SYSTEMATIC REVIEW

Validity of the assessment method of skeletal maturation by cervical vertebrae: a systematic review and meta-analysis

¹G O Cericato, ²M A V Bittencourt and ³L R Paranhos

¹School of Dentistry, IMED, Passo Fundo, Rio Grande do Sul, Brazil; ²School of Dentistry, Federal University of Bahia, Salvador, Bahia, Brazil; ³Dentistry Department of Lagarto, Federal University of Sergipe, Sergipe, Brazil

Objectives: To perform a systematic review with meta-analysis to answer the question: is the cervical vertebrae maturation index (CVMI) effective to replace hand–wrist radiograph (gold standard) in determining the pubertal growth spurt in patients undergoing bone growth?

Methods: A search in three databases was performed, in which studies were selected that compared one of the two main assessment methods for cervical vertebrae (Hassel B, Farman AG. Skeletal maturation evaluation using cervical vertebrae. *Am J Orthod Dentofacial Orthop* 1995; **107**: 58–66, or Baccetti T, Franchi L, McNamara JA Jr. An improved version of the cervical vertebral maturation (CVM) method for the assessment of mandibular growth. *Angle Orthod* 2002; **72**: 316–23) to a carpal assessment method. The main methodological data from each of the texts were collected and tabulated after. Later, the meta-analysis of the correlation coefficients obtained was performed.

Results: 19 articles were selected from an initial 206 articles collected. Regardless of the method used, the results of the meta-analysis showed that every article selected presented a positive correlation between skeletal maturation assessment performed by cervical vertebrae and carpal methods, with discrepancy of values between genders indicating higher correlation for the female gender (0.925; 0.878) than for the male (0.879; 0.842). When the assessment was performed without gender separation, correlation was significant (0.592; 0.688) but lower in the cases when genders were separated.

Conclusions: With the results of this meta-analysis, it is safe to affirm that both CVMI used in the present study are reliable to replace the hand–wrist radiograph in predicting the pubertal growth spurt, considering that the highest values were found in female samples, especially in the method by Hassel and Farman.

Dentomaxillofacial Radiology (2015) **44**, 20140270. doi: 10.1259/dmfr.20140270

Cite this article as: Cericato GO, Bittencourt MAV, Paranhos LR. Validity of the assessment method of skeletal maturation by cervical vertebrae: a systematic review and meta-analysis. *Dentomaxillofac Radiol* 2015; **44**: 20140270.

Keywords: cervical vertebrae; hand–wrist; skeletal maturation; skeletal age assessment

Introduction

Growth and development of the human being is a phenomenon that happens naturally and has acceleration periods that are called growth spurts.^{1,2} From these, the most used and availed in orthodontic treatment is perhaps the one occurring during puberty, also known as pubertal growth spurt (PGS).^{3,4} Chronological age has

not proved to be the most reliable method to determine the biological maturity level of the individual, so other indicators are recommended to assess the development stage in which the individual lies.^{3,5}

The most popularly known assessment method of the PGS is the one that uses carpal radiograph and skeletal changes that occur in the hand and wrist region, including the gradual appearance of carpal bones and changes in fusions among epiphyses and diaphyses of the phalanges

Correspondence to: Graziela Oro Cericato. E-mail: gracericato@ig.com.br

Received 5 August 2014; revised 25 November 2014; accepted 17 December 2014

Table 1 Strategies for database search

<i>MeSH</i> search terms	<i>Database</i>			
	<i>PubMed</i>	<i>ScienceDirect</i>	<i>SciELO</i>	<i>Total</i>
“Cervical Vertebrae”	36	153	X	189
[MeSH] AND “Hand-wrist” AND “Skeletal Maturation” OR “Cervical Vertebrae” AND “Hand-wrist” AND “Skeletal Age Assessment”				
[MeSH] OR “Cervical Vertebrae” AND “Hand-wrist” AND “Maturation”	X	X	17	17
“Cervical” AND “Vertebrae” AND “Maturation”				
Total	36	153	17	206

of the fingers.^{4,6} However, although this is a reliable method that requires low doses of radiation, it is an additional examination to the orthodontic documentation, and thus an additional exposure to the patient. This goes against the principles of as low as reasonably achievable for ionizing radiation, which aims to minimize the doses that patients and workers are exposed to.^{4,7}

A more recent method to assess the PGS is the one that uses changes in shape and level of development of the cervical vertebrae C2, C3 and C4, the images of which show up on the profile telerradiographs—a routine test in clinical orthodontic practice.^{8,9} Thus, the most used methods are the ones developed by Hassel and Farman,¹⁰ and Baccetti *et al.*¹¹ A distinct advantage of the assessment of cervical maturity is that it does not imply additional exposure to radiation.⁹ Therefore, if proved that carpal and cervical vertebrae methods present high correlation, an additional radiograph to assess skeletal maturation would not be needed, and such a request would not be justified.^{2,7}

Thus, this work aimed to perform a systematic review and meta-analysis to answer the question: is the cervical vertebrae maturation index effective to replace hand-wrist radiographs (gold standard) in determining the PGS in patients undergoing bone growth?

Methods and materials

Search strategy and eligibility criteria

To perform this work, a systematic search in literature was performed with no language restriction to identify relevant studies. Databases used were ScienceDirect, PubMed and SciELO. A search filter for the last 10 years was applied, with the aim to work with the most updated literature on the subject. Keywords used for the search were “cervical vertebrae”, “hand-wrist”, “skeletal maturation” and “skeletal age assessment”, as shown in Table 1.

The selection of studies included either cross-sectional or descriptive longitudinal studies, written in Portuguese, Spanish or English, that qualitatively or quantitatively compared the two main assessment methods of skeletal maturation of the cervical vertebrae (Hassel and Farman¹⁰ method and method of Baccetti *et al.*¹¹) to the carpal assessment method, considered the gold standard.

Excluded from the selection were studies with samples made by unhealthy patients (patients with obesity, syndromes, cleft lip/palate, idiopathic scoliosis and other deformities), studies introducing a modified version of the cervical vertebrae method, abstracts, dissertations and/or theses, patents, convention abstracts, opinion articles, commentaries and editorials.

Initially, titles and abstracts of articles were identified, and when this information could not be collected solely based on the abstract, the full text of the scientific article was searched. Cases of publication duplicity in more than one of the databases consulted were only considered once. After the initial selection, the full texts were recovered for an assessment of the methodological strength by two reviewers for eligibility. The reviewers were not blinded to the authors or journals.

Data extraction

Using a standardized data extraction sheet, the following information was extracted and recorded from the studies: authors, year of publication, size and characteristics of the sample, age, assessment method of skeletal maturation by cervical vertebrae used as gold standard, inter- and intraexaminer correlation test used and correlation value between both methods assessed—these data were tabulated in a worksheet for later analysis. Moreover, each study received a score and was considered to be of low quality (0–5 points), medium quality (6–8 points) or high quality (9–11 points)—evaluation made from an adaptation by Santiago *et al.*¹² (Table 2). The studies considered low quality were held as methodologically poor and were discarded. Disagreements between the reviewers were solved through a group reassessment of the article, until both reviewers were satisfied with the decision.

The study design was considered adequate when it was either cross-sectional or longitudinal, in which the

Table 2 Quality scoring rubric for articles included in initial review, as suggested by Santiago *et al.*¹²

<i>Selection criteria</i>	<i>Score</i>
Adequate study design	3 points
Adequate presentation of objectives	1 point
Adequate sample size	1 point
Adequate description of sample selection process and sample losses	1 point
Presentation of keywords inserted in MeSH	1 point
Method used for error analysis	1 point
Valid statistical methodology	1 point
Clear and objective presentation of results	1 point
Declared <i>p</i> -value	1 point

Table 3 Criteria for exclusion after initial review

Reason for exclusion	PubMed (n = 36)	ScienceDirect (n = 153)	SciELO (n = 17)	Total
Exclusive use of VMI or CMI	6	12	2	20
Use of other VMI methods	5	5	3	13
Use of dental methods	1	9	1	11
Inadequate samples (syndromes, metabolic diseases)	1	2	0	3
Literature and/or systematic reviews	1	8	0	9
Articles in Chinese or French	1	2	0	3
Absence of correlation between VMI and CMI	4	3	2	9
Use of CT	1	3	0	4
Letters from the editor, opinion articles, abstracts for conferences	0	30	0	30
Other (glossary, indexes, appendices, bibliographies, responses to the authors, book chapters, handbooks)	0	70	6	76
Total exclusions	20	144	14	178
Articles included	16	9	3	28

CMI, hand-wrist maturation index; VMI, vertebral maturation index.

conclusion clearly met the objectives. The sample was considered adequate when it mentioned the proper description of age and gender, ethnicity, systemic health problems, clearly excluding any growth or nutritional problem; any other condition, that is, drug use, which may change teeth and skeletal maturation; with no history of orthodontic treatment and size definition by sample calculation.

The use of method for error analysis was considered valid when mentioning the performance of intra-examiner or interexaminer correlation tests, regardless of the mention of the *p*-value, and the test used. The

statistical methodology was considered valid when Pearson's or Spearman's correlation tests were presented between both assessment methods studied (vertebral and carpal).

Data analysis

Later, the meta-analysis of the correlation coefficients obtained was performed to analyse the results obtained in the studies that were part of the review. Calculations were performed in the program MedCalc v. 12.7.8 (MedCalc Software, Ostend, Belgium).

Figure 1 Statement flowchart of article selection process.

Table 4 Main characteristics of articles included in the study

Study	Article score	VMI	CMI	Sample (n)	Age (years)	Correlation intra	Correlation inter
Damian et al ¹³	9	HF	Grave and Brown	105	7–18	0.939 ^a ; 0.804 ^b	0.948 ^a ; 0.779 ^b
Flores-Mir et al ⁶	8	BFM	Fishman	79	ND	0.985 ^a ; 0.889 ^b	NP
Gandini et al ¹	9	BFM	Bjork	30	7–18	VNP	NP
Grippaudo et al ¹⁴	8	BFM	Grave and Brown	90	6–14	NP	NP
Kamal et al ¹⁵	9	HF	Fishman	50	10–12	0.81	NP
Ozer et al ²	9	HF	MP3	150	9–19	0.98 ^b ; 0.966 ^a	NP
Uysal et al ¹⁶	9	HF	Bjork	503	5–24	0.955 ^b ; 0.983 ^a	0.987 ^b ; 1.00 ^a
Alkhal et al ³	9	BFM	Fishman	400	10–17	0.846	0.846
Lai et al ⁴	9	BFM	NTUH	709	8–18	0.933	0.90
Moscatiello et al ¹⁷	8	BFM	Greulich and Pyle	140	4–14	NP	NP
Kapoor et al ⁵	9	HF	Fishman	90	9–12	VNP	NP
Wong et al ¹⁸	9	BFM	MP3	400	10–17	0.574 ^b ; 0.083 ^a	0.161
Litsas and Ari-Dermikaya ⁸	9	BFM	Grave and Brown	393	8–18	0.160 ^b ; 1.00 ^a	NP
Warmeling et al ¹⁹	10	BFM	Martins	158	6–18	0.80	NP
Mahajan ²⁰	9	HF	Fishman	100	8–18	VNP	NP
Sachan et al ²¹	9	HF	Fishman	90	9–13	VNP	NP
Shim et al ⁷	10	HF	Fishman	62	11–17	0.997 ^a ; 0.844 ^b	0.983 ^a ; 0.877 ^b
Navlani and Makhija ⁹	8	BFM	MP3	120	8–16	NP	NP
Prasad et al ²²	8	HF	MP3	200	10–19	NP	NP

BFM, Baccetti et al;¹¹ HF, Hassel and Farman;¹⁰ MP3, phalanx average third finger method; ND, not declared; NP, not performed. NTUH, National Taiwan University Hospital skeletal maturation index; VNP, test performed, but value not presented.

^aValues related to the carpal method used in the study.

^bValues related to the vertebral method used in the study.

Results

Initial research resulted in a sample comprising 206 articles. After analysing them according to the inclusion and exclusion criteria, 16 articles were selected in the PubMed database, 9 articles in the ScienceDirect database and 3 articles in the SciELO database. The main reasons for exclusion are shown in Table 3 and Figure 1.

From the 28 articles selected, 5 were excluded because of duplicity in the PubMed and ScienceDirect databases, 3 were excluded for receiving a methodological score between 0 and 5 points (low quality) and 1 article was excluded because it was simultaneously published in 2 journals. Thus, the total sample was 19 articles, as shown in Table 4.

Regarding the cervical assessment method selected, nine articles used Hassel and Farman,¹⁰ and ten articles used Baccetti et al.¹¹ Regardless of the method used, the results of the meta-analysis of this work (Tables 5–10, Figures 2 and 3) showed that every article selected presented a positive correlation between the maturation assessments performed by both methods and the assessment methods that

used the hand–wrist radiographs (gold standard), with discrepancy of values between genders.

Because they were different methods, the statistical analyses of the meta-analysis were separated according to the vertebral method and gender used in the sample.

Regarding the sample, from ten articles that used the method by Baccetti et al,¹¹ seven used samples separated by gender so as to assess the correlation between carpal and vertebral indexes and three articles presented no gender distinction for analysis (Tables 5–7, Figure 2). The results indicate higher correlation for the female gender (0.878) than for males (0.842). When the assessment was performed without gender separation, correlation was significant (0.688) but lower than for the cases when genders were separated.

Nine articles that used the method by Hassel and Farman¹⁰ were assessed in the same way. Thus, two articles presented no gender distinction for analysis, six articles used samples separated by gender and one article used an exclusively male sample (Tables 8–10, Figure 3). The results also indicated higher correlation for the female gender (0.925) than for males (0.879).

Table 5 Values obtained in studies and meta-analysis results for the method by Baccetti et al¹¹ and male gender

Study	n	r	Confidence interval 95%
Grippaudo et al ¹⁴	48	0.700	0.519–0.821
Alkhal et al ³	200	0.920	0.896–0.939
Lai et al ⁴	330	0.910	0.889–0.927
Moscatiello et al ¹⁷	66	0.507	0.302–0.667
Wong et al ¹⁸	200	0.952	0.937–0.963
Litsas and Ari-Dermikaya ⁸	170	0.846	0.797–0.884
Navlani and Makhija ⁹	60	0.693	0.533–0.805
Meta-analysis	1074	0.842	0.733–0.909

Table 6 Values obtained in studies and meta-analysis results for the method by Baccetti et al¹¹ and female gender

Study	n	r	Confidence interval 95%
Grippaudo et al ¹⁴	42	0.840	0.720–0.911
Alkhal et al ³	200	0.936	0.916–0.951
Lai et al ⁴	379	0.937	0.923–0.948
Moscatiello et al ¹⁷	74	0.731	0.603–0.822
Wong et al ¹⁸	200	0.940	0.921–0.954
Litsas and Ari-Dermikaya ⁸	223	0.716	0.645–0.775
Navlani and Makhija ⁹	60	0.861	0.777–0.915
Meta-analysis	1178	0.878	0.789–0.930

Table 7 Values obtained in studies and meta-analysis results for the method by Baccetti *et al*¹¹ with no gender distinction

Study	n	r	Confidence interval 95%
Flores-Mir <i>et al</i> ⁶	79	0.720	0.593–0.812
Gandini <i>et al</i> ¹	30	0.783	0.589–0.892
Warmeling <i>et al</i> ¹⁹	158	0.616	0.509–0.704
Meta-analysis	267	0.688	0.579–0.772

When the assessment was performed without gender separation, correlation was significant (0.592) but lower than for the cases when genders were separated. Furthermore, it is possible to observe that in the analyses with samples separated by gender, the values found when using the method by Hassel and Farman¹⁰ are higher in relation to the method by Baccetti *et al*,¹¹ considering this relation is inverted when the sample had no gender distinction.

Discussion

Cervical vertebrae, which are many times ignored by orthodontists who are not familiar to its analysis, have been increasingly used to assess skeletal maturation of the individual because it comprises an easy assessment method and eliminates the need for an additional radiograph (hand and wrist) for such ends. This work aimed to perform a systematic review and meta-analysis of the literature to verify the correlation between the two main vertebral indexes mentioned in literature and carpal assessment, by answering a question developed with the patient, intervention, comparison, outcomes (PICO) strategy.

It is important to stress the care that must be taken while applying the results presented in this systematic review, for although 14^{1–5,7,8,13,15,16,18–21} out of the 19 articles selected had received a score of either 9 or 10 (high quality), most of them work with convenience samples. Another limitation concerns the cutbacks of articles, considering that there are almost no studies with longitudinal assessment. Most articles use files from either courses or smaller samples owing to the radiographic exposure required to collect data. These cross-sectional studies present limitations regarding growth analysis, since it is relatively insensitive to individual variability. In this

Table 8 Values obtained in studies and meta-analysis results for the method by Hassel and Farman¹⁰ and male gender

Study	n	r	Confidence interval 95%
Kamal <i>et al</i> ¹⁵	25	0.892	0.767–0.952
Ozer <i>et al</i> ²	150	0.893	0.855–0.921
Uysal <i>et al</i> ¹⁶	213	0.780	0.721–0.828
Kapoor <i>et al</i> ⁵	45	0.849	0.740–0.915
Mahajan ²⁰	50	0.981	0.967–0.989
Sachan <i>et al</i> ²¹	45	0.849	0.740–0.915
Prasad <i>et al</i> ²²	100	0.727	0.619–0.808
Meta-analysis	628	0.879	0.787–0.933

Table 9 Values obtained in studies and meta-analysis results for the method by Hassel and Farman¹⁰ and female gender

Study	n	r	Confidence interval
Kamal <i>et al</i> ¹⁵	25	0.858	0.700–0.936
Uysal <i>et al</i> ¹⁶	290	0.880	0.851–0.904
Kapoor <i>et al</i> ⁵	45	0.932	0.879–0.962
Mahajan ²⁰	50	0.975	0.956–0.986
Sachan <i>et al</i> ²¹	45	0.932	0.879–0.962
Prasad <i>et al</i> ²²	100	0.910	0.869–0.939
Meta-analysis	555	0.925	0.881–0.953

sense, longitudinal research would be the most indicated method for the detailed study of craniofacial growth, through which it would be possible to determine the type of development of the patient. Thus, it is suggested that longitudinal studies are performed in different populations, allowing a deeper understanding about the use of cervical vertebrae as an indicator of skeletal maturation.

A great inquiry regarding the validity of the cervical vertebrae method is about its reproducibility. From the 19 articles included in this study, most of them^{1,2,5,6,8,9,14,15,17,19–22} did not perform interexaminer statistical tests. However, in cases when this test was applied, the results showed significant correlations. Hence, further studies with the goal to assess the reproducibility of the method are required along with different dentistry expertise, aiming to obtain more knowledge about this subject that has not yet been clarified.

Another important aspect is the great variety of assessment methods of skeletal maturation by cervical vertebrae, including simple qualitative analysis of the vertebral shape, quantitative measurements of the vertebral shape (some limited to height and width) and depth of lower concavity, and others with more specific measurements performed through either morphometric analyses or linear regression. The results of this study refer to methods by Hassel and Farman¹⁰ and Baccetti *et al*,¹¹ both subjective methods of visual assessment of vertebrae C3 and C4 shapes, and the existence of lower concavity in C2, C3 and C4 vertebral bodies, since these two methods are the most used in literature, thus considerably increasing the possibilities of article search on the subject.

The authors investigated are unanimous in affirming that chronological age is not a good indicator to assess the rate of skeletal maturation of the individual and that vertebral methods may be used instead of carpal ones.^{1–22} Thus, the results of the meta-analysis of this work showed that every article

Table 10 Values obtained in studies and meta-analysis results for the method by Hassel and Farman¹⁰ with no gender distinction

Study	n	r	Confidence interval 95%
Damian <i>et al</i> ¹³	105	0.625	0.492–0.729
Shim <i>et al</i> ⁷	62	0.530	0.323–0.689
Meta-analysis	167	0.592	0.483–0.683

Figure 2 Values obtained in the studies and meta-analysis result for male gender, female gender and no gender distinction with Baccetti et al.¹¹

selected presented positive correlation between the two assessment methods of skeletal maturation, with discrepancy of values between genders. Regardless of the method used, the correlation values found by meta-analysis were higher for the female gender (0.878 for Baccetti et al.¹¹ and 0.925 for Hassel and Farman¹⁰) than for males (0.842 for Baccetti et al.¹¹ and 0.879 for Hassel and Farman¹⁰). In cases where genders were not separated, correlations found were lower (0.688 for Baccetti et al.¹¹ and 0.592 for Hassel and Farman¹⁰).

Some studies^{1–3,8,14,20–22} highlight the need for special attention concerning gender distinction during the peak of the PGS, since the female gender always shows an advance regarding chronological age. Hence, in the present study care was taken to separate genders whenever possible, so as to perform the meta-analysis. The highest correlation found was for the female gender when using the method by Hassel and Farman.¹⁰ Perhaps, this might be explained by the fact that both vertebral methods used as inclusion criteria come from the Lamparski method (1972)—mentioned by Hassel and Farman,¹⁰ the first authors to describe the use of cervical vertebrae to assess skeletal maturation using an exclusively female sample to develop the method. The fact that correlation values were lower when samples were not separated ($n = 5$) could

probably be explained by the small number of studies using a mixed sample.

The great advantage presented by the authors is the lack of need to require an additional radiograph,^{1–22} since cervical vertebrae are visualized in profile tele-radiographs, which is part of the basic orthodontic documentation.^{3,8} Yet, several authors^{5–7,15,16,18–21} mention that the visualization of the vertebrae by orthodontists is more easily performed owing to the familiarity of these professionals with this type of radiograph.

Conclusion

Based on the results found, it is safe to affirm that both cervical vertebrae maturation indexes used in the present study are reliable to replace the hand–wrist radiographs in predicting the PGS, considering the highest values were found in female samples, especially in the method by Hassel and Farman.¹⁰ However, questions such as reproducibility of the methods assessed and the possibility of assessing growth and development of the individual has not yet been clarified, so the elaboration of more specific studies for elucidation are required.

Figure 3 Values obtained in the studies and meta-analysis result for male gender, female gender and no gender distinction with Hassel and Farman.¹⁰

References

- Gandini P, Mancini M, Andreani F. A comparison of hand-wrist bone and cervical vertebral analyses in measuring skeletal maturation. *Angle Orthod* 2006; **76**: 984–9.
- Ozer T, Kama JD, Ozer SY. A practical method for determining pubertal growth spurt. *Am J Orthod Dentofacial Orthop* 2006; **130**: 131e 1–6.
- Alkhal HA, Wong RW, Rabie AB. Correlation between chronological age, cervical vertebral maturation and fishman's skeletal maturity indicators in Southern chinese. *Angle Orthod* 2008; **78**: 591–6. doi: [10.2319/0003-3219\(2008\)078\[0591:CBCACV\]2.0.CO;2](https://doi.org/10.2319/0003-3219(2008)078[0591:CBCACV]2.0.CO;2)
- Lai EH, Liu JP, Chang JZ, Tsai SJ, Yao CC, Chen MH, et al. Radiographic assessment of skeletal maturation stages for orthodontic patients: hand-wrist bones or cervical vertebrae? *J Formos Med Assoc* 2008; **107**: 316–25.
- Kapoor DN, Sachan K, Sharma VP, Tandon P. A correlative study of dental age and cervical vertebrae maturation. *J Pierre Fauchard Acad (India Section)* 2009; **23**: 125–32.
- Flores-Mir C, Burgess CA, Champney M, Jensen RJ, Pitchere MR, Major PW. Correlation of skeletal maturation stages determined by cervical vertebrae and hand-wrist evaluations. *Angle Orthod* 2006; **76**: 1–5.
- Shim JJ, Bogowicz P, Heo G, Lagraverre MO. Interrelationship and limitations of conventional radiographic assessments of skeletal maturation. *Int Orthod* 2012; **10**: 135–47. doi: [10.1016/j.ortho.2012.03.007](https://doi.org/10.1016/j.ortho.2012.03.007)
- Litsas G, Ari-Demirkaya A. Growth indicators in orthodontic patients. Part 1: comparison of cervical vertebral maturation and hand-wrist skeletal maturation. *Eur J Paediatr Dent* 2010; **11**: 171–5.
- Navlani M, Makhija PG. Evaluation of skeletal and dental maturity indicators and assessment of cervical vertebral maturation stages by height/width ratio of third cervical vertebra. *J Pierre Fauchard Acad (India Section)* 2013; **27**: 73–80.
- Hassel B, Farman AG. Skeletal maturation evaluation using cervical vertebrae. *Am J Orthod Dentofacial Orthop* 1995; **107**: 58–66.
- Baccetti T, Franchi L, McNamara JA Jr. An improved version of the cervical vertebral maturation (CVM) method for the assessment of mandibular growth. *Angle Orthod* 2002; **72**: 316–23.
- Santiago RC, de Miranda Costa LF, Vitral RW, Fraga MR, Bolognese AM, Maia LC. Cervical vertebral maturation as a biologic indicator of skeletal maturity. *Angle Orthod* 2012; **82**: 1123–31. doi: [10.2319/103111-673.1](https://doi.org/10.2319/103111-673.1)
- Damian MF, Woitchunas FE, Cericato GO, Cechinato F, Moro G, Masochin ME, et al. Reliability and correlation analysis of two skeletal maturation evaluation indexes: hand-wrist index and cervical vertebrae index. *Dental Press Ortodon Ortop Facial* 2006; **11**: 110–20.
- Grippaudo C, Garcovich D, Volpe G, Lajolo C. Comparative evaluation between cervical vertebral morphology and hand-wrist morphology for skeletal maturation assessment. [In Italian.] *Minerva Stomatol* 2006; **55**: 271–80.
- Kamal M, Ragini, Goyal S. Comparative evaluation of hand wrist radiographs with cervical vertebrae for skeletal maturation in 10-12 years old children. *J Indian Soc Pedod Prev Dent* 2006; **24**: 127–35.
- Uysal T, Ramoglu SL, Basciftci FA, Sari Z. Chronologic age and skeletal maturation of the cervical vertebrae and hand-wrist: is there a relationship? *Am J Orthod Dentofacial Orthop* 2006; **130**: 622–8.
- Moscatiello VAM, Lederman H, Moscatiello RA, Faltin Júnior K, Moscatiello RM. Cervical vertebral maturation and the correlation between the skeletal age of the hand-wrist as orthodontic treatment indicators. *Rev Dent Press Ortodon Ortop Facial* 2008; **13**: 92–100.
- Wong RW, Alkhal HA, Rabie AB. Use of cervical vertebral maturation to determine skeletal age. *Am J Orthod Dentofacial Orthop*. 2009; **136**: 484.e1–6. doi: [10.1016/j.ajodo.2007.08.033](https://doi.org/10.1016/j.ajodo.2007.08.033)
- Warmeling D, Rodrigues KM, Zastrow MD, Thiesen G. Comparative study of two skeletal maturation evaluation indexes. *Rev Odonto Cienc* 2010; **25**: 188–93.
- Mahajan S. Evaluation of skeletal maturation by comparing the hand wrist radiograph and cervical vertebrae as seen in lateral cephalogram. *Indian J Dent Res* 2011; **22**: 309–16. doi: [10.4103/0970-9290.84310](https://doi.org/10.4103/0970-9290.84310)
- Sachan K, Sharma VP, Tandon P. A correlative study of dental age and skeletal maturation. *Indian J Dent Res* 2011; **22**: 882. doi: [10.4103/0970-9290.94698](https://doi.org/10.4103/0970-9290.94698)
- Prasad M, Ganji VS, George SA, Talapaneni AK, Shetty SK. A comparison between cervical vertebrae and modified MP3 stages for the assessment of skeletal maturity. *J Nat Sci Biol Med* 2013; **4**: 74–80. doi: [10.4103/0976-9668.107264](https://doi.org/10.4103/0976-9668.107264)