

## RELIABILITY, EFFICACY AND REPRODUCIBILITY OF THE CERVICAL VERTEBRAE MATURATION INDEX (CVMI)

### *VALIDADE, EFETIVIDADE E REPRODUTIBILIDADE DO ÍNDICE DE MATURAÇÃO DAS VÉRTEBRAS CERVICAIS*

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**ABSTRACT:** Assessing skeletal maturation is an important determinant of successful orthodontic treatment planning for children and adolescents. While several methods are used skeletal maturation assessment, the hand-wrist radiograph is one of the most widely used. However, it does require additional exposing growing patients to additional radiation. Information on skeletal maturation can also be retrieved after evaluation of cervical vertebrae, which are commonly portrayed on the lateral cephalometric radiographs included in standard orthodontic documentation. By means of a systematic review of the available literature, this work aimed to verify the reliability, efficacy, and reproducibility of skeletal age determination based on the evaluation of cervical vertebrae. The LILACS, SciELO and PubMed databases were searched using the keywords "cervical vertebrae" and "cervical maturation". Only texts in Portuguese, Spanish, and English published in the last 10 years were selected. Twenty-nine full articles were retrieved and critically appraised. According to these references, the Cervical Vertebrae Maturation Index appears to be a valid, reliable, and reproducible method for skeletal maturation assessment and may substitute the analysis of hand-wrist radiograph in orthodontic treatment planning.

**KEYWORDS:** Cervical Vertebrae. Radiograph. Cervical Maturation. Systematic Review.

### INTRODUCTION

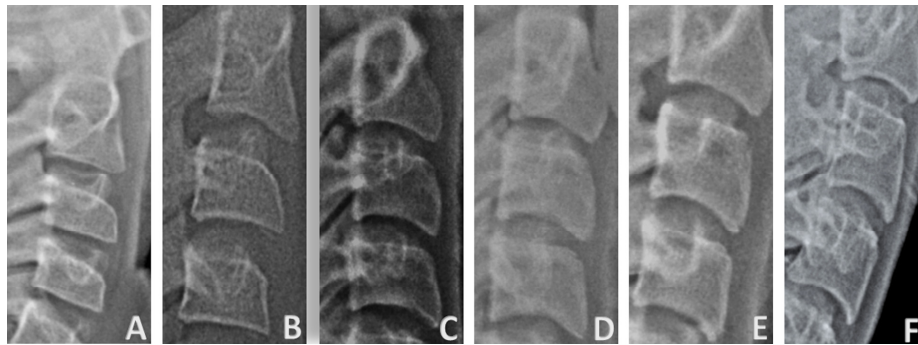
Assessing skeletal maturation is essential for proper orthodontic treatment planning of children and adolescents since critical decisions concerning diagnosis, treatment mechanics and prognosis are affected by the patient's skeletal age. Chronological age is not a reliable parameter in determining an individual's growth potential as it is influenced by genetics, socioeconomical and hormonal factors (MARCELINO; TAVANO, 2005). From the standpoint of orthodontic diagnosis and treatment planning, skeletal maturation is a much more reliable base to support one's clinical decisions (GENEROSO et al., 2010).

As in any diagnostic workup, concerns are raised against "over imaging" in orthodontics. Researchers were therefore prompted to develop a method of assessing skeletal maturity based on evaluation of the cervical vertebrae commonly portrayed in lateral cephalometric films. The rationale is grounded on the fact that cervical vertebrae (CV) undergo changes in shape and size throughout development and growth and, therefore, could be used as reference for the determination of skeletal age. Lamparski (1972) pioneered the field

after studying changes occurred in the vertebrae of young women and describing six stages of vertebral maturation. He concluded that changes in vertebral size and shape are determined by the progressive development of concavities in the lower margins of the vertebral body, which grows in height and changes progressively from a trapezoid to a vertical shape. This method of skeletal age assessment was proven statistically valid and reliable, with clinical value similar to that of the assessments based on hand-wrist radiographs.

Given that lateral cephalometric radiographs are part of the standard orthodontic documentation, others have built upon Lamparski's original work (HASSEL; FARMAN, 1995; MARCELINO; TAVANO, 2005; DAMIAN et al., 2006; KAMAL et al., 2006; CALDAS et al., 2007; MOSCATIELLO et al., 2008) in order to establish the Cervical Vertebrae Maturation Index (CVMI) (Figure 1).

Given the ingenuity and cost-effectiveness of the CVMI, this work aimed to verify, by means of a systematic review of the pertaining literature, the reliability, efficacy, and reproducibility of CV-based methods of skeletal age determination.



**Figure 1.** Representation of the six stages of the Cervical Vertebrae Maturation Index (CVMI) developed by Hassel and Farman (1995).

**METHODS**

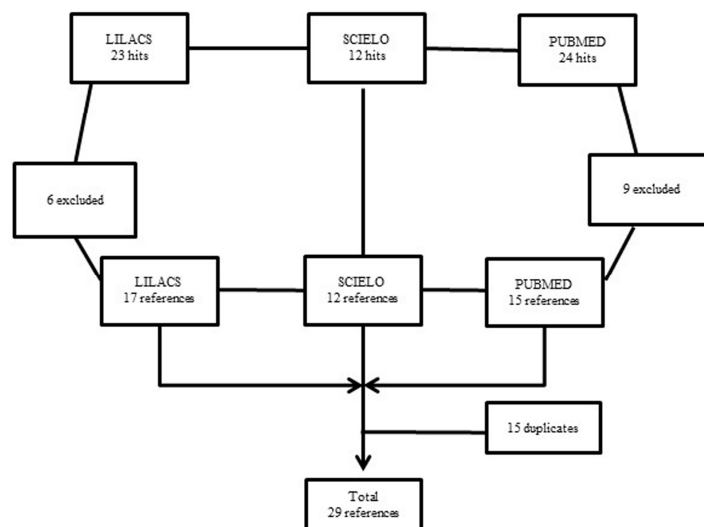
A systematic literature review was conducted in September, 2014. The search strategy included the terms "cervical vertebrae" and "cervical maturation" joined by the boolean operator "AND". The LILACS, SciELO and PubMed databases were searched for articles published in Portuguese, English or Spanish during the past ten years and with full text available online. Literature reviews, case reports, theses or dissertations, books, letters to the editor, editorials, and other scientific production not susceptible to systematic reviewing were excluded. Duplicated works were included only once.

After retrieval of the selected articles, all were critically and independently appraised by two of the authors (G.O.C. and L.R.P.). All relevant information regarding the assessment of skeletal maturation based on CV evaluation was gathered,

tabulated and categorized or compared whenever feasible.

**RESULTS**

The initial search produced 23 hits in the LILACS database, 12 hits in the SciELO database and 24 hits in PubMed, totaling 59 possible references for analysis. After an initial screening based on the titles and abstracts, six works were excluded from the LILACS results: two were full theses, two were not directly related to CVMI assessment, one was a literature review, and another one was a duplicate. From PubMed results, six articles were excluded as they were not directly related to the subject, one was a duplicate, and another one more because it was published in French. After the initial screening and removal of duplicates, the amount of references was reduced to 29 (Figure 2). The articles appraised in this study are listed in Table 1.



**Figure 2.** Workflow for article selection.

**Table 1.** List of articles used in the study.

Year	Author	Database	Journal	Correlation	Results
2005	Marcelino et al.	LILACS	Salusvita	Fissured CVMI	VMI reliable
2005	Santos et al.	LILACS SciELO	DentalPress J Orthod	CVMI reproducibility	VMI reproducible
2006	Damian et al.	LILACS SciELO	Dental Press J Orthod	CVMI x CMI	VMI valid
2006	Kamal et al.	PubMed	J Indian Soc Pedod Prev Dent	CVMI x CMI	IMV valid
2006	Vieira et al.	LILACS SciELO	Dental Press J Orthod	CVMI x skeletal classes I and II	No difference
2007	Caldas et al.	LILACS SciELO; PubMed	Braz Oral Res	New CVMI method	VMI valid
2007	Damian et al.	SciELO; PubMed	J Appl Oral Sci	CVMI x growth	VMI valid
2008	Moscatiello et al.	LILACS SciELO	Dental Press J Orthod	CVMI x CMI	VMI additional
2009	Vieira et al.	LILACS SciELO	Dental Press J Orthod	CVMI x teeth	Positive correlation
2010	Caldas et al.	SciELO; PubMed	Braz Oral Res	Computer CVMI	Valid
2010	Generoso et al.	PubMed	Braz Oral Res	CVMI x classes I and II	Sexual dimorphism
2010	Jaqueira et al.	LILACS, SciELO, PubMed	Braz Oral Res	CVMI three methods	Bacetti et al. higher reproducibility
2010	Joshi et al.	LILACS	Rev Clín Pesq Odontol	CVMI x CMI	VMI reliable
2010	Mayari and Lugo	LILACS	Rev Cubana Estomatol	CVMI x CMI	VMI reliable
2010	Warmeling et al.	LILACS; SciELO	Rev odontociênc	CVMI x CMI	VMI more reliable
2011	Martins et al.	LILACS	Braz Dent Sci	CVMI x CMI	VMI reliable
2011	Baptista et al.	LILACS	J Health Inform	Computerized CVMI	Valid
2011	Mahajan	PubMed	Indian J Dent Res	CVMI x CMI	Positive correlation
2011	Różyło-Kalinowska et al.	PubMed	Eur J Orthod	CVMI x teeth	Positive correlation
2011	Sachan et al.	PubMed	Indian J Dent Res	CVMI x teeth	Positive correlation
2012	Armond et al.	LILACS; SciELO	Braz Oral Res	CVMI x malocclusion	Positive correlation
2012	Altan et al.	PubMed	Eur J Orthod	CVMI	VMI reliable
2012	Kothavade et al.	PubMed	J Indian Soc Pedod Prev Dent	CVMI x teeth	Canine not reliable
2012	Perinetti et al.	PubMed	Eur J Orthod	CVMI x teeth	Lower second molar valid
2012	Mayari	LILACS	Rev Cubana Estomatol	CVMI x teeth	Positive correlation
2013	Aguiar et al.	LILACS; PubMed	Braz Dent J	Formula CVMI method	VMI invalid
2013	Prasad et al.	PubMed	J Nat SciBiol Med	CVMI x CMI	Good correlation
2013	Valisadeh et al.	PubMed	Iran J Radiol	CVMI x teeth	Positive correlation
2013	Matsui et al.	LILACS; SciELO	Dental Press J Orthod	CVMI X growth in rats	Positive correlation

Thirty-eight percent (11/29) of the articles reviewed compared the cervical vertebrae maturation index (CVMI) against the carpal

maturation index (CMI), while the other 62% (18/29) compared CVMI with other variables such as chronological age, stages of pubertal growth

spurt, among others. The most commonly used method for cervical vertebrae assessment was the one developed by Hassel and Farman (1995) (55%, 16/29), followed by Bacetti's method (2002) (24%, 7/29). Alternative methods were employed in the remaining 21% of our sample of papers.

## DISCUSSION

Assessing skeletal maturity is essential for determining the growth stage by the time of orthodontic diagnosis so that treatment planning is determined by the most appropriate approach for that particular stage. Usually, a clinician can determine how mature is the skeleton based on the ossification of selected bones from the hand and wrist (MARCELINO et al., 2005; MAHAJAN, 2011). However, this method requires an additional radiographic film, with more exposure to radiation outside of the craniofacial region. In a quest to avoid unnecessary exposure to radiation and to reduce redundant diagnostic material, some have correlated the morphological changes that occur in CV to mandibular growth (GENEROSO et al., 2010; DAMIAN et al., 2011), Angle malocclusions (VIEIRA et al., 2006; ARMOND et al., 2012), skeletal age (CALDAS et al., 2007; CALDAS et al., 2010; AGUIAR et al., 2013), and dental age (VIEIRA et al., 2009; RÓŻYŁO-KALINOWSKA et al., 2011; SACHAN et al., 2011; KOTHAVADE et al., 2012; MAYARÍ, 2012; VALIZADEH et al., 2013).

Several authors (DAMIAN et al., 2006; KAMAL et al., 2006; JOSHI et al., 2010; MAYARÍ and LUGO, 2010; WARMELING et al., 2010; MARTINS et al., 2011; ALTAN et al., 2012; MAHAJAN, 2012; MAYARÍ, 2012; PRASAD et al., 2013) have made estimates of skeletal growth potential by assessing CV radiographically and comparing the data obtained to that retrieved from hand-wrist films. While not all papers from our sample verified the reliability of methods that estimate skeletal maturation based on CV assessments, most authors agreed that different CV evaluation methods can deliver satisfactory and sufficiently reliable estimates of the degree of skeletal maturation.

In addition, works comparing CV assessments to the analysis of ossification events in the hand and wrist did not verify significant statistical differences for intra- and inter-examiner agreement levels (SANTOS et al., 2005; DAMIAN et al., 2006; JAQUEIRA et al., 2010; SACHAN et al., 2011).

Jaqueira et al. (2010) carried out a study comparing three different CV-based methods to assess skeletal maturation and showed that the method proposed by Bacetti et al. (2002) is the most reliable and reproducible one.

The greater advantage of determining skeletal maturation by lateral cephalometric radiographs would be that it is already part of routine orthodontic documentation. Thus, additional films and consequent exposure to radiation (hand-wrist radiograph) are waived (DAMIAN et al., 2006; KAMAL et al., 2006; MOSCATELLO et al., 2008; MAYARÍ; LUGO, 2010; WARMELING et al., 2010; JOSHI et al., 2011; MARTINS et al., 2011; ALTAN et al., 2012; PRASAD et al., 2013). However, the greatest challenge in using CV as an indicator of skeletal maturation seems to be the correct staging described by Hassel and Farman (1995). For proper staging, radiograph quality and knowledge of vertebral anatomy are essential. Indeed, Generoso et al. (2010) suggested that intermediate stages might exist among the established CVMI stages, as some anatomical traits are not covered by the standard CVMI. Therefore, developing a more precise method would require including more stages or changing the assessment from visual-subjective into a more objective nature.

Changes in cervical vertebrae parallel the ossification events in the hand and wrist, suggesting that radiograph-based determination of skeletal maturation is reliable (MAYARÍ; LUGO, 2010; MAHAJAN, 2011). However, the lack of an obvious convergence of both methods at the final growth stages does not provide for unequivocal support of CV-based assessments.

While different methods for CV assessment methods have been proposed, most of them were based on the subjective analyses of morphological changes in the vertebral bodies. The traits assessed usually include:

1. Changes in the shape of the vertebral body, from a wedge-shaped leaning cranially and dorsoventrally to downward rectangular, then square, and at last to a upward rectangular shape;

2. Changes in the caudal concavity of the vertebral body, from flat to a more evident concavity throughout growth.

Due to the high level of subjectivity of the original analyses, some authors proposed that vertebral bodies be measured from the third and fourth cervical vertebrae, thereby establishing a formula to assess skeletal age more objectively (CALDAS et al., 2007; CALDAS et al., 2010; BAPTISTA et al., 2011). However, Aguiar et al.

(2013) suggested that this method fails to provide good estimates of skeletal maturation.

There has been a trend towards the use of either dental age or dental calcification stages as an aid to determining skeletal maturation (VIEIRA et al., 2009; RÓŻYŁO-KALINOWSKA et al., 2011; KOTHAVADE et al., 2012; MAYARÍ, 2012; PERINETTI et al., 2012; PRASAD et al., 2013; VALIZADEH et al., 2013). Many of these works pointed out that dental calcification stages have moderate to weak correlation with skeletal age, either with the Nolla (VIEIRA et al., 2009; SACHAN et al., 2011; KOTHAVADE et al., 2012; VALIZADEH et al., 2013) or the Demirjian classification (RÓŻYŁO-KALINOWSKA et al., 2011; MAYARÍ, 2012; PERINETTI et al., 2012). Perinetti et al. (2012) stated that the use of tooth-based methods are limited, suggesting that dental age would not be a good replacement for either

carpal radiographs or teleradiographs in the assessment of skeletal maturation.

## CONCLUSION

Based on our review of the pertaining literature, the Cervical Vertebrae Maturation Index (CVMI) appears to be a valid, reliable, and reproducible method for the analysis of skeletal maturation. Among the indexes presented in literature, the one developed by Hassel and Farman (1995) is the most commonly used, while the index proposed by Bacetti et al. (2002) is considered the most reproducible. However, the transition from standard assessments to CV-based ones should not be abrupt, but gradual, at least until the clinician becomes familiar with the new method and replicates his own analysis reliably and consistently.

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**RESUMO:** A determinação da fase de maturação esquelética é ponto fundamental no tratamento ortodôntico de crianças e adolescentes, e muitos métodos são utilizados com este objetivo, sendo a análise da radiografia de mão e punho o mais comumente difundido no meio ortodôntico. Entretanto, esta informação também pode ser obtida por meio de radiografias cefalométricas laterais, com base na avaliação das vértebras cervicais, eliminando a necessidade de exposição a mais de radiação e o custo associado de novos exames. O objetivo deste trabalho foi checar, com base na literatura, a confiabilidade, a efetividade e a reprodutibilidade do método de estimativa da idade esquelética, por meio das vértebras cervicais. Para tanto, foi realizada uma revisão crítica da literatura, utilizando as palavras-chave “vértebras cervicais” e “maturação cervical”. Foram encontrados 29 artigos nas bases de dados LILACS, PubMed e SciELO. De acordo com as referências encontradas, o Índice de Maturação das Vértebras Cervicais pode ser considerado um método válido, confiável e reprodutível na análise da maturação óssea, podendo ser utilizado na prática ortodôntica, em substituição à análise da radiografia de mão e punho.

**PALAVRAS-CHAVE:** Vértebras Cervicais. Radiografia. Maturação cervical. Revisão Sistemática.

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