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Correlation between different methods of assessing bone maturation

Correlação entre diferentes métodos de avaliação de maturação óssea

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Abstract

Introduction: *the skeletal maturity of na individual can be evaluated through different methods and it is an important tool to the diagnostic and treatment in othodontics.* ***Objective:*** *to verify the correlation between different methods of assessing bone maturation: Carpal Maturation Index (CMI), Cervical Vertebrae Maturation Stages (CVM) and Dental Mineralization Stages (DM).* ***Methodology:*** *the sample consisted of digitalized images of cephalometric, panoramic and hand and wrist radiographs of 73 patients. 50 were selected for analysis. Two examiners were properly calibrated, through images analysis from another database. Inter and intra-examiner reliability was measured by Kappa coefficient. The images were assessed according to Fishman (1982), Baccetti, Franchi and McNamara Junior (2002) and Nolla (1960) methods. All images were coded and data of all analyzes was transferred to spreadsheets. The data was processed in Matlab program for Windows, version 7.10.0, and analyzed using descriptive and inferential statistics.* ***Results:*** *the results demonstrated a positive correlation among bone maturity methods (CMI, CVM and DM), as well as between those methods and chronological age. Females showed precocity in reaching the stages of skeletal maturation indicators and CVM compared to males. It was observed that there was a correspondence between maturation methods for both genders.* ***Conclusion:*** *there was a correlation between skeletal maturation assessment methods and dental mineralization in patients. Significant differences were observed between genders for skeletal maturity assessment methods. There was a relation between the methods used for skeletal maturation and dental mineralization, as well as chronological age.*

Key words*: Growth. Skeletal Maturation. Cervical Vertebrae. Mineralization.*

Resumo

Introdução: a maturidade esquelética de um indivíduo pode ser avaliada por diversos métodos e é uma importante ferramenta para o diagnóstico e tratamento em odontologia. **Objetivo**: verificar a correlação entre diferentes métodos de avaliação da maturação óssea: Índice de Maturação do Carpal (IMC), Estágios de Maturação das Vértebras Cervicais (MVC) e Estágios de Mineralização Dentária (MD). **Metodologia**: a amostra foi constituída por imagens digitalizadas de radiografias cefalométricas, panorâmicas e de mão e punho de 73 pacientes. 50 foram selecionados para análise. Dois examinadores foram devidamente calibrados, por meio da análise das imagens de outro banco de dados. A confiabilidade inter e intraexaminadores foi medida pelo coeficiente Kappa. As imagens foram avaliadas de acordo com os métodos de Fishman (1982), Baccetti, Franchi e McNamara Junior (2002) e Nolla (1960). Todas as imagens foram codificadas e os dados de todas as análises foram transferidos para planilhas. Os dados foram processados no programa Matlab para Windows, versão 7.10.0, e analisados por meio de estatística descritiva e inferencial. **Resultados**: os resultados demonstraram correlação positiva entre os métodos de maturação óssea (IMC, MVC e MD), bem como entre esses métodos e a idade cronológica. O gênero feminino apresentou precocidade em atingir os estágios indicadores de maturação esquelética e MVC em relação ao gênero masculino. Observou-se que houve correspondência entre os métodos de maturação para ambos os gêneros. **Conclusão**: houve correlação entre os métodos de avaliação da maturação esquelética e a mineralização dentária nos pacientes. Diferenças significativas foram observadas entre os gêneros para os métodos de avaliação da maturidade esquelética. Houve relação entre os métodos utilizados para a maturação esquelética e mineralização dentária, bem como a idade cronológica.

Palavras-chave: Crescimento. Maturação Esquelética. Vértebra cervical. Mineralização.

INTRODUCTION

The skeletal maturity of an individual can be affected by aspects as genetic, ethnic and environmental influences (BALA; PATHAK; JAIN, 2010; GRGIC et al., 2020). Proper planning of orthodontic treatment as well as its prognosis is directly associated with skeletal maturity as orthopedic appliances have proved to be more effective when used at mandibular growth peak (BACCETTI et al., 2000; FALTIN JUNIOR et al., 2003; OK et al., 2020).

For a long time, the growth of hand and wrist bones has been used to assess skeletal maturation, with the Fishman method being one of the methods widely used (FISHMAN, 1982; FLORES-MIR et al., 2004; LEE et al.,

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2019). However, the simplification of orthodontic treatment has led to the identification of such useful features in routine examinations, such as cephalometric images, through the analysis of cervical vertebrae (BACCETTI; FRANCHI; MCNAMARA, 2005; LEE et al., 2019), and later panoramic radiography, which can be used to assess dental calcification and bone maturation (GOYAL; GOYAL; GUGNANI, 2014; LECCA-MORALES; CARRUITERO, 2017; KUMAR, H. et al., 2012).

Dental mineralization is a more reliable indicator of dental maturity than tooth eruption, as it is not affected by local factors, such as loss of primary teeth, lack of space, malnutrition, caries, ankylosis, orthodontic changes (DEMIRJIAN; GOLDSTEIN; TANNER, 1973; PAZ CORTÉS et al., 2019). However, there is still no consensus on which tooth is the most accurate predictor of dental maturity, so there are studies that use the different dental groups for such an evaluation (KAMAL; SHAIKH; FIDA, 2018; LECCA-MORALES; CARRUITERO, 2017; OJHA, 2019).

The canine mineralization phase can be the reference chosen to provide readily available and easily recognized information on the individual's bone maturity status, the lower one being more strongly correlated with this aspect (AL-BALBEESI et al., 2018; KHAN; IJAZ, 2011).

Given this context, the present study aimed to verify the correlation between the different methods of assessing bone maturation: Carpal Maturation Index (CMI), Cervical Vertebrae Maturation Stages (CVM) and Dental Mineralization Stages (DM).

METHODOLOGY

This is an observational and retrospective study, which was approved by the Research Ethics Committee of University Hospital Professor Lauro Wanderley/Universidade Federal da Paraíba.

This research was developed with digitalized images of cephalometric, panoramic and hand and wrist radiographs of patients who were attended in the Orthodontics Course of the Brazilian Dental Association – Paraíba Section. The sample consisted of all radiographs, which belonged to patients aged between 8 to 14 years, resulting in 73 patients. All images was obtained using the Ortoralix 9200 Gendex device (Gendex Dental Systems, Hatfield, PA, USA).

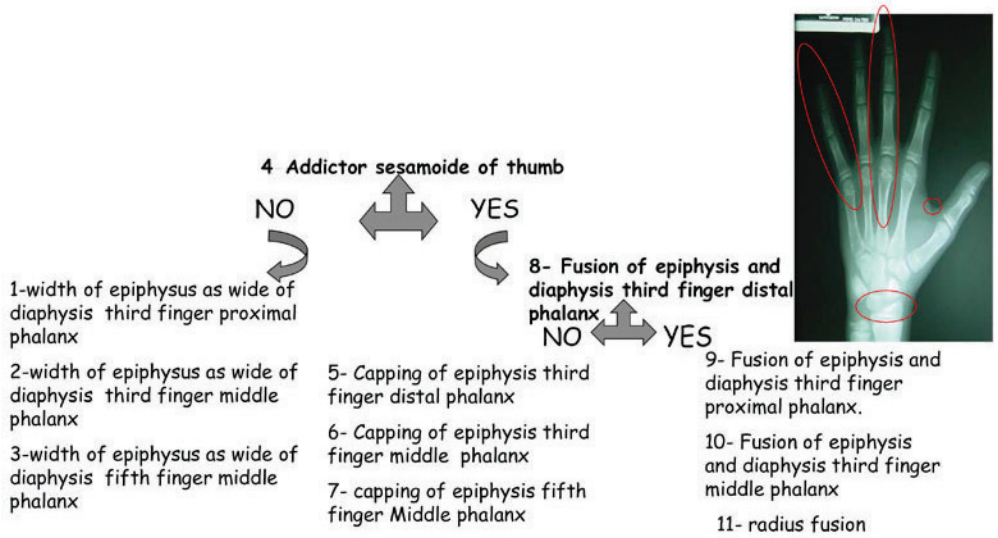
Hand and wrist images and cephalometric radiographs show 1: 1 magnification, and panoramic 27% magnification (distortion). All images were scanned with a resolution of 300 dpi and 256 levels in gray scale.All images were imported from the software CDT and distributed, randomly, in Windows® Viewer.

The excluded criteria was radiographs that did not present good image quality and patients that did not have all three images: panoramic, hand and wrist and cephalometric. 50 of the 73 patients were selected for analysis.

Two examiners were properly calibrated, through images analysis from another database. Inter – and intra-examiner reliability was measured by Kappa coefficient. The sample was evaluated twice by each examiner and the interval between the first and the second evaluation was 10 days.

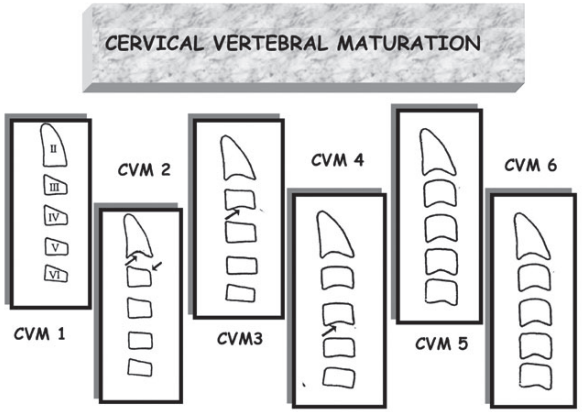
Skeletal maturation stages of hand and wrist were classified according to the method of Fishman (FISHMAN, 1982) (Figure 1). The skeletal maturation stages of cervical vertebrae were classified into 5 stages that are correlated with pubertal growth, according to the method of Hassel, Farman and Abomr (HASSEL; FARMAN; ABOMR, 1995) modified by Baccetti, Franchi and McNamara Junior (BACCETTI; FRANCHI; MCNAMARA JUNIOR, 2002) (Figura 2 and 3).

Figure 1 – *Fishman indicators sequence of analyzes*



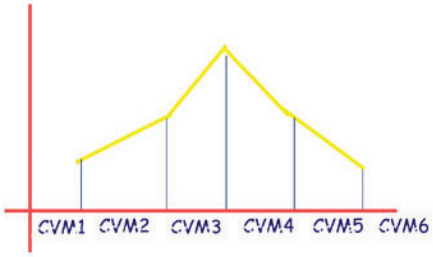
Source: Own Authorship.

Figure 2 – *Cervical vertebral maturation. Skeletal age assessment utilizing cervical vertebrae*



Source: Lamparski, 1972.

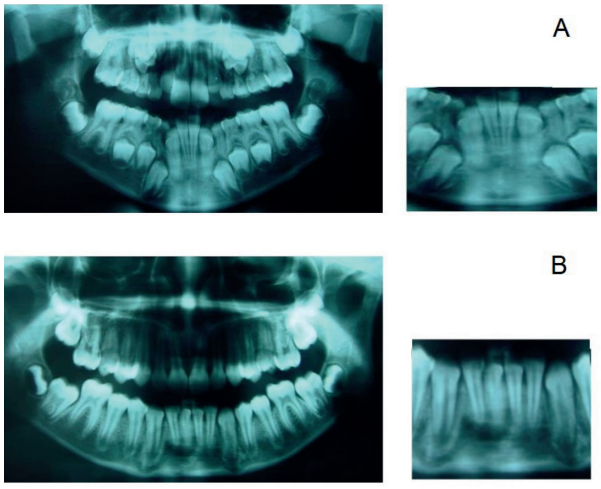
Figure 3 – *Cervical vertebral maturation stages and correspondence in growth spurt*

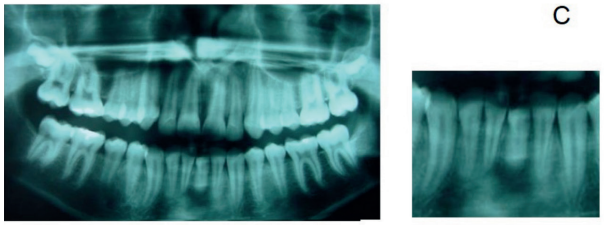


Source: Own Authorship.

Dental mineralization stages were classified according to Nolla (NOLLA, 1960) (Figure 4 and 5). The lower arch permanent canines on both sides were analyzed, as those teeth have their growth over the studied age range, and are still easily seen on panoramic radiographs.

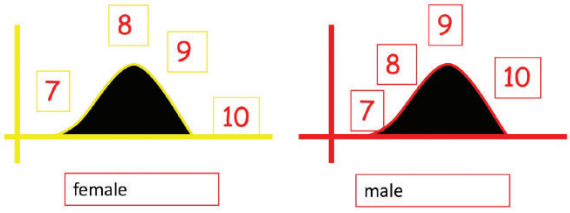
Figure 4 – *Nolla Stages*





Nolla Stages. A. Stage 7 - 1/3 of root. B. Stage 8 - 2/3 of root. C. Stage 9 - complete root with open apex.

Figure 5 – *Correspondence of Nolla stages and growth spurt curve*



Source: Own Authorship.

All images were coded and data of all analyzes was transferred to spreadsheets. The data was processed in Matlab program for Windows, version 7.10.0 (MathWorks Inc., USA), and analyzed using descriptive and inferential statistics. Statistical inference procedures were performed by means of simple linear regression analysis, Spearman's correlation coefficient and significance test, Wilcoxon test was used for comparison of medians.

RESULTS

Inter and intra-examiner reliability was measured by Kappa coeficiente and showed high values in all measurements. About CMI, inter-examiners value was 0.93, and intra-examiners values were 1 and 0.97. Inter-examiners coefficient in CVM was 0.78 and intra-examiners values were 1 for both of them. DM was 0.90 inter-examiners and 1 intra-examiners for both upper canines.

The sample (n = 50) was composed by 23 (46%) males and 27 (54%) females, with ages ranging from 6 to 14 years old. Considering the chronological age in relation to the hand and wrist skeletal maturation criteria, the highest percentage of male participants was at CMI 0 (mean age: 9.0 years), 4 (mean age: 12.2 years) and 5 (average age: 13.7 years), being in the pre-peak phase of the growth curve. Female participants were more numerous on 4 (average age: 9.6 years), 8 (average age: 12.7 years) and 10 (average age: 13.2 years), placing them in the phase pre-peak and post-peak growth curve, what can be seen in Table 1.

Table 1 – *Distribution of patients according to carpal maturation index (CMI), age and gender*

AGE (GROUP)	STAGE 0		STAGE 1		STAGE 2		STAGE 3		STAGE 4	
GENDER	M n (%)	F n (%)	M n (%)	F n (%)	M n (%)	F n (%)	M n (%)	F n (%)	M n (%)	F n (%)
8	2 (28.7)	0 (0.0)	0 (0.0)	1 (33.3)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
9	3 (42.8)	1 (14.3)	0 (0.0)	1 (33.3)	0 (0.0)	0 (0.0)	0 (0.0)	1 (20.0)	0 (0.0)	4 (28.6)
10	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	3 (21.4)
11	1 (14.3)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (20.0)	2 (40.0)	1 (7.1)	1 (7.1)
12	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
13	0 (0.0)	0 (0.0)	1 (33.3)	0 (0.0)	0 (0.0)	0 (0.0)	1 (20.0)	0 (0.0)	2 (14.3)	0 (0.0)
14	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
TOTAL N (%)	6 (83.3)	1 (16.7)	1 (33.3)	2 (66.6)	1 (100.0)	0 (0.0)	2 (40.0)	3 (60.0)	6 (50.0)	8 (50.0)
AGE (MEAN ±SD)	9 (1.1)	9 (0)	13 (0.0)	8.5 (0.7)	12 (0.0)	0 (0.0)	12 (1.4)	10.3 (1.1)	12.2 (0.7)	9.6 (0.7)
AGE (GROUP)	STAGE 5		STAGE 6		STAGE 7		STAGE 8		STAGE 10	
GENDER	M n (%)	F n (%)	M n (%)	F n (%)	M n (%)	F n (%)	M n (%)	F n (%)	M n (%)	F n (%)
8	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
9	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
10	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (66.7)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
11	0 (0.0)	1 (25.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (33.3)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
12	0 (0.0)	0 (0.0)	0 (0.0)	1 (50.0)	0 (0.0)	2 (40.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (16.7)
13	1 (25.0)	0 (0.0)	1 (50.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (20.0)	0 (0.0)	1 (16.7)
14	2 (50.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (20.0)	1 (20.0)	2 (33.3)	2 (33.3)
TOTAL N (%)	3 (75.0)	1 (25.0)	1 (50.0)	1 (50.0)	0 (0.0)	3 (100.0)	1 (20.0)	4 (80.0)	2 (33.3)	4 (66.7)
AGE (MEAN ±SD)	13.7 (0.6)	11 (0)	13 (0)	12 (0)	0 (0)	10.3 (0.6)	14 (0)	12.7 (1.0)	14.0 (0)	13.2 (1.0)

Source: Own Authorship

In Table 2 is shown the evaluation of skeletal maturation through cervical vertebrae, the largest percentage of male participants was concentrated in CVM stages 1 (mean age: 10.0 years), 2 (mean age: 12.3 years) and 3 (mean age: 12.7 years), placing them in the pre-peak (CVM 1) and peak (CVM 2 and 3) phases of growth curve. Female participants also were more presente on CVM stages 1 (mean age: 10.0 years), 2 (mean age: 10.4 years) and 3 (mean age: 12.0 years).

Table 2 – *Distribution of patients according to Cervical Vertebrae Maturation Stages (CVM), age and gender*

AGE (GROUP)	CVM 1		CVM 2		CVM 3		CVM 4		CVM 5	
GENDER	M n (%)	F n (%)	M n (%)	F n (%)	M n (%)	F n (%)	M n (%)	F n (%)	M n (%)	F n (%)
8	2 (15.4)	1(7.7)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
9	2 (15.4)	1 (7.7)	1 (4.3)	6 (26.1)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
10	0 (0.0)	1 (7.7)	0 (0.0)	2 (8.7)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
11	1 (7.7)	3 (23.1)	2 (8.7)	1 (4.3)	1 (11.1)	2 (22.2)	0 (0.0)	1 (25.0)	0 (0.0)	0 (0.0)
12	1 (7.7)	0 (0.0)	2 (8.7)	1 (4.3)	1 (11.1)	2 (22.2)	0 (0.0)	1 (25.0)	0 (0.0)	0 (0.0)
13	1 (7.7)	0 (0.0)	3 (13.0)	0 (0.0)	2 (22.2)	1 (11.1)	0 (0.0)	1 (25.0)	0 (0.0)	0 (0.0)
14	0 (0.0)	0 (0.0)	3 (13.0)	2 (8.7)	0 (0.0)	1 (11.1)	1 (25.0)	0 (0.0)	1 (100.0)	0 (0.0)
TOTAL N (%)	7 (53.9)	6 (46.2)	11 (47.8)	12 (52.2)	3 (33.3)	6 (66.6)	1 (25.0)	3 (75.0)	1 (100.0)	0 (0.0)
AGE (MEAN ±SD)	10 (2.0)	10 (1.0)	12.3 (1.6)	10.4 (1.9)	12.7 (0.6)	12 (1.4)	14 (0.0)	11.7 (1.5)	14 (0.0)	0 (0.0)

Source: Own Authorship

Regarding dental mineralization stages, 0 to 6 were not observed for lower canines (33 and 43) within age range of the sample in 1st stage. The highest percentage of male participants was concentrated for both tooth 33 and 43 between stages 8 (tooth 33 and 43 – average age: 8.7 years), 9 (tooth 33 and 43 – average age: 12.7 years) and 10 (teeth 33 and 43 – mean age: 12.7 years) and females were also concentrated in stages 8 (tooth 33 – mean age: 9.5 years and tooth 43 – average age: 9.6 years), 9 (tooth 33 and 43 – average age: 10.5 years) and 10 (tooth 33 and 43 – average age: 12.3 years).The chronological age averages for stages 8, 9 and 10 of teeth 33 and 43 are practically the same in both genders (Tables 3 and 4).

Table 3 – *Distribution of patients according to the stages of dental mineralization (DM 33), age and gender*

AGE (GROUP)	STAGE 7		STAGE 8		STAGE 9		STAGE 10	
GENDER	M n (%)	F n (%)	M n (%)	F n (%)	M n (%)	F n (%)	M n (%)	F n (%)
8	1 (33.3)	0 (0.0)	1 (8.3)	1 (8.3)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
9	0 (0.0)	2 (66.7)	3 (25.0)	3 (25.0)	0 (0.0)	2 (12.5)	0 (0.0)	0 (0.0)
10	0 (0.0)	0 (0.0)	0 (0.0)	3 (25.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
11	0 (0.0)	0 (0.0)	0 (0.0)	1 (8.3)	2 (12.5)	3 (18.7)	1 (5.3)	1 (5.3)
12	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (12.5)	1 (6.2)	2 (10.5)	3 (15.8)
13	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	3 (18.7)	0 (0.0)	3 (15.8)	2 (10.5)
14	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	3 (18.7)	0 (0.0)	2 (10.5)	3 (15.8)
TOTAL N (%)	1 (33.3)	2 (66.7)	4 (33.3)	8 (66.7)	10 (62.5)	6 (37.5)	8 (42.1)	11 (57.9)
AGE (MEAN ±SD)	8 (0.0)	9 (0.0)	8.75 (0.5)	9.5 (0.9)	12.7 (1.2)	10.5 (1.2)	12.7 (1.0)	12.3 (1.5)

Source: Own Authorship

Table 4 – *Distribution of patients according to the stages of dental mineralization (DM 43), age and gender*

AGE (GROUP)	STAGE 7		STAGE 8		STAGE 9		STAGE 10	
GENDER	M n (%)	F n (%)	M n (%)	F n (%)	M n (%)	F n (%)	M n (%)	F n (%)
8	1 (25.0)	0 (0.0)	1 (9.1)	1 (9.1)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
9	0 (0.0)	3 (75.0)	3 (27.3)	2 (18.2)	0 (0.0)	2 (11.8)	0 (0.0)	0 (0.0)
10	0 (0.0)	0 (0.0)	0 (0.0)	3 (27.3)	0 (0.0)	0 (0.0)	0 (0.0)	2 (11.1)
11	0 (0.0)	0 (0.0)	0 (0.0)	1 (9.1)	2 (11.8)	3 (17.6)	1 (5.6)	1 (5.6)
12	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (11.8)	1 (5.9)	2 (11.1)	3 (16.7)
13	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	4 (13.5)	0 (0.0)	2 (11.1)	1 (11.1)
14	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	3 (17.6)	0 (0.0)	2 (11.1)	3 (16.7)
TOTAL N (%)	1 (25.0)	3 (75.0)	4 (36.4)	7 (63.6)	5 (64,4,)	6 (35.6)	7 (38.9)	11 (61.1)
AGE (MEAN ±SD)	8 (0.0)	9 (0.0)	8.7 (0.5)	9.6 (1.0)	12.7 (1.1)	10.5 (1.1)	12.7 (1.1)	12.3 (1.5)

Source: Own Authorship

Comparing data between genders and maturation methods, it may differ between the male and female genders in relation to CMI ($p < 0.05$). It can be inferred that females show an earlier age for CMI compared to males. There was not a significant difference between genders in relation to the CVM values ($p = 0.06$), and the difference was not statistically significant between genders ($p = 0.26$) for dental mineralization problems in lower canines (33 and 43).

The correlation between bone maturation assessment methods was verified, as well as the correlation of these methods with chronological age, and can be checked in table 5. According to data, a negative correlation was observed only between CVM stages DM stages of DM of tooth 43 in males, and between CVM stages and DM stages of tooth 33 and 43 in females.

Table 5 – *Correlation between CMI, CVM, DM33, DM43 and chronological age*

Gender		CMI		CVM		DM33		DM43	
		r	p	r	p	r	p	r	p
MALE	CMI	1.00	0.00	0.64	0.001	0.57	0.005	0.52	0.01
	CVM	0.64	0.001	1.00	0.000	0.42	0.04	0.36	0.08
	DM33	0.57	0.005	0.42	0.04	1.00	0.000	0.96	0.000
	DM43	0.52	0.01	0.36	0.09	0.96	0.000	1.00	0.000
	Chronological age	0.86	0.000	0.62	0.002	0.57	0.005	0.56	0.005
FEMALE	CMI	1.00	0.000	0.77	0.000	0.66	0.000	0.65	0.000
	CVM	0.77	0.000	1.00	0.000	0.27	0.175	0.27	0.179
	DM33	0.66	0.000	0.27	0.175	1.00	0.000	0.99	0.000
	DM43	0.65	0.000	0.27	0.179	0.99	0.000	1.00	0.000
	Chronological age	0.81	0.000	0.43	0.026	0.75	0.000	0.76	0.000

Source: Own Authorship

Table 6 describes the patients' chronological age and the different bone maturation assessment methods used in the study. It is observed that with na increase of chronological age there is also a tendency for a classification stages increase in the different methods.

Table 6 – *Correspondence between all methods and chronological age*

AGE	CMI		DM33		DM43		CVM	
	Male	Female	Male	Female	Male	Female	Male	Female
8	-1.1	1.6	7.9	7.8	7.9	7.7	0.9	1.6
9	0.1	2.9	8.2	8.2	8.2	8.1	1.2	1.8
10	1.3	4.3	8.5	8.6	8.5	8.6	1.5	2.0
11	2.6	5.7	8.8	9.0	8.8	9.0	1.8	2.3
12	3.8	7.1	9.1	9.5	9.1	9.5	2.1	2.5
13	5.0	8.5	9.5	9.9	9.4	9.9	2.4	2.7
14	6.2	9.8	9.8	10.3	9.7	10.3	2.7	2.9

Source: Own Authorship

Table 7 describes the values of different methods for assessing bone maturation, that is, between CMI, which was used as the gold standard method, CVM and DM methods.

Table 7 – *Correspondence between CMI and CVM and DM (33 and 43) according to gender*

		CVM					DM33				DM43			
		1	2	3	4	5	7	8	9	10	7	8	9	10
CMI	Male	1.4	3.5	5.5	7.6	9.7	-0.5	1.4	3.4	5.3	-0.3	1.6	3.5	5.4
	Female	2.6	4.9	7.2	9.5	11.9	1.8	3.6	5.5	7.4	2.1	3.8	5.6	7.3

Source: Own Authorship

DISCUSSION

The association between different methods of skeletal and dental maturation evaluation has been studied in several populations. Some authors suggested that ethnic origin and factors related to the region, may have an influential role in the evaluation methods (CAMACHO-BASALLO et al., 2017; MAPPES; HARRIS; BEHRENTS, 1992; UYSAL et al., 2006).

Among the methods for assessing craniofacial maturation, the use of cervical vertebrae maturation method has been suggested as a valid replacement for the hand and wrist assessment method (CERICATO; BITTENCOURT; PARANHOS, 2015; FUDALEJ; BOLLEN, 2010; SOUZA-JUNIOR; WANDERLEY-CRUZ, 2009; SZEMRAJ; WOJTASZEK-SŁOMIŃSKA; RACKA-PILSZAK, 2018), which is in concordance with this research results, that demonstrated a substantial level of agreement, while the test values denote an almost perfect level of agreement for most comparisons.

The determination of skeletal age through cervical vertebrae evaluation has proved to be valid and reliable, presenting the same clinical value as the evaluation using hand and wrist method. Its viability is related to the easy visualization of cervical vertebrae (BACCETTI; FRANCHI; MCNAMARA JUNIOR, 2002; SANTOS et al., 2005; VIEIRA et al., 2009).

In this study, the female gender had an earlier age for CMI compared to the male gender. This difference between genders was not observed in relation to the CVM stages (p = 0.06).

The correlation between skeletal maturation assessment methods was verified, as well as the correlation of these methods with chronological age. According to data, the correlation was negative only between CVM stages and DM stages of tooth 43 in males, and between CVM stages and DM stages of tooth 33 and 43 in females.

It was observed that with the increase of chronological age there is also a tendency for the stages increase between the evaluated methods. Considering that CMI gorwth peak occurs in stages 6 and 7, the chronological age corresponding to these stages was approximately 11 to 12 years for females and 14 years for males.

Considering the data obtained from analysis of relation between methods, male non-cleft patients approach the peak in stages 3 of CVM and 10 in DM 33 and 43. For females, the peak approaches in stages 3 of CVM and 9 of DM 33 and 43. The lower canine can be used as an indicator of pubertal growth spurt, since it was observed that when the canine apex is not completely closed, it is a sign that the individual has not yet reached his peak growth in adolescence. In addition, they are easily viewed on panoramic radiographs (COUTINHO et al., 1993; KUMAR, S. et al., 2012).

The cervical vertebrae maturation method adopted in the study, fits the peak growth at levels 2 and 3, with the chronological age corresponding to these stages,

approximately 10 to 12 years for females and 12 to 14 years for males. There was a significant difference (p = 0.03) between genders (p <0.05), with females affecting CVM levels at an earlier age.

Based on all results, we agree with literature that cervical vertebrae maturation method provides the same accurate and simple information as the assessment based on carpal radiographs (CHEN et al., 2010; FUDALEJ; BOLLEN, 2010), which proves to be a useful and applicable method, as it has a statistically significant correlation with the pubertal growth spurt (BACCETTI et al., 2006; DAMIAN et al., 2006; GENEROSO et al., 2003; MOSCATIELLO et al., 2008). However, cervical vertebrae maturation indicators should not be used as an absolute parameter in determining skeletal age (ARMOND; CASTILHO; MORAES, 2001).

Knowing the results obtained, the use of CVM and DM methods can be suggested as aids in determining the degree of growing individuals skeletal maturation. In this way, the results contribute to reinforce the use of radiographs that are part of routine orthodontic documentation, for example, lateral radiographs and panoramic radiographs to estimate the skeletal maturation of growing individuals. In addition to ensuring the health of patients, avoiding exposure to an extra dose of radiation, this procedure simplifies the assessment and reduces the additional cost.

CONCLUSION

There was a correlation between skeletal maturation assessment methods (CMI and CVM) and dental mineralization in patients. Significant differences were observed between genders for skeletal maturity assessment methods (CMI and CVM). There was a relation between the methods used for skeletal maturation and dental mineralization, as well as chronological age.

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