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Featured Review Article

Determination of timing of functional and interceptive orthodontic treatment: A critical approach to growth indicators

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ABSTRACT

Importance: Treatment timing of intervention for interceptive and functional treatments has been reported to be a critical issue in orthodontics when dealing with several types of malocclusions. Identification of the specific prepubertal, pubertal, and postpubertal growth phases, through the assessment of skeletal maturity, relies on the use of different growth indicators. These include the hand and wrist maturation (HWM), third finger middle phalanx maturation (MPM), cervical vertebral maturation (CVM), and dental maturation methods and others.
Observations: Reliability of the different growth indicators in the identification of the circumpubertal growth phases varies according to the indicator and growth phase, whereas data on true diagnostic capability of these methods is still limited to the MPM and CVM methods. Generally, optimal treatment timing for maxillary transverse deficiency, palatally displaced canines and skeletal Class III malocclusion should be early, (i.e., pre-pubertal), whereas optimal (functional) treatment timing for skeletal Class II malocclusion should be late (i.e., pubertal). Growth indicators are better used in combination or chosen according to the type of growth phase/malocclusion to be treated, with dental maturation having the least clinical applicability. Moreover, for radiographic indicators, ossification events should to be preferred over the use of single stages.
Conclusion: Although not all growth indicators proved to be fully reliable and in spite of the limitation of present evidence, the use of these growth indicators is recommended both in clinical practice and research.

1. Introduction

In orthodontics, determination of the timing of intervention for interceptive and functional treatments has been reported to be a critical issue to determine success or failure in the treatment of several types of malocclusions [1,2]. Optimal timing for orthodontic treatment, especially dentofacial orthopedic, relies on the identification of specific growth phases through the assessment of skeletal maturity. The relevant growth phases in orthodontically treated subjects are the circumpubertal ones, as the prepubertal, pubertal, and postpubertal growth phases [2–4], each of which is characterized by differential growth of the maxillary and mandibular basal bones [3,5,6]. Herein, the most investigated growth indicators are described, along with the optimal timing for interceptive and functional orthodontic treatment according to the type of malocclusion (including transverse maxillary deficiency, palatally displaced canines, skeletal Class II and Class III malocclusions). Finally, a critical approach to the use of the proposed indicators also has been reported.

2. Main growth indicators

2.1. Hand and wrist maturation method

One of the well-known hand and wrist maturation (HWM) methods is likely that proposed by Fishman [7], also referred to as skeletal maturation assessment (SMA). This method includes 11 stages (also defined SMI), in which stages 1 to 4 have been reported as prepubertal, those from 5 to 7 have been reported as pubertal, and the rest as postpubertal. Details of the method are reported

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elsewhere [7]. Another common variant of the method is that proposed by Hagg and Taranger [8]. These previous studies have reported a good correlation between the different stages of the methods and the pubertal growth phase as defined by mandibular growth peak [7] or standing height peak [8]. In this regard, the stage-based HWM methods have been reported as valid tools in assessing skeletal maturity, being independent of differences among populations and secular trends [9].

2.2. Third finger middle phalanx maturation method

Over the past 2 decades, the use of the sole third finger middle phalanx for a maturational method has been proposed [10,11]. This third finger middle phalanx maturation (MPM) method [10,12] would have the advantage of an easy interpretation of the stages, without double contours or superimposition by other structures. This method would be of easy execution, and may be performed in any clinical setting with minimal instrumentation and radiation exposure to the patient. In spite of the potential clinical advantages offered by the MPM method, current evidence is still sparse. Details of a five-stage MPM method have been recently reported by Perinetti et al. [12], who reported the MPM stage 2 to precede the mandibular growth peak, which is generally concomitant to the subsequent stage 3 with an overall diagnostic accuracy of 0.91. Although further investigations are needed, the MPM stages 2 and 3 have been considered associated with the onset and maximum mandibular growth peak, respectively.

2.3. Cervical vertebral maturation method

The cervical vertebrae modifications in growing subjects have gained increasing interest during the past few decades as a biological indicator of individual skeletal maturity. The cervical vertebral maturation (CVM) method was initially proposed by Lamparski [13] several decades ago. Subsequently, different versions of the method were proposed, including the one proposed by Baccetti et al. [2], which constitutes probably the most common CVM currently used both in research and clinical practice. This method comprises six stages (also defined CS), in which stages 1 and 2 have been reported as prepubertal, stages 3 and 4 have been reported as pubertal, and the rest as postpubertal. Details of the method are reported elsewhere [2].

Among the main advantages of the CVM method is that it does not require supplementary radiographic exposure, as for the HWM method, because lateral head film is usually available as a pretreatment record. However, contrasting evidence has been reported regarding the capability of the CVM method in the identification of the pubertal growth phase or mandibular growth peak. More in detail, few [14,15] or clinically relevant [2,16] correlations between mandibular growth peak and progression of the CVM stages have been reported. It has been suggested that reasons behind such apparent discrepancy may be related to the different CVM methods or designs used in previous investigations [1]. Even though mandibular growth peak has been reported to occur in coincidence with CVM stages 3 and 4 [2,17,18], further evidence from longitudinal studies is still necessary.

2.4. Dental maturation

A further proposed method for skeletal maturation assessment is that based on dental maturation, which can be easily assessed through the evaluation of tooth formation [19], and which can be carried out on panoramic or even intraoral radiographs that are routinely used for different purposes. The most common dental maturation method is that proposed by Demirjian et al. [19], which comprises eight stages from A to H according to the degree of tooth formation, and that can be applied to any tooth. Foreshortened or elongated projections of developing teeth will not affect the reliability of this assessment, as this method consists of distinct details based on shape criteria and proportion of root length, using relative values to the crown height. Details of the method are reported elsewhere [19].

Previous reports have shown a high degree of correlation between dental maturation and hand and wrist [20] or cervical vertebral [21] maturations, according to which dental maturation has been proposed as a reliable indicator for skeletal maturation assessment. However, diagnostic performance of these dental maturational stages remains sparse for mandibular canine, premolars, and second molars [22]. The only exception was seen for the mandibular second molar, in which complete formation of the distal apex (stage H) has been seen to occur generally in the postpubertal growth phase [22] or after the mandibular growth peak [23]. Interestingly, spontaneous eruption of maxillary canines has been reported to occur always before the closure of the apex of the mandibular second molar (up to stage G) [24], making this stage a potential indicator for the timing of interceptive treatment for palatally displaced canines [25,26].

2.5. Chronological age

It has been reported extensively that the average ages at the onset and peak of pubertal growth in stature are approximately 12 and 14 years in boys, and 10 and 12 years in girls [7,8,27–29]. However, high variability was seen among individual subjects and there is little diagnostic accuracy of the method [5]. Of note, onset of the pubertal growth phase is influenced by several factors, including genetics, ethnicity, nutrition, and socioeconomic status [30], responsible for a secular trend [31]. However, it has been reported that boys up to 9 years old and girls up to 8 years old are generally in the prepubertal growth phase [5]. Therefore, clinical applicability of chronological age as an indicator of the onset of the pubertal growth phase in the individual patient is very limited [2,8,12,18].

2.6. Standing height

Standing height has long been used as an indicator of the pubertal growth phase [32]. This procedure relies on serial recordings of standing height at regular intervals to build an individual curve of growth. Several investigations [3,32,33] reported a satisfactory degree of correlation between the standing height peak and mandibular growth peak, with an overall diagnostic accuracy in the identification of the mandibular growth peak between 0.61 and 0.95 [18]. According to this evidence, the recording of standing height may be useful in clinical practice to determine the onset of the pubertal growth phase, although true feasibility of the method limits its application in clinical practice.

2.7. Biochemical markers

The use of biomarkers has been proposed very recently as a new aid in assessing individual skeletal maturity with the advantage of avoiding radiation. The few data reported to date include biomarkers from the gingival crevicular fluid, such as alkaline phosphatase [34,35] or from the serum, such as insulinlike growth factor I [36–38]. These studies reported increased levels of the investigated biomarkers during the pubertal growth phase [34–38]. Of interest are the biomarkers from the gingival crevicular fluid, as its sampling involves a very simple, rapid, and noninvasive procedure