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Interobserver Reliability of Cervical Vertebral Maturation Staging

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ABSTRACT

Background: the accurate identification of a patient's maturation stage, particularly during the pubertal growth spurt, takes on heightened importance, particularly when addressing cases of dentoskeletal problem Active growth determination is crucial for orthodontic treatment.

Objectives: The objective of this study was to determine interobserver reliability of Cervical Vertebrae Maturation (CVM) staging

Material and Methods: This cross-sectional correlational study, conducted in the Department of Orthodontics on 70 subjects. Ten orthodontic clinicians, including 4 orthodontists and 6 orthodontic residents, with no prior experience in CVM staging, underwent comprehensive training. The study involved assessing 70 lateral cephalograms with clear visibility of cervical vertebrae, evaluated by two independent examiners using the Baccetti et al. staging system. The collected data were analyzed using R programming, including descriptive statistics for age, Spearman's correlation, and Cohen's Kappa for assessing interobserver agreement, with stratification by gender.

Results: The mean age of participants was 12.60±3.93 years, with 38 females (54.29%) and 32 males (45.71%). The study revealed varying levels of agreement between two observers for different CVM stages, ranging from perfect agreement in CS1 to strong agreement in CS3. CS4, CS5, and CS6 also showed varying agreement rates. Additionally, there was robust and statistically significant agreement ($p<0.001$) between observers in cervical maturation staging, supported by a high Spearman's rho value ($r=0.927$). Furthermore, substantial agreement was observed with a Kappa value of 0.748, indicating a strong consensus in cervical staging assessments.

Conclusion: Cervical vertebral maturation staging is reliable in term of inter-observers agreement.

Keywords: Cervical vertebral maturation, Interobserver agreement, Growth assessment

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INTRODUCTION

Comprehending growth events within orthodontics carries substantial significance within clinical practice owing to their potential influence on diagnostic procedures, formulation of treatment plans, selection of appliances, and eventual treatment outcomes.[1,2] Consequently, the accurate identification of a patient's maturation stage, particularly during the pubertal growth spurt, takes on heightened importance, particularly when addressing cases of dentoskeletal problem.[3,4]

The cervical vertebrae maturation (CVM) method is considered a reliable way to assess the growth spurt of the whole body and mandible. This method can be easily assessed from a lateral cephalogram, with no extra radiation to the patient, which is available as part of the diagnosis.[5-7]

The validity of Baccetti's method remains unverified against an appropriate standard of comparison.[8] As this method is based on annual changes in mandibular length over a period of time, there should be a corresponding collection of data to serve as the reference standard.[9] There are ongoing disputes about its reliability. Therefore, the primary goal of this study was to assess the reliability of the Cervical Vertebrae Maturation (CVM) method for gauging skeletal maturation between two observers.

The CVMS method, which assesses skeletal maturation through cervical vertebrae development, has potential benefits. However, concerns about its reproducibility have been raised, leading to its limited endorsement for precise timing of orthodontic treatments.[10] Although it offers advantages like non-invasiveness and simplicity, doubts about result consistency have emerged.[11] Reproducibility issues arise from varying interpretations by different observers, influenced by subjectivity, experience, and interpretation criteria.[12]

This study seeks to investigate the consistency and accuracy of the Cervical Vertebral Maturation Stage (CVMS) method in assessing skeletal maturation for orthodontic purposes. This method has theoretical advantages but has faced doubts about its practical reliability due to varying interpretations by different observers. The study aims to determine the extent to which orthodontists and clinicians can agree on the same maturation stage using the CVMS method. By addressing this issue, the study intends to provide insights that could impact orthodontic practices and improve treatment planning precision. So the purpose of this study was to determine interobserver reliability of Cervical Vertebrae Maturation staging.

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MATERIAL AND METHODS

This cross-sectional correlational study was conducted at the Department of Orthodontics in University of Lahore, Pakistan from January 10, 2022, to August 30, 2023. The sample size was calculated as 9 cases using a 5% Type 1 error and 20% Type II error, considering an interobserver correlation (r) of 0.83 between two observers performing CVM staging by online correlation calculator for sample size(https://sample-size.net/correlation-sample-size/).[9] However, for the normality assumption, 70 cases were included. The sample was selected using a non-probability consecutive sampling technique.

The study involved two phases focused on evaluating reliability. Ten orthodontic clinicians (4 orthodontists and 6 orthodontic residents) from Lahore College, all new to the CVM staging method, underwent training to use an improved version of the technique. The training occurred at the start of each reliability phase and covered various aspects, including explaining the morphological features of each cervical stage (CS) using diagrams, providing written descriptions of CS radiographic traits, utilizing a PowerPoint presentation according to the Baccetti et al[13], and conducting a calibration exercise to ensure all observers comprehended the method thoroughly.

A total of 70 lateral cephalograms with high clarity, clearly showing cervical vertebrae, were included in the study. Each cephalometric film was evaluated by two independent examiners following the Baccetti et al. staging system. The examiners assessed CVM staging using a light illuminator. Participant's age, gender, and their assigned scores were recorded in a prestructured proforma.

The data were analyzed using R software 4.1.3. Descriptive statistics were generated by calculating the mean and standard deviation of the age variable. Interobserver agreement for CVM stages was assessed using both Spearman's correlation test and Cohen's Kappa. The analysis was stratified by gender to account for potential confounders. A significance level of $P < 0.01$ was employed for the correlation analysis.

RESULTS

The mean age of participants was 12.60±3.93 years. Females were 38 (54.29%) and males were 32 (45.71%). Table 01 provides a detailed overview of the agreement between the two observers for different CVM stages. For example, in the "CS1" row, Observer 1 and Observer 2 had 100.00% agreement, indicating perfect agreement for this particular stage. On the other hand, in the "CS3" row, the agreement is 83.33%, suggesting a strong level of agreement for this stage. The agreement of CS4, CS5 and CS6 were 66.67%, 66.67% and 71.43%.

The results presented in Table 02 indicate a robust and statistically significant ($p<0.001$) agreement between the two observers in their evaluations of cervical maturation staging. This strong agreement is in accordance with the high Spearman's rho value ($r=0.927$), and the low p-value reinforces the confidence in the observed correlation.

Table 03 demonstrates substantial agreement among observers, with a Kappa value of 0.748, signifying a strong level of consensus in cervical staging assessments. The p-value, which is less than 0.001, underscores the high statistical significance of this agreement, affirming that it is not due to random chance. Furthermore, the Z-Statistics value of 11.7 indicates a pronounced deviation from what would be expected by chance, further solidifying the robustness of the observed interobserver agreement in cervical staging assessments.

The correlation between two observers was closer to each other in both genders. (Fig 01)

Table 01. Concordance of two observers for CVM staging

	Characteristics	Observer 2					
		CS 1, N = 7	CS 2, N = 17	CS 3, N = 30	CS 4, N = 6	CS 5, N = 3	CS 6, N = 7
Observer 1	CS1	**7 (100.00)**	2 (11.76)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
	CS2	0 (0.00)	**14 (82.35)**	4 (13.33)	0 (0.00)	0 (0.00)	0 (0.00)
	CS3	0 (0.00)	1 (5.88)	**25 (83.33)**	2 (33.33)	0 (0.00)	0 (0.00)
	CS4	0 (0.00)	0 (0.00)	1 (3.33)	**4 (66.67)**	0 (0.00)	0 (0.00)
	CS5	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	**2 (66.67)**	2 (28.57)
	CS6	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (33.33)	**5 (71.43)**

Table 02. Interobserver correlation for cervical maturation Staging

Spearman rho	P-value	Level of Agreement
0.927	<0.001	Strong

Table 03.
Interobserver agreement on Cervical Staging

Kappa Value	P-value	Z-Statistic
0.748	<0.001	11.7

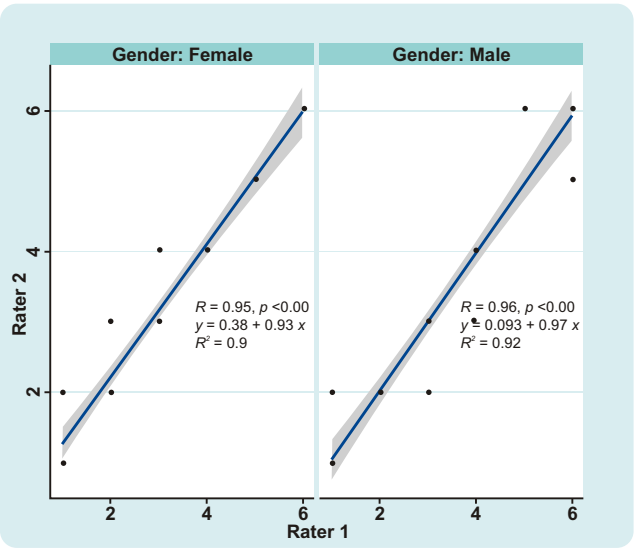


Fig 01. Interobserver correlation for both males and females participants

DISCUSSION

Our findings showed that there is a high degree of agreement in labeling CVM staging among clinicians.

Orthodontists utilize CVM as a valuable tool in treatment planning, helping them determine the optimal timing for orthodontic interventions. It informs decisions about the choice of appliances, treatment timing, and expected treatment duration. While CVM is a powerful tool, it is not a definitive predictor of growth potential or growth cessation timing.[14] Therefore, it is often used alongside other growth assessment methods and clinical judgment. CVM assessment relies on lateral cephalometric radiographs to accurately gauge cervical vertebral maturation. This method has been extensively researched, validated, and documented, making it a vital resource not only for orthodontists but also for other dental and medical professionals who need to assess growth and development. Overall, CVM contributes to improved orthodontic care by aiding in treatment planning and facilitating more informed clinical decision-making.[15]
The kappa statistic is a valuable tool for assessing agreement among observers in cervical cancer staging. In this study, a kappa value of 0.748 indicates a noteworthy level of agreement beyond chance, quantifying consensus among observers.[16] Using a scale, values below 0.20 suggest poor agreement, 0.21-0.40 represent fair agreement, 0.41-0.60 signify moderate agreement, 0.61-0.80 indicate substantial agreement, and 0.81-1.00 represent almost perfect agreement. With a kappa value of 0.748, our study demonstrates substantial agreement among healthcare professionals, indicating high consistency in cervical staging assessments.

Previous study assessed the reliability of the cervical vertebral maturation (CVM) method for evaluating mandibular growth. Twenty orthodontic clinicians, initially inexperienced in CVM staging, were trained and independently assessed 72 lateral cephalograms on two occasions. The study found substantial agreement with weighted kappa values ranging from 0.6 to 0.8.[12]

In another research, ten proficient orthodontists, each well-trained in the CVM method, undertook an evaluation of the morphology of cervical vertebrae C2 through C4 using a set of questions rooted in the CVM method. To gauge the level of agreement between these experts, the study employed the Fleiss kappa statistic for assessing interobserver agreement. Interestingly, the study's findings revealed that intraobserver agreement averaged at 62%, albeit with the exclusion of inconclusive stagings to mitigate disagreements among the assessors.[11] These results are different from our study. The difference can be attributed to sample size and level of experience.

However another study reported that the CVM method's reliability is in doubt (k= 0.44), and when deciding whether to start orthodontic treatment based on maximum growth, it's advisable to take into account other biological markers.[17]

However, limitations exist, such as the single-center nature of the study, limited diversity among observers, and potential selection bias due to consecutive sampling. The study's duration was relatively short, potentially impacting the capture of long-term variations in inter-observer agreement. Additionally, reliance on observer recall during training might introduce recall bias.

CONCLUSION

This study showed a high level of agreement between two observers in their assessments of cervical maturation staging. This agreement was consistent across different stages, affirming the reliability of the assessments. The results support the use of this method in clinical practice for evaluating cervical maturation.

Ethical Consideration

This study was approved by the ethical review board of University of Lahore, Pakistan.

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Conflict of Interest

Authors declared no conflict of interest

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DATA SHARING STATEMENT: The data that support the findings of this study are available on request from the corresponding author. The data is not publicly available due to privacy or ethical restrictions.

AUTHORS' CONTRIBUTION

The following authors fullfill authorship criteria as per ICMJE guidelines;

Ali MM, Azeem M:	Substantial contribution to conception and design, drafting the manuscript, final approval, agreed to be accountable for all the work.
Noman M, Hashmi D:	Substantial contribution to conception and design, data acquisition, drafting the manuscript, final approval, agreed to be accountable for all the work.
Saeed MH:	Analysis and interpretation of data, drafting the manuscript, final approval, agreed to be accountable for all the work.
Hussain M:	Analysis and interpretation of data, critical revision,final approval, agreed to be accountable for all the work.

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