

# THE CORRELATION BETWEEN CERVICAL VERTEBRAL MATURATION AND MANDIBULAR DIMENSIONS IN CHILDREN AGED 8-16 YEARS: STUDY ON CHILDREN'S POPULATION IN JAKARTA, INDONESIA

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## ABSTRACT

**INTRODUCTION:** The mandible provides a basis for occlusion and mastication in collaboration with the maxilla. It is important to perform biological assessments of growth and development of the mandible in dentofacial orthopedics.

**OBJECTIVES:** The aim of this cross-sectional study was to analyze a correlation between cervical vertebral maturation and changes occurring in mandibular dimensions to predict the right time for orthopedic treatments, using data of 30 lateral cephalograms of subjects (18 girls, 12 boys), aged 8-16 years in Jakarta, Indonesia.

**MATERIAL AND METHODS:** Following parameters were evaluated in this study: visual measurements of lateral cephalogram, mandibular dimensions assessed from the total mandibular length of a condylon-gnathion line, height of mandibular ramus from the condylon-gonion intersection line, and length of mandibular body from the gonion intersection-gnathion line during maturity stages of cervical vertebra (cervical stage 1 to cervical stage 6), which were assessed from the second to fourth branches of cervical vertebral bone. Spearman method was used to analyze a correlation between cervical vertebral maturation and changes in mandibular dimensions.

**RESULTS:** A significant and strong correlation was observed between cervical vertebral maturation stages and the total mandibular length, the height of mandibular ramus, and the length of mandibular body, along with the pre-pubertal, pubertal, and post-pubertal periods.

**CONCLUSIONS:** Growth and development of the mandible can be used as skeletal maturity indicators during the pubertal age in case of a dentofacial orthopedic treatment.

**KEY WORDS:** skeletal maturation, mandible, growth and development, puberty.

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## INTRODUCTION

Growth is a term that is used to indicate an increase in size or number of anatomical parts, whereas development is a process that advances toward maturity, indicating an increase in the complexity of an organ [1]. Craniofacial growth is a complex process consisting of several relationships between various bones, which

form a skull, and also between hard tissue and soft tissue for attaining a functional and structural balance [2]. Based on the function, the mandible provides a basis for occlusion and mastication in collaboration with the maxilla. An increase in the size of the ramus, the body, and the alveolar process as well as an eruption of teeth in the mandible occur parallelly with the nasomaxillary complex [3].

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It is important to understand biological assessments of growth and development of the mandible in dentofacial orthopedics. The primary purpose of functional therapy in treating mandibular growth deficiency is to accelerate the increase of the length of mandible by stimulating an enhanced growth of the condylar cartilage [4]. The effectiveness of therapeutic functional devices is highly dependent on responsiveness of the condylar cartilage, which also depends on mandibular growth rates [4]. Therefore, it is important to evaluate the mandibular skeletal maturity and the individual's growth potential to improve treatment outcomes.

Craniofacial growth and development in humans vary between individuals with pubertal growth increase by following a pattern [5]. Skeletal maturation indicates the degree of development of ossification in the bone and is a more reliable method for growth assessment [6]. Maturation may be described as a development process that completes the physical growth, and its stage can be measured and graphically represented [7]. Previous studies have demonstrated a correlation between cervical vertebral maturation and mandibular growth in adolescence, which has also received increasing attention. Measurement of cervical vertebral maturation has proven to be effective and clinically reliable for the assessment of mandibular skeletal maturation in children during growth [8]. The intensity, onset, and duration

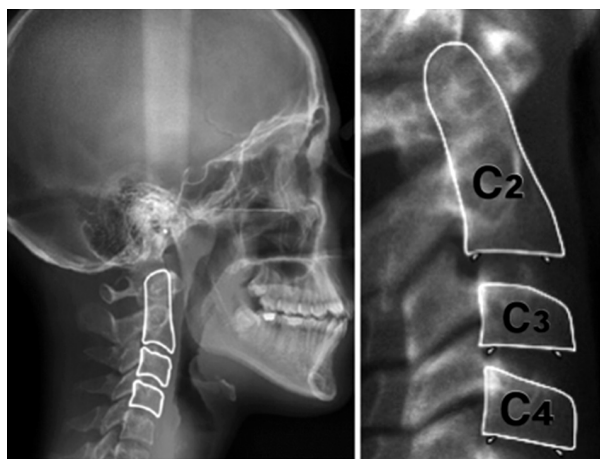
of pubertal peak in relation to the growth of mandible differ significantly among individuals. Evaluation of cervical vertebral maturation is generally performed by observing the shape and size of the second branch (C2), third branch (C3), and fourth branch (C4) of the cervical vertebral bone. The method is divided into six stages according to the stage of maturity, and can be identified during the pubertal period.

## OBJECTIVES

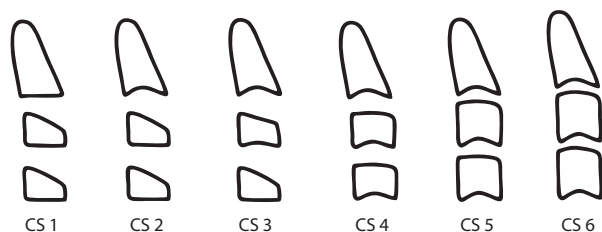
This cross-sectional study was conducted to analyze a correlation between cervical vertebral maturation and changes in mandibular dimensions. Skeletal maturation can be used to assess mandibular growth and development in puberty, as a consideration in optimizing skeletal modification in orthopedic treatment time.

## MATERIAL AND METHODS

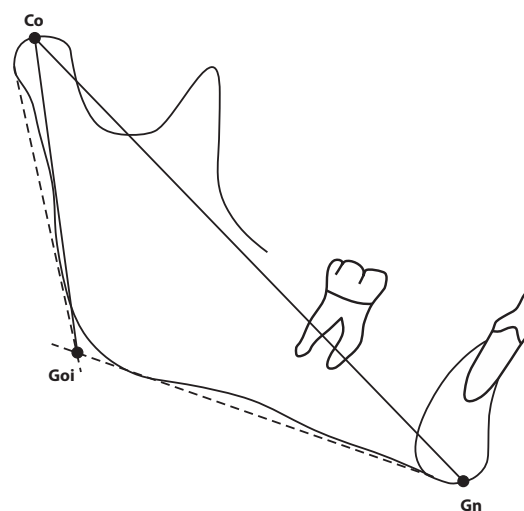
Considering an effect size (ES) of 0.5, which is a large ES based on Cohen's recommendation (with  $\alpha = 0.05$  and power = 0.80), the projected sample size required with this ES was approximately  $n = 29$ . The study sample in this research consisted of 30 lateral cephalograms, which were retrospectively selected from clinics and radiology laboratories in Jakarta between June 2016 and June 2019. The cephalogram was obtained by analogue machine. The study cohort consisted of 18 girls and 12 boys, who fulfilled the inclusion criteria using visual observations. Subjects were children aged 8-16 years with class 1 skeletal malocclusion, without a history of orthodontic treatment, and class 1 molar relationship. Cephalogram quality was good in contrast, detail, and sharpness. Ethical approval was obtained from Dental Research Ethics Committee, with a protocol number of 050340319, Faculty of Dentistry, Universitas Indonesia, Jakarta, Indonesia.



**FIGURE 1.** Assessment of cervical vertebrae C2, C3, and C4 based on morphological shape and lower border [9]



**FIGURE 2.** Schematic representation of cervical vertebral maturation stages according to McNamara *et al.* [9]



**FIGURE 3.** Schematic representation of the measurements of mandibular dimensions [10]

Cervical vertebral maturation was assessed from cephalogram by visual observation using a light box based on morphological shape and depth of the lower border of cervical vertebrae C2, C3, and C4 (Figure 1). The stages of cervical vertebral maturation were based on classification of McNamara *et al.* (Figure 2) [9]. There were six cervical stages (CS), including CS 1 and CS 2 categorized as pre-pubertal, CS 3, and CS 4 classified as pubertal, and CS 5 and CS 6 characterized as postpubertal.

The mandibular dimensions comprised the total length of mandible represented by the distance of condylon–gnathion line, the ramus height was represented by the distance of condylon–gonion intersection line, and the body length was characterized by the distance of gonion intersection–gnathion line (Figure 3) [10].

Reliability tests for the assessment of cervical vertebral maturation were conducted by inter-operators between researchers and consultants, with a  $\kappa$  value of 0.83 and by intra-operators who performed the test 2 weeks after the first assessment, with a  $\kappa$  value of 1.0. Reliability tests for the total mandibular length measurements between operators and consultants were conducted using Bland-Altman plots, with mean  $\pm$  SD values of 0.040  $\pm$  0.069 and limits of agreement values of  $-0.097$  and  $0.177$  (good reliability interval between  $-5$  and  $5$ ).

The correlations between cervical vertebral maturation groups (pre-pubertal, pubertal, and post-pubertal) and the changes in mandibular dimensions were statistically analyzed using Spearman bivariate correlation test.

## RESULTS

Table 1 shows differences between the median values of the total mandibular length, the height of mandibular ramus, and the length of mandibular body with pre-pubertal, pubertal, and post-pubertal periods. The total mandibular length was the highest median enhancement in the pre-pubertal, puberty, and post-pubertal groups of children.

Furthermore, Table 2 shows a correlation analysis of the cervical vertebral maturation and the mandibular di-

mension. From the results, it can be concluded that there is a strong and significant correlation between the cervical vertebral maturation and the total mandibular length ( $r = 0.797$ ); between cervical vertebral maturation and the height of mandibular ramus ( $r = 0.674$ ); between cervical vertebral maturation and the length of mandibular body ( $r = 0.752$ ). The differences indicate stages of cervical vertebral maturation along with the growth and development of the mandible. The more cervical vertebral mature, the more mandible increases in size.

## DISCUSSION

This study was conducted to analyze the correlation between cervical vertebral maturation and the changes in mandibular dimensions among individuals with a wide age range. The sample was selected by radiological quality procedures. The selected cephalograms appeared black and white, and included varying shades of gray, clear anatomical landmarks (mandibular with sharp edges), with straight Frankfort horizontal planes and no double images. Results showed strong associations, with a maximum correlation obtained between the cervical vertebral maturation stage and the total mandibular length ( $r = 0.797$ ), followed by the length of mandibular body ( $r = 0.752$ ) and the height of mandibular ramus ( $r = 0.674$ ). The largest amount of mandibular growth occurred during CS 4, when cervical vertebral maturation take place within the pubertal age [10, 11]. This finding is consistent with previous studies, which have reported a relationship between cervical vertebral maturation and changes in mandibular dimensions [8, 10, 12]. The degree of cervical vertebral maturation can be observed during pubertal age and can be used as a biological indicator of skeletal maturation in an individual [9, 12].

Mandibular growth arises with bone remodeling. An increase of mandibular height occurs primarily with alveolar bone formation; also, some bones deposition take place with the lower border of mandible. The mandibular length increases because of bone deposition on posterior

**TABLE 1.** Changes in mandibular dimensions according to cervical vertebral maturation groups

| Mandibular growth variable, median (minimum-maximum) | n  | Pre-pubertal CS 1-CS 2 | n  | Pubertal CS 3–CS 4 | n  | Post-pubertal CS 5–6 |
|--|----|------------------------|----|--------------------|----|----------------------|
| Total length of mandible                             | 10 | 10.5 (9.6-11.2)        | 10 | 11.5 (11.1-11.8)   | 10 | 11.95 (10.9-12.2)    |
| Height of mandibular ramus                           | 10 | 5.15 (4.5-5.6)         | 10 | 5.9 (5.6-6.3)      | 10 | 6.05 (5.4-6.6)       |
| Length of mandibular body                            | 10 | 7.05 (6.7-7.3)         | 10 | 7.45 (7.3-7.9)     | 10 | 7.8 (7.2-8.3)        |

**TABLE 2.** The correlation between the cervical vertebral maturation stage and the mandibular dimensions

| Cervical vertebral maturation stage | Total mandibular length                | Height of mandibular ramus             | Length of mandibular body              |
|-------------------------------------|--|--|--|
|                                     | $r = 0.797$<br>$p = 0.001$<br>$n = 30$ | $r = 0.674$<br>$p = 0.001$<br>$n = 30$ | $r = 0.752$<br>$p = 0.001$<br>$n = 30$ |

surface of the ramus as well as due to a process of resorption, as a compensation of anterior surface. It is accompanied by bone deposition on posterior surface of coronoid process and a conduction of anterior surface of the condyle. The mandibular width increases due to bone deposition on the outer surface of mandible and the resorption of mandibular surface [13]. Therefore, the mandible grows in a posterior-superior (backward-upward) direction causing an anterior-inferior displacement [14, 15]. The reported mandibular growth becomes enlarged in size during pubertal period. Some researchers suggest that mandibular growth spurts can occur, but not of the same number and duration in each individual [14]. Relationship between cervical vertebral stages with mandibular growth has received much attention, and it proven to be clinically effective and reliable for the assessment of mandibular skeletal maturation in puberty [16].

Puberty is associated with morphological and physiological changes, which occur during growth in boys or girls throughout childhood till adulthood. The characteristics of pubertal stages include the onset of sexual development, skeletal maturity, and hormonal changes. Puberty is a complex stage, and the process is influenced by several factors, including genetic, nutritional, socioeconomic, and environmental aspects, which mediate both physiological and hormonal processes [17, 18]. Bones grow faster during pubertal growth spurt because the increase of sex hormone levels triggers bones growth [19]. Therefore, a comparison between subjects in the three stages, i.e., pre-pubertal, pubertal, and post-pubertal could help in analyzing the significant changes in mandibular dimensions. In patients who require orthopedic treatment, the time of treatment during the process of growing would significantly contribute towards achieving an effective and efficient outcome for skeletal problems of every individual [9].

The occurrence of mandibular growth is affected by condyle. Condyle is one of the main growth areas in the face (apart from the maxilla, alveolar process, and mandible) until adolescence, and continues into young adulthood [13, 20]. Heterogeneous tissue contain fibroblasts, osteochondral progenitor cells, and chondrocytes. The peripheral condyle cartilage includes chondroid bone, a specialized calcified tissue with intermediate morphological properties between bone and cartilage. This tissue plays an important role in regulating the different bone formation rates in intramembranous and endochondral ossification, allowing for a variety of growth directions of condyle and maxillofacial morphology [15]. This supports the concept of great increase in mandibular growth along pubertal period in accordance with cervical vertebral maturation. Therefore, the cervical vertebral maturation method is an efficient indicator of mandibular growth during puberty [8]. The use of growth indicators is recommended in clinical practice and research in cases of malocclusion requiring interceptive or functional treatment [21]. The success of functional appliance can be assessed by intervention in mandibular length, suggesting

a relationship between mandibular growth potential and treatment response [22].

A limitation of this study was that linear two-dimensional X-rays were not used to measure the growth and development effectively; therefore, this should be done by evaluating three-dimensional X-ray. Moreover, performing calibration in each cephalogram could be suggested for future research to obtain more accurate measurement results. A longitudinal study could be conducted on the same subjects in child and adolescence period by observing the individual's growth and development, with cephalogram taken at different ages, which would reveal the growth and development of the same individual.

## CONCLUSIONS

The correlation between cervical vertebral maturation and mandibular dimensions can be used as an indicator of skeletal maturation during the pubertal age. This can be used as a reference to determine the time to perform dentofacial orthopedic treatment. The effectiveness of therapeutic functional devices can be influenced by the process and state of growth, thus maximizing the outcome of treatment.

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## CONFLICT OF INTEREST

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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