REVIEW ARTICLE

Skeletal maturity indicators

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ABSTRACT

Growth biologically and histologically is a composite of morphogenetic and histogenetic changes occurring continuously over a period in response to genetic coding and environmental influence. It is one of the most myriad variations and plays an important role in the etiology of malocclusion and also in the evaluation of diagnosis, treatment planning retention and stability of any case. In this review, various methods currently used as skeletal maturity indicators have been discussed.

Key words: Cervical vertebrae maturation indicators, hand and wrist radiographs, middle phalanx of third finger, skeletal maturity indicators

Introduction

An understanding of growth events is of primary importance in the practice of clinical orthodontics. Maturational status can have considerable influence on diagnosis, treatment goals, treatment planning, and the eventual outcome of orthodontic treatment. Clinical decisions regarding the use of extra oral traction forces, functional appliances, extraction versus nonextraction treatment, or orthognathic surgeries are, at least partially, based on growth considerations. Prediction of both the times and the amount of active growth, especially in the craniofacial complex, would be useful to the orthodontist.[1]

Growth modulation procedures, which bring about changes in the skeletal base such as the use of extra oral orthopedic forces or functional appliances, are based on active growth periods. These active growth periods have to be objectively assessed for both the timing and the amount of active growth vector or direction of growth. Maturational status of an individual can be best-evaluated relative to different stages of physiologic maturity rather than evaluating it with chronologic age because the latter is not a reliable indicator. Physiologic maturity is best-estimated by the maturation of one or more tissue systems, such as somatic, sexual, skeletal, and dental maturity. Skeletal maturity assessment involves visual inspection of the developing bone and their initial appearance, sequential ossification, and related changes in shape and size. Thus, the skeletal maturity indicators provide an objective diagnostic evaluation of stage of maturity in an individual.

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Importance of Pubertal/Adolescent Growth Spurt

The timing of recognition of the last and important growth spurt that is, the pubertal growth spurt is important in percept of orthodontics. It is during this growth phase, the somatic growth rate is at its maximum. Every growth spurt has definite onset, accelerating phase, peak of the growth spurt, decelerating phase, end of the growth spurt. The duration of this growth spurt is short in females around 3-4 years compared to males in which it extends 4-5 years. The girls have an earlier onset of puberty whereas in the boys, late onset is seen. The accelerating phase may last for 2 years on average. After 3-4 years of the end of this growth spurt, the active growth ceases.[2-5]

Assessment of Timing of Adolescent Growth Spurt

The timing of the growth spurt can be assessed by chronological age, skeletal age, physiologic age, and dental age. The chronological age is not reliable as variability is the rule of growth pattern. In most of the conditions, skeletal age

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is assessed to pinpoint identify the different phases of the growth spurt. A number of methods are available to assess the skeletal maturity of an individual in orthodontic practice. Practically, the following methods are followed:

Radiological

1. Special radiographs:
   Use of hand-wrist radiographs: This is the most common method and widely accepted method.[6-10]
2. Lateral cephalograms:
   Use of cervical vertebrae on a lateral cephalogram.[11,12]
   Use of frontal sinus using lateral cephalogram.[13]
3. Orthopantomogram (OPG)/intraoral periapical:
   Use of different stages of tooth development.[12-17]

Biochemical

Recent biochemical method in saliva and serum are the:[18-27]

A. Insulin-like growth factor (IGF) growth hormone (GH),
B. Creatinine,
C. Alkaline phosphatase (ALP).

The review of the literature shows a vast ore on this topic. These studies or reviews are related to methods of assessment, correlation between different methods, correlation between skeletal age and dental age and chronological, etc. This article reviews and presents a simple clinical method of reference for skeletal assessment.

Radiological

Hand wrist radiographs

The hand wrist radiograph is considered to be the most standardized method of skeletal assessment. Assessment of skeletal maturation using hand wrist radiograph as an index based upon time and sequence of appearance of carpal bones and certain ossification events has been reported by many investigators. A number of methods have been described to assess the skeletal maturity using hand-wrist radiographs.[6-10] The following are the most commonly used methods:

A. Atlas Method by Greulich and Pyle.
B. Biork, Grave and Brown Method modified by Schopf in 1978.
C. Fishman's skeletal maturity indicators.
D. Hägg and Taranger Method.
E. Singers Method.

Among them, Atlas Method by Greulich and Pyle is a comparative method whereas all the other methods are individualized methods. All of these methods rely on the stage of the development of the epiphysis over the diaphysis. Usually, all the methods depend on the assessment of the following stages in ossification of phalanges:

Stage 1: The epiphysis and diaphysis are equal (Sign convention '=').
Stage 2: The epiphysis caps the diaphysis by surrounding it like a cap (cap).
Stage 3: Fusion occurs between the epiphysis and diaphysis (U-Union).

These stages occur at different times in different miniature skeletal bones of the hand wrist.

Anatomical sites

The different sites used by all these methods are:
Proximal phalanx of the third finger.
Middle phalanx of the third finger (MP3).
Distal phalanx of the third finger.
Middle phalanx of the fifth finger.
R-Radius and
S-Sesamoid (thumb).
H-Hook of hamate.

Among them MP3, R, and S are the found to be most reliable and can be correlated with the development of cervical vertebrae or dental development.

Drawback: Unnecessary exposure to radiation.

Lateral Cephalograms

Skeletal Maturation Evaluation Using Cervical Vertebrae

Hassel and Farman using the cervical vertebrae developed a system of skeletal maturation determination. Later, this was modified by Baccetti *et al*. The shapes of the cervical vertebrae were seen to differ to teach level of skeletal development. This provided a means to determine the skeletal maturity of a person and thereby determine whether the possibility of potential growth existed. The shapes of the vertebral bodies of C3 and C4 changes from wedge shape to rectangle followed by square shape. In addition, they became taller as skeletal maturity progressed. The inferior vertebral borders were flat when immature and became concave with maturity. The curvatures of the inferior vertebral borders seem to appear sequentially from C2 to C3 to C4 as the skeleton matures. The concavities become more distinct as the person matures.[10,11]

Frontal Sinus and Mandibular Growth Prediction

The frontal sinus is part of the anterior ethmoidal cells which evaginate from the frontal recess directly to the frontal bone. These are two irregular cavities, which extend backward, upward, and lateral ward for a variable distance between the two tables of the skull; they are separated from one another by a thin bony septum. They are absent at birth, but they come to become evident as the child grows.

Rossouw *et al*. (1991) evaluated the skeletal growth patterns of 103 subjects with Class I and III malocclusions were cephalometrically analyzed as advocated by Ricketts *et al*., to assess abnormal mandibular growth. The surface area (mm) of the frontal sinus was assessed by a summagraphics decoder linked to a microcomputer. The results indicate that there is a significant correlation between maxillary length, mandibular length, symphysis width, condylar length, and frontal sinus size on a lateral cephalogram. The frontal sinus can possibly be used as an additional indicator when one is predicting mandibular growth.[11]

Intraoral Radiographs/OPG

Tooth Mineralization as an Indicator of Skeletal Maturity

Dental maturity can be determined by the stage of tooth eruption or the stage of tooth formation. Tooth formation is proposed as more reliable criteria for determining dental maturation. The ease of recognition of dental development stages, together with the availability of periapical or panoramic radiographs in most orthodontic and dental practices are practical reasons for attempting to assess the physiologic maturity without resorting to hand wrist radiographs. Various researchers have carried out extensive work to correlate the dental age and skeletal age. It is believed that stages of root formation and mineralization have a close relationship with the skeletal maturation of an individual. Relationships between the stages of tooth mineralization of the mandibular canine appear to correlate better with ossification stages than do the other teeth. Some of the dental indicators for skeletal maturity were put forward by Chertkow and Fatti based on the mineralization of the lower canine. Nolla's stage of calcification was utilized by some workers to correlate with skeletal maturity. Goldstein and Tanner have described a similar method based on third molar. If a strong association exists between skeletal maturity and dental calcification stages, the stages of the dental calcification might be used as a first level diagnostic tool to estimate the timing of the pubertal growth spurt. Relationships between the stages of tooth mineralization of the mandibular canine appear to correlate better with ossification stages than do the other teeth. According to the method given by Demirjian *et al*., stage of calcification of the mandibular canine is assessed by the radiological appearances of the tooth. Each tooth has been rated according to developmental criteria (amount of dentinal deposit, shape change of the pulp chamber, etc.) rather than changes in size. Eight stages, A to H, have been defined from the first appearance of calcified points to the closure of the apex.[13-17]

Biochemical Methods/Physiologic Method

Radiation leads to various problems from skin diseases to cancers and has to be avoided. Recent literature has given much emphasis on biochemical methods for detection of skeletal maturity.[18-27] These biochemical markers of skeletal maturity were initially detected in serum, but nowadays, these are also detected in saliva.

Insulin-Like Growth Factor-1

In 1957, Salmon and Daughaday discovered IGF-1, as a mediator of GH functions. IGF-1 is a circulating GH factor, the level of which correlates with sexual maturity. It is used to diagnose GH deficiencies and excess. Precise assessment of IGF is useful diagnostic tool for determining growth status as its levels do not fluctuate throughout the daily, unlike other GH levels. It is measurable in serum, urine, and saliva. Various reviews have shown a positive correlation with cervical skeletal maturity from the prepubertal to the late pubertal stages.

Alkaline Phosphatase

The ALP rises significantly in parallel with the growth velocity between the ages of 8-12 in girls and 10-14 in boys and thereafter it falls rapidly to adult levels. It is a physiologic response to the growth spurt and does not signify disease. Their level also rises in gingival inflammation and also in bone deposition. Perinetti *et al*.[23] found that gingival crevicular fluid (GCF) ALP levels rises during puberty and these studies were correlated with MP3, cervical vertebrae maturation indicators and also with hand wrist radiographic have seen significant results suggesting ALP is biomarker and can be considered as the noninvasive method to determine maturation stage.

Creatinine

The other index of maturity are the ratio of creatine to creatinine in the urine, this ratio is thought to fall progressively with age after about the age of 14 years, probably under hormonal influences. Girls maturing early have a lower ratio than those of the same chronological age maturing late. A measurement of this ratio might be used to add information regarding the maturity along with skeletal and other data obtained at same time.

Various studies were conducted in serum, saliva, and GCF to correlate its finding with the skeletal maturity indicators of the radiological origin.

Conclusion

1. Growth maturation stages are important for proper timing and treatment management.
2. Various methods are present of which skeletal and physiologic/biochemical methods are reliable for the clinical references.
3. The review also suggests that more simplified noninvasive methods can be considered as additional diagnostic tool to avoid exposure to radiation.

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