Maturation of cervical vertebrae and chronological age in children and adolescents

Mariela Ramírez-Velásquez[1], Tony J. Viloria- Ávila[2], Dianiris A. Rodríguez[3], María E. Rojas[3], Olga Zambrano[3]

[1] Universidad Católica de Cuenca, Carrera de Odontología, Departamento de Investigación, Azogues, Ecuador.
[2] Universidad Politécnica Salesiana, Carrera de Ingeniería Ambiental, Laboratorio de Radiactividad Ambiental y Toxicología, Cuenca, Ecuador.
[3] Universidad del Zulia, Facultad de Odontología, Posgrado de Ortopedia Maxilar, Venezuela.

ABSTRACT

In maxillary orthopedics and related areas, it is essential to determine patient growth peak in order to provide timely diagnosis and treatments. This requires the use of biological indicators that enable children and adolescents to be assigned to maturation stages. The aim of this study was to determine the correlation between cervical vertebrae maturation stages and chronological age in children and adolescents. In this study were evaluated 93 lateral cranium radiographs of 6- to 17-year-old patients who visited the Postgraduate Maxillary Orthopedics Clinic at the School of Dentistry at Universidad del Zulia. Two examiners made independent assessments of cervical vertebrae maturation stage using the method described by Baccetti et al. For each stage, descriptive statistics for chronological age were evaluated, classified according to sex. In addition, parametric and non-parametric tests were performed in which $p < 0.05$ was considered significant. Mean age of the children and adolescents studied was 9.6 years, with standard deviation 2.5 years. The correlation coefficient ($r=0.771$) certified a high positive correlation between bone maturation and chronological age. This correlation coefficient was highly positive for girls ($r=0.858$) and moderately positive for boys ($r=0.688$). The model obtained explains 59.4 % of the variation between bone maturation and chronological age, evidencing an average age increase of three years when maturation stage increases by approximately 1 year. The results suggest that although the degree of covariance between chronological age and maturation stages was highly positive in this study, chronological age does not allow bone maturation to be determined precisely, since it may be influenced by genetic and/or environmental factors.

Key words: *Cervical vertebrae, age, bone age.*

Maduración de vértebras cervicales y edad cronológica en niños y adolescentes

RESUMEN

En ortopedia maxilar y áreas afines resulta esencial determinar el pico de crecimiento de los pacientes para establecer diagnósticos y tratamientos oportunos para lo cual es necesario utilizar indicadores biológicos, que permiten ubicar a los niños y adolescentes en estadios de maduración. El objetivo de este estudio fue determinar la correlación de los estadios de maduración de las vértebras cervicales según la edad cronológica en niños y adolescentes. Se evaluaron 93 imágenes de radiografías lateral de cráneo, de pacientes entre 6 y 17 años de edad que asistieron a la clínica del Posgrado de Ortopedia Maxilar de la Facultad de Odontología de La Universidad del Zulia, dos examinadores estimaron de forma independiente el estadio de maduración de las vértebras cervicales, utilizando el método descrito por Baccetti et al. y para cada estadio se evaluaron los estadísticos descriptivos de la edad cronológica categorizando según sexo, además se realizaron pruebas paramétricas y no paramétricas donde un $p < 0,05$ fue considerado como significativo. La edad media de los niños y adolescentes estudiados resultó de 9,6 años y una desviación típica de 2,5 años. El coeficiente de correlación ($r=0,771$) certificó una correlación positiva alta entre maduración ósea y edad cronológica, igual producto se obtuvo en el caso de las niños y adolescentes del sexo femenino ($r=0,858$), mientras los del sexo masculino obtuvieron una correlación positiva moderada ($r= 0,688$). El modelo obtenido explica el 59,4 % de la variación entre maduración ósea y edad cronológica, lo cual evidencia el aumento de la edad promedio en tres años, cuando el estadio de maduración aumenta 1 año aproximadamente. Los resultados registrados sugieren que, aunque el grado de covarianza entre edad cronológica y estadios de maduración en esta investigación fue positiva alta, la edad cronológica no permite determinar con exactitud la maduración ósea, pudiendo estar influenciada por factores genéticos y/o ambientales.

Palabras clave: *Vértebras cervicales, edad, edad ósea.*

INTRODUCTION

Throughout human life, the different periods of growth and development involve biological transformations that characterize an individual and are influenced by genetic and environmental factors. The study of craniofacial growth is essential for diagnosis and therapeutic planning in orthodontics and maxillary orthopedics. Some authors[1-5] highlight the need to identify the degree of skeletal maturation in order to begin treatment of certain craniofacial skeletal alterations in a timely manner. Treatments with removable appliances in functional or dentofacial orthopedics during the early developmental stage or during the pubertal phase increase the therapeutic efficacy of the treatment of class II dysgnathia, according to Perinnetti[6] et al. and at dentoalveolar level[7].

Bone maturation is evaluated by means of different biological indicators such as height, weight, chronological age, dental age, carpal x-rays or cervical vertebrae.[8,9]

When the degree of biological maturity is evaluated according to dental, skeletal and chronological age, there may be inconsistencies, and all three indicators are often studied for patient diagnosis. Nevertheless, skeletal age is the most reliable method for determining an individual's physical development.

The determination of growth periods through the evaluation of cervical vertebrae has been supported by Baccetti[10] et al., Haseel[11] et al. and McNamara[1] et al. Other studies criticize the subjective nature of such evaluations[12]. Gray et al.[13] claim that the analysis of cervical vertebrae may be useful for determining whether mandibular growth spurt has occurred.

Bone maturation can be studied in the cervical vertebrae viewed in lateral cephalic radiographs instead of by taking left-hand radiographs, thereby reducing patient exposure to radiation.[14,15]

The study of cervical vertebrae bone maturation is controversial, so further research is needed to contribute more in-depth knowledge to different areas. The aim of the current study was to determine the correlation between cervical vertebrae maturation stages and chronological age, categorized according to sex, in a group of children and adolescents aged 6 to 17 years.

MATERIALS AND METHODS

Patients

One hundred and three (103) patients of both sexes, 6 - to 17-year-old, who attended the clinic in the program "Atención integral del niño y adolescente" (Comprehensive child and adolescent care) of the Postgraduate Degree in Maxillary Orthopedics at the School of Dentistry of University del Zulia (FACOLUZ), Maracaibo City, Zulia State, Venezuela, between March 2012 and June 2016, were selected for this study. Inclusion criteria were: children and adolescents born in Venezuela, with lateral cephalic x-ray of cranium taken at beginning of orthopedic treatment and showing up to fourth cervical vertebra, and complete clinical history. Exclusion criteria were: patients undergoing orthodontic treatment, patients with craniofacial syndromes or malformations, patients with structural problems in cervical vertebrae or related diseases, patients with special healthcare needs, lateral cephalic radiographs with distortion. All parents and/or representatives of the children who participated in the study signed an informed consent after having the purpose of the study explained to them and in accordance with the Ethics Code for Life of the Ministry of Popular Power for Science, Technology and Intermediate Industries of the Bolivarian Republic of Venezuela and the principles of the Declaration of Helsinki.

Study Design

A cross-sectional correlational study was conducted. The selected images were assessed by two raters who made independent assessments of cervical vertebral maturation stage using the method described by Baccetti[10].

A lateral cephalic cranial x-ray is requested as part of the examinations required for the FACOLUZ maxillary orthopedics post-graduate diagnostic protocol. All radiographs were taken at the same radiological center.

Estimation of bone maturation

To estimate the cervical vertebrae maturation, the selected radiographs were digitalized using a SONY DSC-W220 digital camera. To obtain the images, the radiographs were placed on a conventional portable negatoscope, without flash. Subjects' sex and age in years were recorded. Digitalized images were evaluated using Adobe Photoshop software. Brightness, contrast and magnification features were used during assessment. The two raters were trained and calibrated following the method described by Baccetti[10], by evaluating 10 lateral cephalic radiographs of children and adolescents. The Kappa coefficient was calculated, finding intra-rater reliability 0.85 to 0.92 and inter-rater reliability 0.81.

Statistical analysis of results

After obtaining the database on an Excel file, statistical analysis was performed using the IBM SPSS Statistics 24 package. Descriptive statistics were used to obtain frequency tables, contingencies, central tendency measures and dispersion, which enabled adequate interpretation of the set of qualitative and quantitative variables included in the study. Normality assumptions for ages per comparison group were tested using Shapiro-Wilk's test, and equality of variances were tested by Levene's test. In both cases, rejection of the null hypothesis indicated the need to use non-parametric tests to compare age means (Kruskal-Wallis test). All tests used a statistical significance level of 0.05.

RESULTS

A total of 93 child and adolescent lateral cephalic radiographs were included in the study. Ten radiographs were excluded due to problems of image distortion. Of the cephalic radiographs included in the study, 51 were females (54.8%) and 42 males (45.2%). Subject age ranged from 6 to 17 years, with mean age 9.6 years and standard deviation 2.5 years, median and mode 9.0 years. Average age for females was 9.4 years with standard deviation 2.5 years, and average age for males was 9.9 years with standard deviation 2.5 years. Mann-Whitney's U test for comparison of means between girls and boys indicated no significant difference (p =0.332) (Table 1).

Analysis of cervical bone maturation showed that the percentages of children and adolescents in stages I, II, III, IV and V were 33.3%, 28.0%, 24.7%, 10.8% and 3.2%, respectively.

Bone maturation stages according to sex were similar to those described above. For stage I, percentage was 33.3% for both girls and boys, decreasing progressively up to stage V, where it was 3.9% for girls and 2.4% for boys (Table 1).

The chi-square test applied to determine the association between the variables, 'sex' and 'bone maturation stage' showed independence between these variables (p=0.489). This result needs to be interpreted with caution considering that in cross tabulation, more than 20% of the expected frequencies were lower than 5.

The average difference between the mean values for chronological ages was 1.5 years between stages I, II and III, and 2.4 years between stages III, IV and V (Table 2).

Considering that at each stage (I, II, III, IV, V) the number of subjects is approximately 30 (in stage I) or lower than 30 (Table 2), Shapiro-Wilk's test was used to test the normality assumption for ages in each group, finding that age distribution is not normal at all stages. Levene's test for the assumption of homogeneity of variances found p=0.010, therefore the null hypothesis was rejected and variances considered unequal.

The Kruskal-Wallis test to determine variability of mean chronological ages among the different stages showed that they differ significantly (p<0.001).

The dispersion diagram (Fig. 1) relating chronological age to the different stages of cervical maturation shows that bone age increases as chronological age increases in the children and adolescents of both sexes studied, reflecting a positive correlation between these variables. Pearson's correlation coefficient (r=0.771) shows a positive correlation between

Table 1: Mean values for ages and cervical bone maturation stages according to sex.

Girls		Boys		P-value
Mean	Standard deviation	Mean	Standard deviation	
9.4	2.5	9.9	2.5	0.332
STAGE	**N**	**%**	**N**	**%**
I	17	33.3	14	33.3
II	13	25.5	13	31.0
III	11	21.6	12	28.6
IV	8	15.7	2	4.7
V	2	3.9	1	2.4
TOTAL	51	100.0	42	100.0

Table 2: Maturation stages and chronological age in children and adolescents studied.

Stage	N	Mean chronological age	Standard deviation
I	31	7.71	1.296
II	26	9.04	1.865
III	23	10.61	1.699
IV	10	13.00	1.491
V	3	15.33	2.082

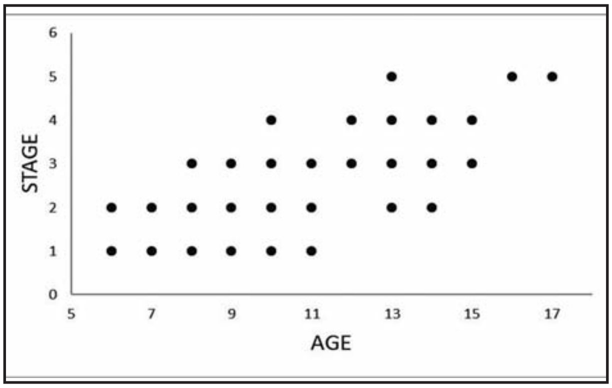

Fig. 1: Dispersion diagram for the variables chronological age and bone age.

these two variables, and was highly positive for girls (r=0.858), and moderately positive for boys (r= 0.688).

A simple linear correlation model was obtained between chronological age and bone age. The result of the ANOVA test ($p < 0.05$) indicated the possibility of constructing a linear regression model with these two variables, with the following predictive model:

STAGE = -1.07 + 0.34·AGE

According to Pearson's correlation coefficient (r), the correlation between chronological age and cervical bone maturation stage in this model is moderate, while the coefficient of determination (R^2) indicates that the model can predict 59.4% of the variability of the stage through the variability of chronological age. Moreover, the equation indicates that when chronological age is increased by one year, stage will vary by 0.34 years.

For female subjects, the correlation between chronological age and bone age was highly positive, while for males it was moderately positive. The linear model obtained for females predicts 73.6% of the variability of bone maturation through chronological age, while for males it predicts 47.4%. The linear regression model for females and males can be seen in the following equations, respectively.

STAGE = -1.545 + 0.411·AGE
STAGE = 0.277·AGE

DISCUSSION

The results of this study on 93 children and adolescents show great variability regarding age and sex in the different maturation stages. The percentages for the whole sample decrease successively as bone maturation increases, as do the percentage of males and females independently. Similar results were reported in the study by Plazas[16].

The Chi square test applied to determine the association between the variables sex and bone maturation stage provided a non-statistically significant result (p=0.489), thereby demonstrating independence between these variables. Similar results were reported by Bedoya[17] (p= 0.120), who found no association between those variables.

The results of the current study show that bone age increases as in chronological age of children and adolescents of both sexes increases, with a highly positive correlation between the variables, expressed with the result of Pearson's correlation coefficient r=0.771. When the samples of both sexes were studied separately, the correlation was highly positive for females, r=0.858 and moderately positive for males, r= 0.688.

Considering the results reported by Bedoya[17], with a highly positive correlation (r= 0.69), the results reported by Seyed[18] in a study on 196 females aged 9 to 14 years, with a low correlation (r=0.62) between chronological age and cervical maturation stage, and adding the results of the current study regarding Pearson's correlation coefficient, it can be inferred that even though the degree of covariance between the variables 'chronological age' and 'maturation stages' in the current study was highly positive, chronological age does not enable bone maturation to be determined precisely as reported by Bedoya[17].

The paper by Bedoya[17] highlights the fact that the values of maturation stage increase as chronological age increases in both sexes, in agreement with the current study. However, according to Bedoya[17], Tukey's post-hoc test indicates that this occurs only up to stage 3. In the current study, the non-parametric tests used did not allow this type of analysis to be performed.

The model obtained in the current study explains 59.4 % of the variation in maturation stage and chronological age, showing that when average age increases by three years, bone maturation stage increases by approximately 1 year, in contrast to other studies[17] which explain 50.4 % of the variability in chronological age in children and adolescents.

The results of the current study show that female children and adolescents attained higher maturation stages at earlier ages, in agreement with Bedoya[17].

CONCLUSIONS

There is no association between sex and bone maturation stage.

There is a positive correlation between chronological age and cervical bone maturation stages. Bone age increases as chronological age increases. For girls, the correlation was highly positive, while for boys it was moderately positive.

This study shows once again that girls attain bone maturation stages at earlier ages than boys do.

FUNDING

None

CORRESPONDENCE

Dr. Mariela Ramírez
Carrera Odontología Universidad Católica de Cuenca,
Sede Azogues.
Av 16 de abril, Azogues, Ecuador
mramirezv@ucacue.edu.ec

REFERENCES

1. McNamara JrJA, Franchi L. The cervical vertebral maturation method: A user's guide. The Angle Orthodontist 2018; 88: 133-143.
2. McNamara JrJA, Bookstein FL, Shaughnessy TG. Skeletal and dental changes following functional regulator therapy on Class II patients. Am J Orthod. 1985; 88:91-110.
3. Franchi L, Baccetti T. New emphasis on the role of mandibular skeletal maturity in dentofacial orthopedics. In: McNamara JA Jr, ed. The Enigma of the Vertical Dimension. Ann Arbor, Mich: Monograph 36, Craniofacial Growth Series, Center for Human Growth and Development, University of Michigan; 2000. URL: https://www.worldcat.org/title/enigma-of-the-vertical-dimension/oclc/44555829
4. Baccetti T, Franchi L, McNamara Jr JA. The Cervical Vertebral Maturation (CVM) method for the assessment of optimal treatment timing in dentofacial orthopedics. Semin Orthod. 2005; 11: 119-129. URL: https://www.dent.umich.edu/sites/default/files/departments/opd/193.pdf
5. Mehrmaz M., Nazanin B. Determination of developmental stage of cervical vertebrae at menarche in a female orthodontic patients in Ahwaz. Int J Med Res Health Sci. 2016; 5: 206-210. URL: https://www.ijmrhs.com/medical-research/determination-of-developmental-stage-of-cervical-vertebrae-at-menarche-in-female-orthodontic-patients-in-ahwaz.pdf
6. Perinetti G, Primozic J, Franchi L, Contardo L. Treatment effects of removable functional appliances in pre-pubertal and pubertal Class II patients: a systematic review and metaanalysis of controlled studies. PLoS One. 2015; 10: e0141198
7. Koretsi V, Zymperdikas VF, Papageorgiou SN, Papadopoulos MA. Treatment effects of removable functional appliances in patients with Class II malocclusion: a systematic review and meta-analysis. Eur J Orthod. 2015;37:418-34.
8. Valizadeh S, Nakissa E, Sara E, Hooman B. Correlation Between Dental and Cervical Vertebral Maturation in Iranian Females. Iran J Radiol 2013;10:1-7. URL: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3618898/
9. Litsas G, Lucchense A. Dental and Chronological Ages as Determinants of Peak Growth period and Its Relationships with dental calcification stages. Open Dental J. 2016;10:99-108.
10. Baccetti T, Franchi L, McNamara JA. An improved version of the cervical vertebral maturation (CVM) method for the assessment of mandibular growth. Angle Orthod 2002; 72: 316-323.
11. Hassel B, Farman AG. Skeletal maturation evaluation using cervical vertebrae. Am J Orthod Dentofacial Orthop 1995; 107:58-66.
12. Nestman TS, Marshall SD, Holton N, Franciscus RG, et al. Cervical vertebrae maturation method morphologic criteria: poor reproducibility. Am J Orthod Dentofacial Orthop 2011;140:182-188.

13. Gray S, Bennan H, Kieser JA., Farella M. Morphometric analysis of cervical vertebrae in relation to mandibular growth. Am J Orthod Dentofacial Orthop , 2016;149: 92-98.
14. Cericato GO, Bittencourt MA, Paranhos LR. Validity of the assessment method of skeletal maturation by cervical vertebrae: A systematic review and meta-analysis. Dentomaxillofac Radiol. 2015; 44:20140270. URL: https://www.ncbi.nlm.nih.gov/pmc/articles/ MC4628429/
15. Szemraj A, Wojtaszek-Słomińska A, Racka-Pilszak B. Is the cervical vertebral maturation (CVM) method effective enough to replace the hand-wrist maturation (HWM) method in determining skeletal maturation? A systematic review. Eur J Radiol. 2018; 102:125-128.
16. Plazas RJE, Martínez BO, López PJ, Franco MT, et al. Determinación de los estadios de maduración esquelética por medio de análisis de Bacceti. Salud, Barranquilla 2015; 31: 228-233.
URL: http://www.redalyc.org/pdf/817/ 81742138003.pdf
17. Bedoya RA, Osorio PJC, Tamayo CJA. Edad cronológica y maduración ósea cervical en niños y adolescentes. Rev cubana Estomatol. 2016; 53: 43-53.
URL:http://scielo.sld.cu/scielo.php?script=sci_arttext&pid =S0034-75072016000100006
18. Seyed MS, Hanie B, Raheleh H, Farnaz Y, et al. Correlation between cervical vertebral maturation and chronological age in a group of Iranian females. Dent Res J (Isfahan). 2015; 12 (5):443-448.
URL: https://www.ncbi.nlm.nih.gov/pmc/articles/ PMC4630708/