Chronologic age (years)			Mean Dental age (years)		
	Male n = 153	Female n = 183	Overall n = 336	Male n = 153	Female n = 183	Overall n = 336
1	10.1 ± 2.0	9.1 ± 2.0	9.7 ± 2.1	11.0 ± 2.4	9.8 ± 2.0	10.5 ± 2.3
2	11.3 ± 2.2	9.3 ± 1.3	10.4 ± 2.1	11.6 ± 2.5	10.3 ± 1.7	11.1 ± 2.4
3	11.9 ± 2.0	11.4 ± 2.1	11.7 ± 2.0	13.5 ± 2.5	12.3 ± 1.6	12.9 ± 2.2
4	13.8 ± 2.5	12.9 ± 1.9	13.2 ± 2.1	13.9 ± 2.2	13.7 ± 1.8	13.7 ± 2.0
5	16.1 ± 0.3	13.9 ± 1.9	14.2 ± 1.9	15.9 ± 0.2	14.7 ± 1.5	14.9 ± 1.4
6	15.5 ± 0.7	14.7 ± 1.7	14.9 ± 1.6	16.0 ± 0.0	15.6 ± 0.9	15.7 ± 0.8
Overall	11.3 ± 2.6	11.3 ± 2.8	11.3 ± 2.7	12.0 ± 2.7	12.1 ± 2.7	12.1 ± 2.7

Table 2: Comparison between dental age and chronological age in both genders using direct correlations

Paired Samples Correlations				
Gender		**N**	**Correlation Coefficient**	**p-value**
Female	Dental age and Chronologic age	183	0.896	0.000*
Male	Dental age and Chronologic age	153	0.863	0.000*

*Statistically significant at p<0.05

Table 3: Pearson's correlation of dental and chronological age for each cervical stage according to gender.

Cervical stages	Female		Male	
	r	p-value	r	p-value
1	0.849	0.000*	0.860	0.000*
2	0.860	0.000*	0.776	0.000*
3	0.518	0.001*	0.804	0.000*
4	0.698	0.000*	0.776	0.000*
5	0.718	0.000*	-0.033	0.957
6	0.262	0.496	------	-------
Total	0.896	0.000*	0.863	0.000*

*Statistically significant at p<0.05

Table 4: Correlation between dental development stages in teeth and cervical stages in both genders

Dental Development Stages in teeth	Female		Male	
	r	p-value	r	p-value
Central Incisor	0.275	0.000*	0.229	0.004*
Lateral Incisor	0.395	0.000*	0.186	0.022*
Canine	0.689	0.000*	0.423	0.000*
First Premolar	0.737	0.000*	0.456	0.000*
Second Premolar	0.720	0.000*	0.477	0.000*
First Molar	0.473	0.000*	0.239	0.003*
Second Molar	0.743	0.000*	0.485	0.000*

* Statistically significant at p-value < 0.05

Table 5: Percentage distribution of dental development stages according to Demirjian's method for subsequent cervical vertebrae maturation stages (CVMS)

Dental stage	Canine		First premolar		Second premolar		Second molar	
	Gender		Gender		Gender		Gender	
	Female	Male %	Female	Male %	Female	Male %	Female	Male %
CVMS								
C	1.6	1.3	6.31	3.8	12.7	6.3	11.1	46.2
D	6.3	2.5	1.13	11.4	17.5	13.9	27	21.5
E	19	26.6	1.73	26.6	27	25.3	34.9	25.3
F	44.4	34.2	3.31	24.1	30.2	22.8	19	21.5
G	20.6	25.3	2.7	15.2	11.1	24.1	6.3	19
H	7.9	10.1	4.8	19	1.6	7.6	1.6	5.1
Total	100	100	100	100	100	100	100	100

CVMS								
C	—	—	—	—	—	3.7	—	11.1
E	10.5	18.5	42.1	18.5	57.9	38.9	47.4	22.2
G	15.8	25.9	15.8	25.9	—	29.6	—	22.2
H	15.8	18.5	10.5	25.9	—	11.1	—	7.4
Total	100	100	100	100	100	100	100	100
CVMS								
C	—	—	—	—	—	—	—	—
D	—	—	—	—	—	5.6	—	5.6
E	—	11.1	—	11.1	5.9	5.6	23.5	22.2
F	29.4	16.7	52.9	27.8	58.8	27.8	47.1	16.7
G	23.5	22.2	11.8	11.1	23.5	16.7	23.5	22.2
H	47.1	50	35.3	50	11.8	44.4	5.9	33.3
Total	100	100	100	100	100	100	100	100
CVMS								
C	—	—	—	—	—	—	—	—
D	—	—	—	—	—	4.5	—	4.5
E	—	4.5	—	4.5	4.2	—	6.3	4.5
F	14.6	18.2	18.8	18.2	20.8	13.6	22.9	9.1
G	29.2	31.8	12.5	18.2	20.8	40.9	43.8	45.5
H	56.3	45.5	68.8	59.1	54.2	40.9	27.1	36.4
Total	100	100	100	100	100	100	100	100
CVMS								
C	—	—	—	—	—	—	—	—
D	—	—	—	—	—	—	—	—
E	—	—	—	—	—	—	3.7	—
F	—	20	3.7	—	14.8	—	14.8	—
G	11.1	20	11.1	—	11.1	—	25.9	—
H	88.9	60	85.2	100	70.4	100	55.6	100
Total	100	100	100	100	100	100	100	100
CVMS								
C	—	—	—	—	—	—	—	—
D	—	—	—	—	—	—	—	—
E	—	—	—	—	—	—	—	—
F	—	—	—	—	—	—	11.1	
G	—	—	—	—	22.2	—	—	—
H	100	100	100	100	77.8	100	80	100
Total	100	100	100	100	100	100	100	100

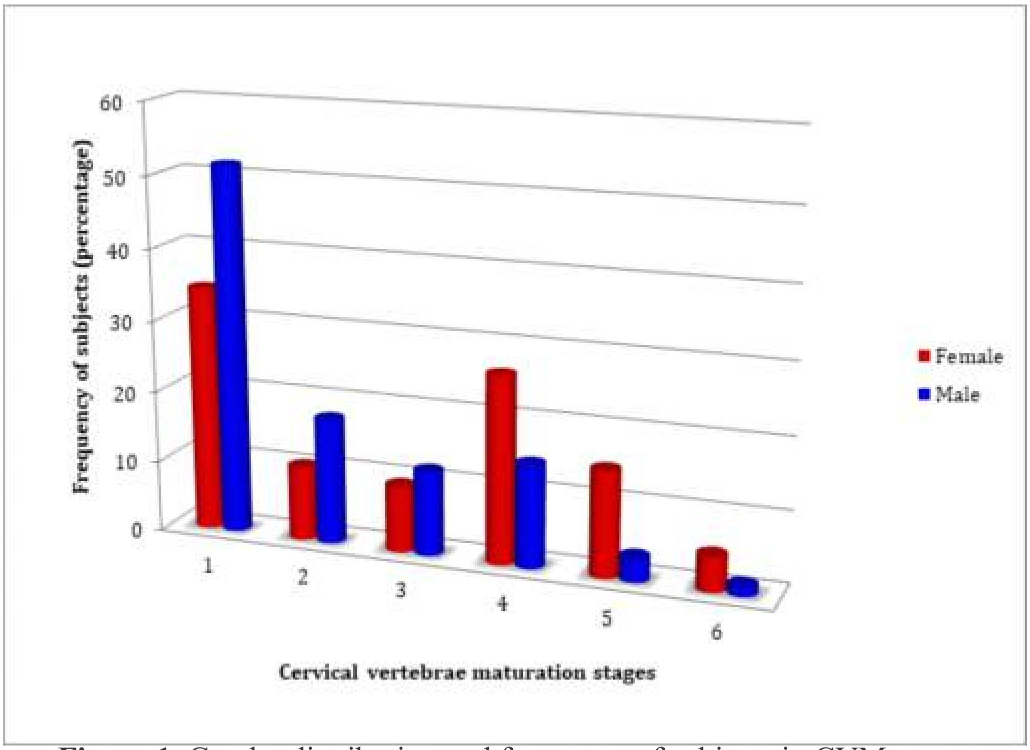

Figure 1. Gender distribution and frequency of subjects in CVM stages

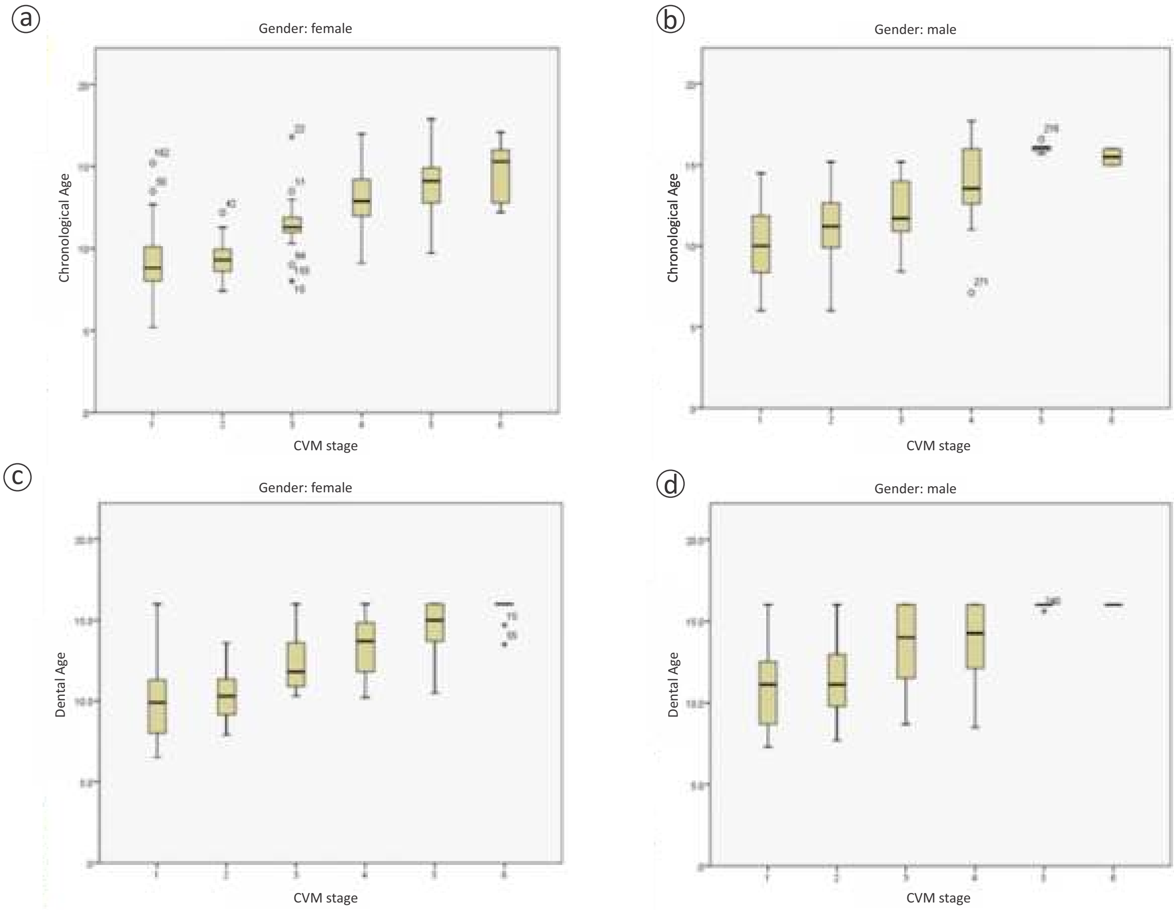

Figure 2: Distribution of chronological and dental age, related to cervical vertebrae maturation stage (CVMS)

Discussion

Reports in the literature agree that there is a strong relationship between skeletal, somatic, and sexual maturation.[10,11,14,17] However, previous studies to investigate the relationship between skeletal and dental maturation have shown low or no correlations between the two.[10,14,27-29] In this present study however the contrary was the case. Cervical vertebrae maturation stages were found to correlate well with dental developmental stages with all the stages displaying a p-value less than 0.05. This showed a good relationship between dental and skeletal maturation. In both genders, the second mandibular molar showed the greatest correlation with CVM with values R= 0.743 in females and R= 0.485 in males. This finding is similar to that of other studies.[30-33] Uysal *et al*.[23] also observed high correlations between dental and skeletal maturation in the second mandibular molar although they assessed skeletal maturity with the use of hand-wrist radiographs. At variance to this study however other authors have recorded higher correlations with other teeth ranging from the first and second premolar to the canine.[22,34,35] Some authors have suggested a significant relationship between the calcification of the mandibular canine and skeletal maturity.[15,32,36-38] Interestingly in this study there was a moderate correlation of the mandibular canine to skeletal maturity (R= 0.689 in females and R= 0.423 in males). These variations in teeth observed to most strongly correlate with skeletal maturation may be attributed to varying protocols followed, ethnicities, varying ages studied, number of subjects recruited in the studies, and nutrition, and environmental factors.[15,34,38-40] Weaker correlations of CVM to the permanent incisors and first molars seen in this study and various other studies have been attributed to early apical closure of these teeth.[35] Surendran and Thomas[41] further implied that stronger associations found between canines, premolars, second molars, and skeletal maturity were a result of the maturation of these teeth during the circum-pubertal period. Some authors have however questioned the diagnostic value of high correlation coefficients obtained in predicting specific stages of skeletal maturity and the pubertal growth spurt arguing that the diagnostic performance of dental maturity for recognizing growth phases, especially the growth spurt is extremely limited.[33,41] Although its usefulness may be limited to certain stages, determination of dental maturity is still beneficial for those stages, especially in a developing continent, and therefore cannot be overlooked. Wide variation was seen in tooth calcification stages, especially in the earlier stages. Cervical stage 1 was the most frequent CVM stage observed, a finding at variance to other studies.[23,42] In CVM stage 2 the most frequently observed stage in females was stage F for the canines and stage E for the second premolars in males and females. Since CVM stage 2 can be regarded as the pre-pubertal phase, it may be postulated that in Nigerian children stage F of the canine in females and stage E of the second premolars in both genders may be indicative of this phase. CVM stage 3 is a crucial stage of development described by Baccetti *et al*.[5] as that in which and following, the peak in mandibular growth will occur. It is the ideal stage in which functional orthopaedic treatment should commence to harness the growth spurt. In this study, CVM3 was accompanied by stage F of the second premolar (which also correlated well to CVM) in females showing the highest percentage. It can therefore be suggested that stages of calcification in the second premolar, especially in females, may be used to predict the pubertal peak in the population studied. The finding of female subjects being dentally and chronologically advanced in age and CVM stages compared to male subjects is in keeping with various other studies.[15,22,30-32,34,43,44] However concerning tooth mineralization stages relative to skeletal maturation, males showed a more advanced trend, except in CVM stage 4, whereas females showed a more advanced trend in all teeth examined except the second molar. This finding is quite similar to that of other authors.[22,23,37] An increase in the CVM stage was also observed with an increase in both chronologic and dental age indicating an increase in maturity and further buttressing the validity of the CVM method.

Conclusion

The assessment of skeletal maturity from the dental developmental stages of canines, premolars, and second molars may be used to assist in treatment planning in Nigerian subjects. In females, canines in stage F may be indicative of the pre-pubertal phase. The second premolar in stage F may be used to predict the pubertal growth spurt in Nigerian female children. The second molar in stage H may be indicative of the post-pubertal period in both genders.

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Conflict of Interest: None declared

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Competing interest for a given manuscript exists when the author has ties to activities that could inappropriately influence his or her judgment, whether or not judgment is in fact affected. Financial relationships with industry for example, through employment, consultancies, stock ownership, honoraria, expert testimony, either directly or through immediate family, are usually considered to be the most important competing interests. However, conflicts can

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A short text of about 150 words depicting the condition with color photographs (vide infra) is needed.
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Only cite those references that are essential to justify the proposed study.

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The methods section should describe, in a logical sequence, how the study was designed (e.g., how randomization was done), carried out (e.g., how subjects were chosen or excluded, ethical considerations, accurate details of materials used, exact drug dosage and form of treatment, etc.) and data were analyzed (e.g., an estimate of the power of the study, exact test used for statistical analysis, etc.).

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Acknowledgements

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