GROWTH ASSESSMENT AMONG NORTHERN NIGERIAN CHILDREN USING THE MIDDLE PHALANX OF THE THIRD FINGER AND ITS CORRELATION WITH MANDIBULAR CANINE CALCIFICATION.

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ABSTRACT

BACKGROUND: Assessment of growth especially skeletal maturation, is considered vital in the treatment planning of orthodontic patients that require jaw modification. Appropriate treatment timing for jaw growth modification will determine the outcome of such intervention especially when clinicans take advantage of the pubertal growth spurt. The need for a quick, reliable and cost effective method using the mandibular canine calcification stages will be of immerse help to the orthodontist.

AIMS: To determine the level of association between mandibular canine calcification stages and skeletal maturation stages.

MATERIALS AND METHODS: It was a prospective cross-sectional descriptive study comprising 74 participants (5-17 years). Skeletal maturation was evaluated using the middle phalanx of the third finger (MP3), and the Demirjian method was used to stage the mandibular canine calcification stages (MCCS). The chi-square test of association and Spearman Spearman's correlation coefficient were used to test the association and correlation between MP3 and the MCCS, respectively. The level of statistical significance was set at $p<0.05$.

RESULTS: Overall, there was a statistically significant association between MP3-skeletal maturation and the MCCS (male r=0.836 p value<0.001; female r=0.824 p value<0.001). The stage of acceleration of pubertal growth spurt (MP3-FG) was more associated with MCCS-G for both males and females. The peak pubertal growth spurt (MP3-G) was more associated with MCCS-H for males and MCCS-G for females.

CONCLUSION: There was gender variation between the association of the period of peak pubertal growth (MP3-G) and the mandibular canine calcification stage. However, There was a significant correlation between the MP3 developmental stages and MCCS.

KEYWORDS: skeletal maturation, middle-phalanx, third finger, mandibular canine calcification.

INTRODUCTION

The assessment of maturation status includes the evaluation of weight, height, chronological age, dental eruption, dental calcification, and skeletal maturation[1-4]. Although dental eruption is commonly used to predict the developmental status in clinics, it has failed to reflect the true state of skeletal maturation due to discrepancies in dental arch space, early loss of deciduous teeth, nutrition, and race[5-8]. Orthodontists consider the estimation of skeletal maturation as an important factor in managing patients, especially when considering the commencement of functional or orthopedic appliance therapy and orthognathic surgery[9-11].

Hand-wrist bones, cervical vertebrae, and biochemical markers have previously been used to estimate the pattern of skeletal maturation[3,12-14]. Also, dental calcification is considered to follow an independent process that is less affected by dental arch space, deciduous teeth extraction, and dental eruption[15]. In addition, to reduce radiation exposure when evaluating skeletal maturity, researchers have attempted to correlate dental calcification stages with cervical vertebrae and hand-wrist bone maturation stages among different populations[16-18]. Chertkow had earlier suggested using lower canines to predict pubertal growth spurt due to the high level of correlation with the hand and wrist bones ossification stages[19].

Even though dental calcification has been recommended to estimate pubertal growth, varying reports still exist regarding its reliability in predicting the onset, peak, and completion of pubertal growth spurt[16,18,20,21].

These differences could be related to the specific teeth used in the various studies. While some authors[22,23] have advised that caution be exercised when evaluating the calcification stages of lower molar for estimating skeletal maturity, another author[24] reported a better correlation of molar calcification with skeletal maturation. The use of canine calcification stages has consistently shown a good correlation with skeletal maturation status[21,25,26]. Racial variation, which has been established to influence the dental developmental stages, has also been observed to have contributed to the different findings[19,20,27].
The justification of this study is based on the inconsistent findings reported by researchers[19,20,27] and the scarcity of research on the association between dental calcification and skeletal maturation among Nigerians. Therefore, This study aims to determine the level of association between the mandibular canine calcification stages described by Demirjian and skeletal maturation stages using the middle phalanx of the third finger.

MATERIAL AND METHODS.

All consecutive patients who presented in the Child Dental Clinic of the Federal Medical Centre, Keffi (December 2020 - August 2021) and have met the criteria for the study were recruited.

Selection criteria: Participants recruited for the study included individuals between 5 to 17 years of age without previous orthodontic treatment history and with no congenital or developmental defect. Individuals with multiple extractions and/or severe debilitating childhood illnesses were excluded from the study.

Ethical approval was obtained from the institution's Health Research Ethical Committee (FMC/KF/HREC/2571/21). Informed consent was obtained from the parents and guardians of the study participants, while verbal assent was obtained from the children before they were recruited for the study.

Data collection:
Each participant was asked to stretch their middle phalanx on a flat base with the proximal interphalangeal joint of the middle finger centered on a Carestream digital peri-apical x-ray sensor measuring 24mm x 40mm. The x-ray tube (Carestream periapical x-ray machine model CS2100) was positioned perpendicular to the digital sensor. The peri-apical radiographs of the mandibular canine were obtained using the bisecting angle technique.
The Demirjian method[4] and the Hagg and Taranger[12] were used to grade the mandibular canine calcification and the developmental stages of the third finger's middle phalanx, respectively.

Figure 1A: Taking of the radiograph of the middle phalanx of the third finger using a digital peri-apical sensor.

Figure 1B: Digital view of a radiograph of the mandibular canine

Figure 1C: Digital view of a radiograph of the middle phalanx of the third finger of a study participant.

Intra-investigator reliability: Eight participants' radiographs of the middle phalanx of the third finger (using a digital peri-apical x-ray sensor) were randomly selected and assessed at two sections of 2 weeks intervals to determine intra-class reliability. Intra-class reliability was 0.948 for the mandibular canine calcification stages and 0.904 for the developmental stages of the middle phalanx of the third finger, $p<0.001$.

Statistical analysis:
Statistical Package for Social Sciences (version 22) was used to analyze the data collected. An unpaired t-test was used to compare the mean chronological age of the various developmental stages of MP3 according to gender. The mean chronological age of the different mandibular canine calcification stages according to gender was also compared using the unpaired t-test. Spearman's correlation was used to determine the relation between chronological age, the mandibular canine calcification stages, and the MP3 developmental stage due to the multi-level of the variables. The chi-square test of association was used to test the level of association between the skeletal maturation stages of MP3 and the mandibular canine calcification stages (MCCS). The level of statistical significance for the study was set at $p<0.05$.

RESULTS
A total of 74 participants were recruited for the study. All 74 participants had clear radiographs of the middle phalanx of the third finger (Mp3), while 2 had distorted peri-apical radiographs of the mandibular canine. 74 radiographs of the MP3 were correlated with the chronological ages, while 72 undistorted radiographs of the canine calcification stages were correlated with the chronological age. Correlation between canine calcification and MP3 was conducted for the undistorted 72 radiographs.

The average mean age of all 74 participants was 10.45 ± 2.85 years. The unpaired t-test showed no statistically significant difference between the mean ages of males and females recruited for the study. The mean age of the 72 participants with undistorted peri-apical radiographs of the mandibular canine was 10.51 ± 2.86. There was also no statistically significant difference in relation to gender (Table 1).

Table 1: Mean chronological age distribution of study participants with MP3 developmental stages and Mandibular Canine Calcification Stages (MCCS).

	Frequency N (%)	Mean ± SD	95% confidence Interval		P value
			Lower	Upper	
MP3					
Male	44 (59.5)	10.75 ± 2.73	-0.592	2.092	0.269
Female	30 (40.5)	10.00 ± 3.01			
Total	74 (100.0)	10.44 ± 2.85			
MCCS					
Male	43 (59.7)	10.81 ± 2.72	-0.623	2.113	0.281
Female	29 (40.3)	10.07 ± 3.03			
Total	72 (100.0)	10.51 ± 2.86			

Table 2 shows the distribution of the developmental stages of the middle phalanx of the third finger (Mp3), with stage F (39.2%) being the most occurring stage, while stages H and I were least represented with 6.8% each. According to gender, most males (25.7%) were in stage F, followed by stage FG (20.3%), while stages H and I had 2.7%, respectively. Among the females, stage F also had the highest representation, with 13.5%, followed by stage G (10.8%), while stages H and I had 4.1% each.

Table 2: Distribution of the Middle phalanx of the third finger (MP3) developmental stages according to gender.

	Gender	CHRONOLOGICAL AGE OF STUDY PARTICIPANTS														
MP3		5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
F	Male	-	-	2(4.5)	6(13.6)	6(13.6)	4(9.1)	-	1(2.3)	-	-	-	-	-	-	19(25.7)
N(%)	Female	2(6.7)	-	3(10.0)	4(13.3)	1(3.3)		-	-	-	-	-	-	-	-	10(13.5)
																29(39.2)
FG	Male	-	-	-	2(4.5)	2(4.5)	2(4.5)	6(13.6)	-	2(4.5)	-	1(2.3)	-	-	-	15(20.3)
N(%)	Female	-	-	-	1(3.3)	2(6.7)	1(3.3)	-	1(3.3)	-	1(3.3)	-	-	-	-	6(8.1)
																21(28.4)
G	Male	-	-	-	-	-	-	1(2.3)	-	3(6.8)	-	1(2.3)	-	1(2.3)		6(8.1)
N(%)	Female	-	-	-	1(3.3)	-	5(16.7)	2(6.7)	-			-	-			8(10.8)
																14(18.9)
H	Male	-	-	-	-	-	-	-	-	-	1(2.3)	1(2.3)	-	-	-	2(2.7)
N(%)	Female	-	-	-	-	-	-	1(3.3)	-	1(3.3)	-	1(3.3)	-	-	-	3(4.1)
																5(6.8)
I	Male	-	-	-	-	-	-	-	-	-	-	-	-	1(2.3)	1(3.3)	2(2.7)
N(%)	Female	-	-	-	-	-	-	-	-	-	1(3.3)	-	1(3.3)	1(3.3)	-	3(4.1)
																5(6.8)
Total	Male	-	-	2(4.5)	8(18.2)	8(18.2)	6(13.6)	7(15.9)	1(2.3)	5(11.4)	2(4.5)	2(4.5)	1(2.3)	-	1(3.3)	44(59.5)
N(%)	Female	2(6.7)	-	3(10.0)	6(20.0)	3(10.0)	6(20.0)	3(10.0)	1(3.3)	1(3.3)	2(6.7)	1(3.3)	1(3.3)	1(3.3)	-	30(40.5)
																74(100.0)

Mandibular canine calcification stage F (27.8%) was the most occurring stage, while stage D was least represented with 4.2%. Stage F was the most occurring stage among male participants, with 19.4%, followed by stage E (16.7%), and the least was stage D with 2.8%. However, stage G was mostly represented in females with 11.1%, followed by stage E (9.7%) and stage D least occurring (1.4%) (Table 3).

Comparison of the mean ages of the various stages of skeletal developmental (MP3) and mandibular canine calcification stages (MCCS) using unpaired t-test, are presented in table 4. The mean age for canine calcification stages were observed to be earlier among females than male participants. A statistical significant difference (p=0.02) was particularly observed between MCCS-F for females (8.33 ± 1.03 years) and MCCS-F for males (10.29 ± 1.73 years). Statistical significant differences in relation to gender, were observed in MP3-F and MP3-G. The mean age for attainment of MP3-F were 8.84 ± 1.21 years for males and 7.20 ± 1.32 years for female, p=0.002. The mean age for MP3-G were 13.33 ± 1.63 years and 10.00 ± 0.93 years for males and females respectively (p<0.001). Therefore, the pattern of skeletal maturation using MP3 according to gender shows that females matured earlier than males in all the developmental stages. Also, the pattern of mandibular canine calcification stages shows that females attain earlier developmental stages than males.

Table 3: Distribution of the mandibular canine calcification stages (MCCS) according to gender.

	Gender	CHRONOLOGICAL AGE OF STUDY PARTICIPANTS														
MCCS		5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
C	Male	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
N(%)	Female	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
D	Male	-		2(4.7)	1(2.3)	4(9.3)	1(2.3)	-	-	-	-	-	-	-	-	2(2.8)
N(%)	Female	1(3.4)		2(6.9)	-	1(3.4)	1(3.4)	-	-	-	-	-	-	-	-	1(1.4)
																3(4.2)
E	Male	-	-	-	5(11.6)	4(9.3)	1(2.3)	3(7.0)	1(2.3)	-	-	-	-	-	-	14(19.4)
N(%)	Female	1(3.4)	-	1(3.4)	2(6.9)	1(3.4)	1(3.4)	-	-	-	-	-	-	-	-	6(8.3)
																20(27.8)
F	Male	-	-	-	1(2.3)	-	4(9.3)	4(9.3)	-	2(4.7)	-	1(2.3)	-	-	-	12(16.7)
N(%)	Female	-	-	-	3(10.3)	1(3.4)	1(3.4)	2(6.9)	1(3.4)	1(3.4)	-	-	-	-	-	7(9.7)
																19(26.4)
G	Male	-	-	-	-	-	-	-	-	3(7.0)	1(2.3)	-	-	-	-	7(8.7)
N(%)	Female	-	-	-	-	-	-	1(3.4)	-	-	1(3.4)	-	-	-	-	8(11.1)
																15(20.8)
H		-	-	-	-	-	-	-	-	-	1(2.3)	1(2.3)	1(2.3)	1(2.3)	1(2.3) -	8(11.1)
N(%)		-	-	-	-	-	-	-	-	-	1(3.4)	1(3.4	1(3.4	1(3.4		7(9.7)
																15(20.8)
Total	Male	-	-	2(4.7)	7(16.3)	8(18.6)	6(14.0)	7(16.3)	1(2.3)	5(11.6)	2(4.7)	2(4.7)	1(2.3)	7(8.7)	8(11.1)	43(59.7)
N(%)	Female	2(6.9)	-	3(10.3)	5(17.2)	3(10.3)	3(10.3)	3(10.3)	1(3.4)	1(3.4)	2(6.9)	1(3.4)	1(3.4)	8(11.1)	7(9.7))	29(40.3)
																72(100.0)

Table 4: Comparison of the mean chronological age of the MP3 developmental stages and the mandibular canine calcification stages (MCCS) according to gender

MP3/ Gen(n)	Mean± SD	95% CI Lower	Upper	P-value	**MCCS/ Gen(n)**	Mean± SD	95% CI Lower	Upper	P-value
F		0.640	2.640	****0.002**	**D**		-18.008	26.008	0.260
M(19)	8.84±1.21				M(2)	9.00±1.41			
Fe(10)	7.20±1.32				Fe(1)	5.00±0.00			
FG		-1.626	2.426	0.684	**E**		-0.576	1.814	0.290
M(15)	10.73±1.91				M(12)	8.33±0.89			
Fe(6)	10.33±2.25				Fe(7)	7.71±1.60			
G		1.840	4.827	***0.0004**	**F**		0.346	3.559	*****0.02**
M(6)	13.33±1.63				M(14)	10.29±1.73			
Fe(8)	10.00±0.93				Fe(6)	8.33±1.03			
H		-3.390	6.390	0.401	**G**		-0.483	2.732	0.155
M(2)	14.50±0.71				M(7)	12.00±1.28			
Fe(3)	13.00 ±2.00				Fe(8)	10.88±1.55			
I		-1.979	5.646	0.233	**H**		-1.364	3.686	0.339
M(2)	17.50±0.71				M(8)	14.88±1.96			
Fe(3)	15.67±1.52				Fe(7)	13.71±2.56			

*= p<0.0001;
** =p<0.001;
***=p<0.05;
Gen=Gender;
M= Male,
Fe=Female.

The correlation coefficients in relation to gender show a very strong positive and statistical significant correlation among males and females participants (Table 5).

Table 5: Correlation of chronological age (CA), mandibular canine calcification stages (MCCS) and Middle phalanx of the third finger (MP3) in relation to gender.

	CORRELATION COEFFICIENTS		
GENDER	CA-MCCS	CA-MP3	MCCS -MP3
Male			
r (P value)	0.820 (0.000)	0.841 (0.000)	0.836 (0.000)
Females			
r (P value)	0.816 (0.000)	0.836 (0.000)	0.824 (0.000)
Average			
r (P value)	0.790 (0.000)	0.786 (0.000)	0.835 (0.000)

p<0.001

When genders were considered separately, there was a statistically significant level of association between MP3 and MCCS with the X2 test (male; X2 = 57.58, p<0.001; female, X2= 33.52, p=0.006; average, X2= 85.76, p<0.001), see table 6.

Table 6: Contingency table showing the MP3 versus mandibular canine calcification stages (MCCS) according to genders.

MP3	GENDER	Mandibular Canine calcification stages -MCCS					
		D N(%)	E N(%)	F N(%)	G N(%)	H N(%)	TOTAL N(%)
F	Male	1(50.0)	12(100.0)	6(42.9)	0(0)	0(0)	19(44.2)
	Female	1(100)	6(85.7)	3(50.0)	0(0)	0(0)	10(34.5)
FG	Male	1(50.0)	0(0)	8(57.1)	5(71.4)	0(0)	14(32.6)
	Female	0(0)	0(0)	2(33.3)	4(50.0)	0(0)	6(20.7)
G	Male	0(0)	0(0)	0(0)	2(28.6)	4(50.0)	6(14.0)
	Female	0(0)	1(14.3)	1(16.7)	3(37.5)	2(28.6)	7(24.1)
H	Male	0(0)	0(0)	0(0)	0(0)	2(25.0)	2(4.7)
	Female	0(0)	0(0)	0(0)	1(12.5)	2(28.6)	3(10.3)
I	Male	0(0)	0(0)	0(0)	0(0)	2(25.0)	2(4.7)
	Female	0(0)	0(0)	0(0)	0(0)	3(42.9)	3(10.3)

1. Overall Male (X2=57.58; Kendall's tau=0.77; P<0.001)
2. Overall Female ((X2=33.52; Kendall's tau-b=0.74; P=0.006).

The acceleration period of skeletal growth (MP3-FG) was majorly associated with the MCCS-G stage; 71.4% and 50% for males and females, respectively. However, MP3-G was mostly associated with MCCS-H (50%) among the male participants as against MCCS-G (37.5%) among the female participants.

DISCUSSION

The evaluation of skeletal maturation stages is fundamental during the treatment planning of orthodontic patients, especially as it relates to the period of the application of orthopedic/functional appliances[10,11,22]. Several researches[18,20,21] have also tried to establish the correlation between canine calcification stages and the developmental stages of the middle phalanx of the third finger.

In the present study, it was observed that female participants were older than males at every development stage of the middle phalanx of the third finger. This is in agreement with previous studies[22,28,29]. The mean chronological age of all the stages of MP3 in this present study is at variance with the findings made by Macha et al.[29]. However, consistent with the observation made by Divyashree & Amarnath[28]. The age at which acceleration of pubertal growth spurt (MP3-FG) began, appears to be earlier in the findings made by Macha et al.[29] when compared to the results of this present study. This present study shows that the mean age for the attainment of MP3-FG among males is comparable to the observation made by Krailassiri et al.[22] In addition, the mean age for the attainment of MP3-FG (11.4 years) among females as reported by the same author[22] is later than the observation made in this current study. These findings suggest that racial differences should be considered when planning growth modification treatment using functional or orthopaedic appliances.

The calcification stages of the female mandibular canine in this present study were also observed to have occurred earlier than in males, corroborating the findings made by Divyashree et al.[28]

In this current study, a significant correlation between chronological age and the developmental stages of the middle phalanx of the third finger was observed in both genders, which is consistent with the findings of Muthe et al.[30]. In this present study, the findings only agree with female participants aged 8-10 years, 12-14 years and male participants aged 12 – 16 years age groups but at variance with female participants aged 10-12 years,14-16 years and male participants between 8-12 years in the study conducted by Nayak et al.[21] Participants in this present study were not divided into groups making it difficult to ascertain which particular age group contributed to the significant correlation with the MP3. It is also important to note that Inconsistency in the correlation between chronological age and skeletal maturation has also been reported by Coutinho et al.[20]. A significant correlation between MP3 and mandibular canine calcification, as observed in this present study, agrees with findings of previous studies[18,19,22,31,32]. In this current study, the MCCS-E was mainly associated with MP3-F among males (100%) and females (85.7%), which is consistent with the observations made by Muthe et al.[30]. The MCCS-G was mainly associated with MP3-FG for both male and females in this present study. This result appears consistent with an earlier observation made among male Caucasians19 but at variance with the findings of Coutinho et al.[20], where they reported MCCS-G to be more associated with MP3-G in both genders. This present study has also shown that at the same MP3 developmental stage, males tend to have advanced canine development more than females, which is consistent with the report of Chertkow[19]. Racial differences should be considered when applying mandibular canine calcification to indicate skeletal maturity.

Therefore, this study shows that the peak pubertal growth spurt (MP3-G) can be evaluated using CCS-G for females and CCS-H for males. Only the observation made among the females in this study agrees with previous reports[18,33].

Clinical Significance: Mandibular canine calcification stages should be used as an adjunctive tool for estimating skeletal maturation among Nigerians. This is due to discrepancies observed in relation to gender, especially with the peak and completion of pubertal growth.

Conclusion.

This current study has shown a statistically significant association between skeletal maturation using the MP3 method and mandibular canine calcification using the Demirjian method. The period of acceleration of pubertal growth spurt (MP3-FG) associates more with MCCS-G in both males and females, while the peak period of the pubertal growth spurt (MP3-G) associate more with MCCS-H in males and more with MCCS-G for females. While mandibular canine calcification stage H (MCCS-H) can be used to evaluate the period of completion of pubertal growth spurt among females, it cannot be categorically used as the period of completion of pubertal growth spurt among males as shown in this present study.

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