Skeletal and Dental age assessment methods: A Review

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Abstract

Identification and determination of age is imperative for diversity of reasons that include disputed birth records, premature delivery, legal issues etc. Assessment of growth and development of a child helps in orthodontic, tooth development, shedding analysis, surgical and orthopedic management in dentistry.Dental age is one of the few measures of physiologic development that is uniformly applicable from infancy to late adolescence.Several methods have been proposed for the assessment of a child's dental age.

Keywords: Development, Skeletal age, Dental age.

INTRODUCTION

In the modern era, identification and determination of age is imperative for diversity of reasons that include disputed birth records, premature delivery, legal issues etc.

Several growth assessment parameters like boneage, dental age and the combination of both have been applied for different population with variable outcomes. The age of a person can be determined by the degree of maturation of the different tissue systems of an individual. The most important anatomical areas for age estimation are dental and the hand-wrist area.1

Skeletal maturation refers to the degree of development of ossification in bone. Size and maturation can vary independently on eachother.2During grow the very bone goes through a series of changes that can be observed radiographically. The sequence of changes is relatively consistent for a given bone in every person. The timing of changes varies because each person has his/her ownbiologicclock.3

Because of an individual's variation in timing, duration and velocity of growth, skeletal age assessment is essential and helpful in formulatingviabletreatmentplans.4

Dental age is one of the few measures of physiologic development that is uniformly applicable from infancy to late adolescence.

Estimationiseitherbasedupontherateofdevelopmentandcalcificationoftoothbudsandtheprogressivesequenceoftheireruptionintheoralcavity.5

Several methods have been developed to assess the dental age according to the degree of calcification observed. Thedental age method involves the recognition of clinically present teeth with eruption charts. The treatment planning and the prognosis of certain treatments greatly depends on the dental age.

SKELETAL AGE ASSESSMENT METHODS

Hand wrist radiograph

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 on time and sequence of appearance of carpal bones and certain ossification events has been reported by many investigators.

Cervical vertebrae maturation methods

Hassel and Farman (1995) found that the shapes of the cervical vertebrae were found to differ with different levels of skeletal development.6

- Initiation: Inferior borders of the second, third and fourth cervical vertebrae are flat at this stage. The third vertebra is

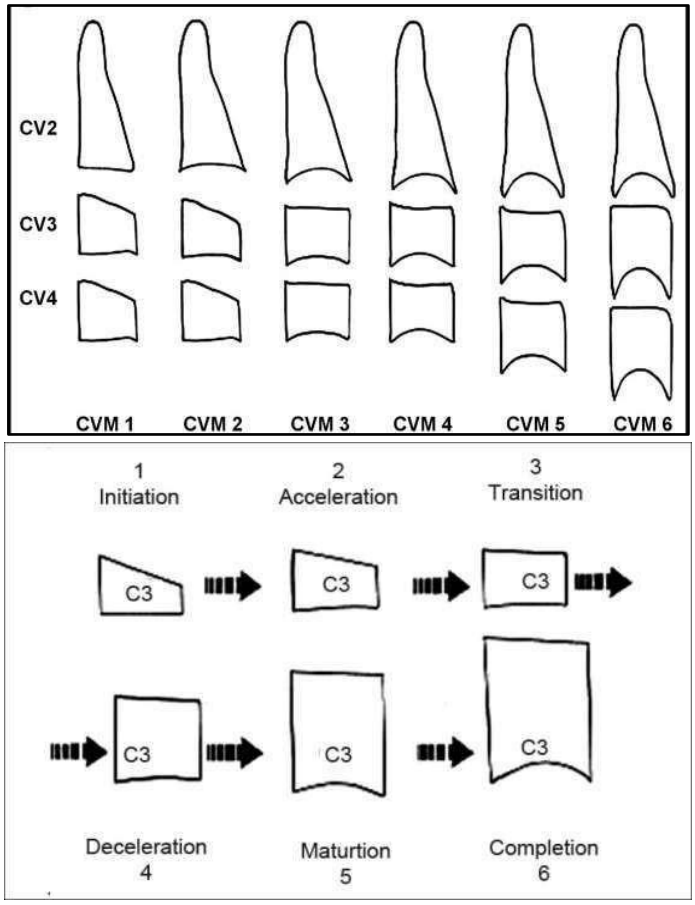
wedge shaped and the superior vertebral borders are tapered from posterior toanterior.100percentof pubertal growth remains.

- Acceleration: Concavities on the inferior borders of second andthirdvertebraebegintodevelop.Inferiorbordersofthefourthvertebrae remain flat. Vertebral bodies of third and fourth vertebrae are nearly rectangular in shape. 65 to 85 percent of pubertal growth remains.
- Transition: Distinct concavities are shown on the inferior borders of second and third vertebrae. A concavity begins to develop on the inferior border of fourth vertebra. Vertebral bodies of third andfourtharerectangularinshape.25to65percent of growth remains.
- Deceleration: Distinct concavities can be observed on the inferior borders of second, third and fourth, cervical vertebrae. Vertebral bodies of third and fourth begin to be squarer in shape. 10 to 25percent of pubertal growth remains.
- Maturation: Marked concavities are observed on the inferior border of second, third and fourth cervical vertebrae.

Vertebralbodiesofthirdandfourtharealmostsquareinshape.5to10percentofpubertalgrowthremains.

- Completion: Deep concavities are observed on the second, third, and fourth cervical vertebrae. Vertebral bodies are greater vertically than horizontally. Pubertal growth has been completed.

Fig1.Diagrammaticrepresentationofcervicalvertebraematuration.



Cervical vertebrae maturation indicator susing C3 as guide

Modified stages of Cervical vertebral maturation given by Mcnamara, Bacettiand Franchi (2005).7

The six stages are defined as follows:(Fig 2).

1. Cervicalstage1(CS1):The lower borders of all the three vertebrae(C2-C4) are flat. The bodies of both C3 and C4 are trapezoid in shape (the superior border of the vertebral body is tapered from posterior to anterior). The peak in mandibular growth will occur on an average two years after this stage.

2. Cervical stage 2 (CS2): A concavity is present at the lower border of C2. The bodies of bothC3 and C4 are still trapezoid shape. The peak in mandibular growth will occur, on an average within one year after this stage. Class III treatment with maxillary expansion andprotraction is effective in the maxilla only when it is performed before the peak(CS1orCS2),whereasitiseffectiveinthemandibleduringbothprepubertalandpubertal stages.

3. Cervicalstage3(CS3): Concavities at the lower borders of bothC2andC3arepresent.ThebodiesofC3andC4maybeeithertrapezoidor rectangular horizontal in shape. Stage CS3 represents

the idealstagetobeginfunctionaljaworthopaedics,asthepeakinmandibulargrowth will occur within the year or after this stage. CS3 is also theappropriateagefortreatmentofverticalmalocclusion,becausepeakin mandibular growthoccursduring thisstage.72

4.

Cervicalstage4(CS4):ConcavitiesatthelowerbordersofC2,C3,andC4arenowpresent.ThebodiesofbothC3andC4arerectangular and horizontal in shape. The peak in mandibular growthhasoccurredwithinoneortwoyears before thisstage.

5.

Cervicalstage5(CS5):TheconcavitiesatthelowerbordersofC2,C3,andC4stillarepresent.AtleastoneofthebodiesofC3andC4is square in shape. 1f not square, the body of the other cervicalvertebra is still rectangular and horizontal. The peak in mandibulargrowthendsat leastoneyear beforethis stage.

6. Cervicalstage6(CS6):TheconcavitiesatthelowerbordersofC2,C3,andC4stillareevident.AtleastoneofthebodiesofC-3andC4is rectangular andvertical If not rectangular and vertical, the bodyof the other cervical vertebra is square. The peak in mandibulargrowthend at least years before this stage.

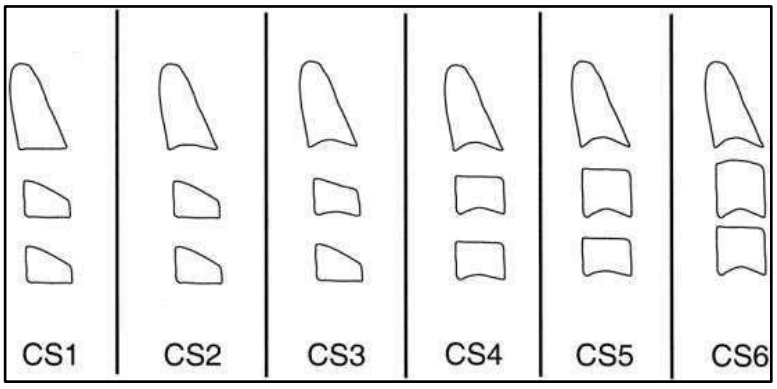


Fig2 Modified cervical vertebrae maturation stages

Singer's method of skeletal maturity assessment

Julian Singer in 1980 proposed a system of hand-wrist radiograph assessment that would enable the clinicianto rapidly and with some degree of reliability help determine the maturational status of the patient.8

Frontal sinus as skeletal maturity indicator Ruf and Pancherz(1996)

Inthismethod,lateralcephalometricradiographisusedformeasuring the size of the frontal sinus at yearly intervals.19

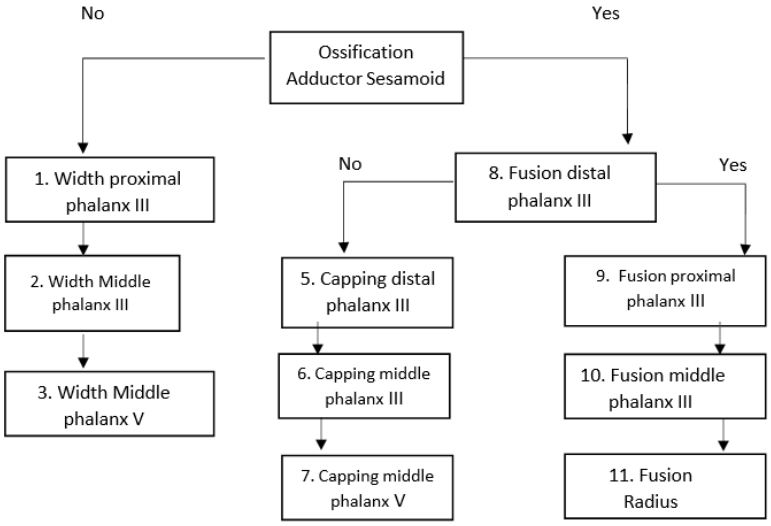
The body height growth data were used only to test the accuracy of thepredictionofpubertalstage as assessed fromfrontalsinusdevelopment.

Fishman'sskeletalmaturityIndicators:

Leonard S Fishman, in 1982 developed this method to predict theskeletal maturation (flow chart). It makes use of the anatomical siteslocatedonthumb,thirdfinger,fifthfingerandradius.9

Eleven discrete adolescent skeletal maturity indicators covering theentireperiodofadolescentdevelopmenthavebeendescribed.TheFishman's system of interpretation uses four stages of bone maturation.Theyare:

- Epiphysisequalinwidthtodiaphysis.
- Appearanceofadductorsesamoidofthethumb.
- Cappingofepiphysis.
- Fusionofepiphysis.



Flow chart - Fishman's 11-grade scheme used to assess skeletal maturityfromahand-wrist radiograph.

The elevenskeletalmaturityindicators are:

- S.M.I.1:Thethirdfingerproximalphalanxshowsepiphysisanddiaphysisof equalwidth.
- S.M.I.2:Widthoftheepiphysisequaltothatofdiaphysisinthemiddlephalanxof thirdfinger.
- S.M.I. 3:Widthoftheepiphysisisequaltothatofthediaphysisinthemiddlephalanxoffifthfinger.
- S.M.I.4:Appearanceofadductor,sesamoidofthethumb.
- S.M.I.5:Cappingofepiphysisseeninthedistalphalanxofthirdfinger.
- S.M.I.6:Cappingofepiphysisseeninmiddlephalanxofthirdfinger.
- S.M.I.7:Cappingofepiphysisseeninthemiddlephalanxofthefifth finger.
- S.M.I. 8: Fusion of epiphysis and diaphysis in the distal phalanx ofthethirdfinger.
- S.M.I.9:Fusionofepiphysisanddiaphysisintheproximalphalanxofthethirdfinger.
- S.M.I. 10: Fusion of epiphysis and diaphysis in the middle phalanxofthethirdfinger.
- S.M.I.11:Fusionofepiphysisanddiaphysisseenintheradius.

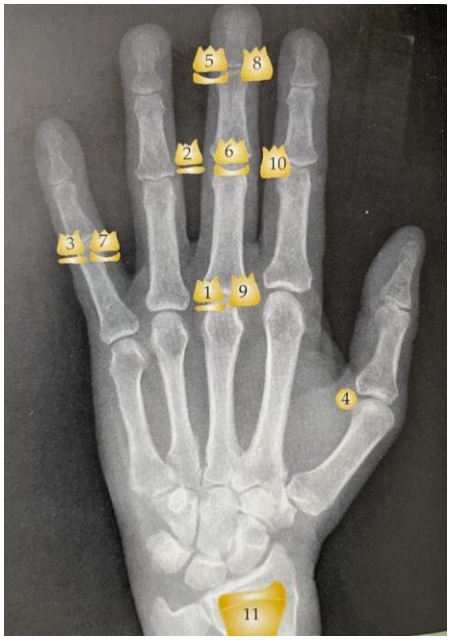


Fig 3– Eleven skeletal maturity Indicators

Development of mandibular third molar as an indicator of skeletal maturation

Thedevelopmentstagesofthirdmolarwerecategorizedintooneofthe followingclasses.10

a) Cusp tips have mineralized but nor coalesced.

b) Mineralized cusps are united so the mature coronal morphology is well defined.

c) The crown is about half formed, the pulp chamber is evident and dentinal deposition is occurring.

d) Crown formation is complete to the dentinoenamel junction. The pulp chamber has trapezoid form.

e) Formation of interradicular bifurcation has begun. Root length is less than the crown length.

f) Root length is atleast as great as the crown length. Roots have funnel shaped endings.

g) Root walls are parallel and apices remain open.

h) Apical ends of the roots are completely closedand the periodontal membrane has a uniform width around the root.

DENTAL AGE ASSESSMENT METHODS

Dental maturity can be determined by the stage of tooth eruption or by the stage of tooth formation. Tooth formation is proposed as a more reliable criterion for determining dental maturation. There are various methods for dental age assessment.11 They are:-

Schourand Massler

In 1941, Schour and Massler studied the development of deciduousand permanent teeth and described 21 steps ranging from 4 to 21 years ofage and published numerical charts for them.12 In 1982, to make thempossible to directly compare calcification stages of teeth on radiographswith the standards American dental association updated these charts andpublishedthem.13

Moorrees, Fanning and Hunt Method

In the longitudinal study, based on lateral cephalogram involving136 boys and 110 girls.14 Moorreeset al. summarized that the graphicrepresentation of the chronology of tooth formation and root resorption ofthe deciduous mandibular canines and molars provides a rapid means forthe assessment of dental development during the early post-natal growthperiod of individualchildren.15

Demirjian, Goldstein and Tanner method

Demirjianetal.in1973and1976definedfourdevelopmentalcrownsandfourdevelopmentalrootstages, whichwerebasedonradiological tooth germs. 16They used stages A-H instead of numbers topresent the impression of an equal duration of each stage.17 Stage 0 wasgiven for nonappearance of any mineralization on radiograph. If there wasnosignofcalcification,arating0wasgiven,cryptformationwasnottakeninto consideration. They rated seven mandibular permanent teeth in orderof second molars (M2), first molars (M1), second premolars (PM2), firstpremolars(PM1)canines(C),lateralincisors(I2),andcentralincisors(I1).18

In this approach a scoring system was used for the formation of leftmandibular teeth. Every stage was assigned a certain dental score withadding-up all scores giving the dental maturity scores which contributedand indicated for individual dental maturity.19 These stages were taken astheindicatorsofdentalmaturityofeachtooth.Thedifferencesinthedentaldevelopmentbetweenmalesandfemaleswerenotsupposedtobeapparentuntil the ageof5years.20

Each stage of mineralization was given a score which provided anestimate of dental maturity on a scale of 0–100 on percentile charts. Thematurity scores (s) for all the teeth was/were added and the total maturityscores might be converted directly into a dental age as per the standardtable or they were substituted in regression formula.21 Females andmales hadseparate formulae.

Infemales,theformulawasgivenbelow:

Age=(0.000055 ×S3)−(0.0095 ×S2)+(0.6479 ×S)−8.4583.

Inmales,theformulawasgivenbelow:

Age=(0.0000615 ×S3)−(0.0106 ×S2)+(0.6997×S)−9.3178.

In this method, missing teeth from one side could be replaced bythose from the other side. If the first molars used to be absent, the centralincisorscouldbesubstitutedforthemastheirdevelopmentalagescoincide.22Theonlydrawbacksincludedthatthesurveydidnotincludethe developing third molars and the mandibular teeth needed to be present forthesurveytobe applicable.23

Williem's modification

Thechronological age is obtained by adding the maturity score of differentteeth.23 This method is simpler and retains the advantage of Demirjian'smethod.24

Nolla'smethod

Nolla in 1960 developed a method in which development of eachtoothwasdividedintotenrecognizablestagesandcategoricallynumbered1–10.25Bythismethod,thedevelopmentofeachtoothofthemaxillaryandmandibular arch could be assessed. The radiograph of the patient wasmatched with the comparative figures (Fig 4)

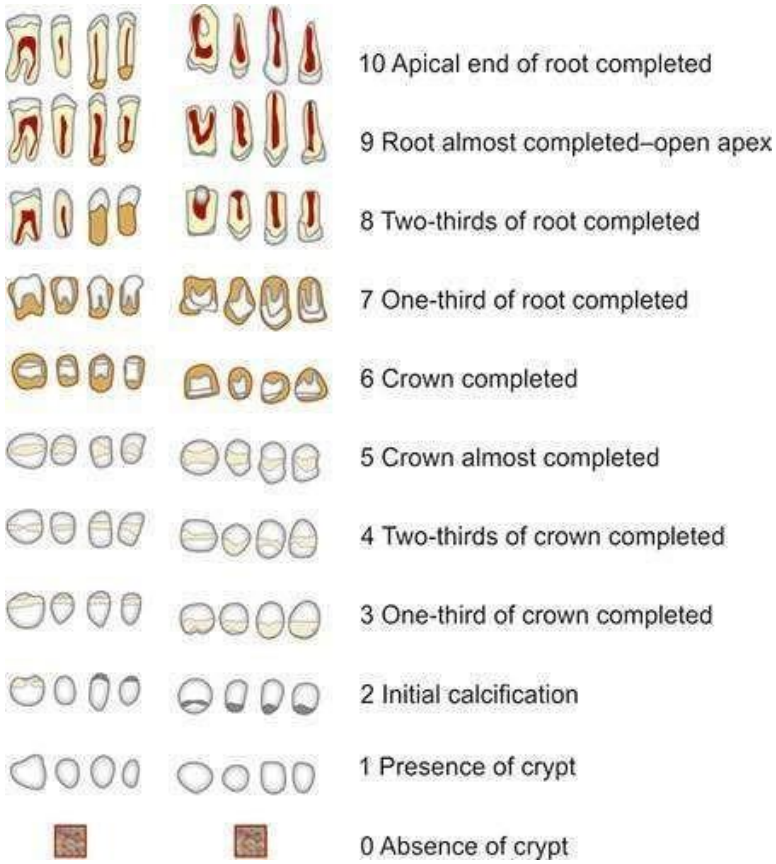


Fig4: Dental development chartbyNolla

Cameriere's method

This is one of the methods that have been given by Camerieeet al., which consists of the age group between 5 and 15 years study done on 455 Italian children.The dental age is calculated based on the relationship between the age and measurement of open apices in teeth. The seven left permanent mandibular teeth excluding third molars are used to calculate the dental age. The height of the calcifying teeth and the width of the "open" apex are measured and their ratio is calculated. Such a ratio is calculated to compensate for magnification and angulation errors that may have been induced during radiography. The number of teeth with complete root development and closed apical ends is noted as N0.24 In the teeth with incomplete root development, the distance between inner sides of the open apex is measured. For the teeth with two roots, the sum of the distances between inner sides of two open apices is taken. The dental maturity is calculated as the sum of normalized open apices (s) and the numbers of teeth with root development complete (N0). The values are substituted in the following regression formula for age estimation.

Age = 8.971 + 0.375 g + 1.631 × 5 + 0.674 N0 − 1.034 s − 0.176 s. N0, where g is a dummy variable equal to 1 for boys and 0 for girls. Hence, this is also an age estimation method for children and adolescents. The median of residual errors between the actual and estimated ages was 0.035 years (interquartile range = 1.18 years).

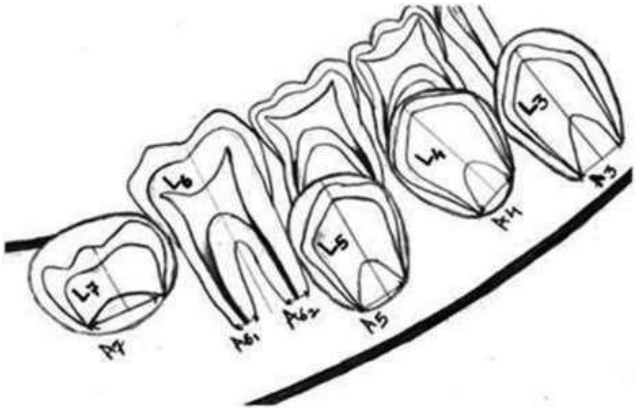


Fig:5 Measurements' chart by Cameriere et al., L=length of tooth (L1,L2),A=distance between inner sides of open apex(A1,A2).

Pulp-to-tooth area ratio method by kvaal

Kvaal et al. introduced an age estimation method by indirectlymeasuring secondary dentine deposition on radiographs and proposed anumber of length and width measurements of teeth and pulp. Camerieretal., later, put forth a similar method based on radiographic estimation ofpulp-to-tooth AR in canines.26

Canines were favored as they were single-rooted teeth with the largest pulp area for ease of analysis. In Kvaal'smethod,pulp-to-toothratiowascalculatedforsixmandibularandmaxillary teeth such as maxillary central and lateral incisors, maxillarysecondpremolars,mandibularlateralincisor,mandibularcanine,andmandibular first premolar. The age was derived using these pulp-to-toothARsintheformulaforagedetermination.

Usingintraoralperiapicalradiographs, the variables

- P = complete pulp length/root length (fromenamel-cementumjunction[ECJ]torootapex),
- r=completepulp length/completetoothlength,
- a=completepulplength/rootwidthatECJ level,
- b=pulp/rootwidthatmidpointlevelbetweenECJlevelandmid- root level, and
- c = pulp/root width at mid-root level and pulp/tooth AR forallsixteethweremeasuredasdevisedinKvaal'sandCameriere'smethodsofage estimation, respectively

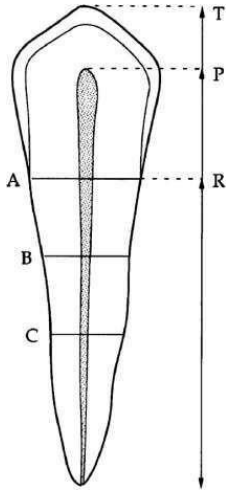


Fig6.Measurements' chart by Kvaal and Camerieretal.

usingpulp - to - tootharearatios,P=Completepulplength/rootlength(from enamel-cementum junction to root apex), r=Complete pulp length/complete toothlength, a=Complete pulp length/root width at enamel-cementum junctionlevel, b=Pulp/rootwidth atmidpointlevelbetweenenamel-cementumjunction level and mid-root level and c=Pulp/root width at mid-root level;and pulp/tootharea ratio.

Calculationsofseverallengthandwidthratiosweredonetocompensateforanymagnificationorangulationoftheoriginaltoothimageon radiographs.

Finally, a simple linear regression analysis was carried out, whereinthe variables mean (M) (meanof variables complete pulp).

CONCLUSION

Precise evaluation of maturation stage is crucial for proper timing, treatment, and its outcome. Researchers have found out various methods, these include chronologic, radiographic, biologic, and physiologic methods to find out the best suitable method for age assessment. Every method has its own pros and cons. This review suggests that methods which are simple and non-invasive and do not have risk of additional radiation exposure can be considered as additional diagnostic tool.

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