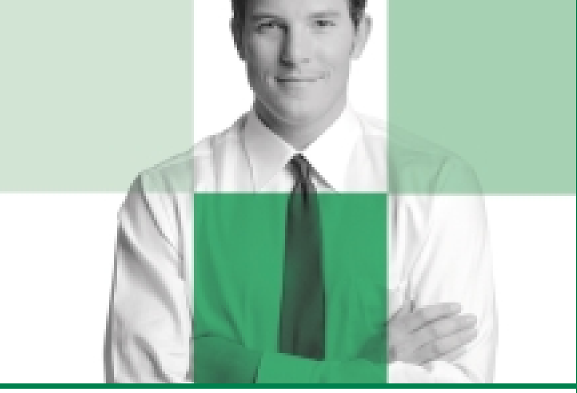


PANORAMIC *Imaging* News

Volume 4, Issue 4 US $6.00

Editor:

Allan G. Farman, BDS, PhD (odont.), DSc (odont.), Diplomate of the American Board of Oral and Maxillofacial Radiology, Professor of Radiology and Imaging Sciences, Department of Surgical and Hospital Dentistry, The University of Louisville School of Dentistry, Louisville, KY.

Featured Article:

Assessing Growth and Development with Panoramic Radiographs and Cephalometric Attachments: A critical tool for dental diagnosis and treatment planning

In The Recent Literature:

Implantology

Lateral cephalograms

Impacted third molars

Calcified stylohyoidal chain

Jaw fracture and third molar impaction

Learning Objectives:

Gain knowledge of the importance of tooth and skeletal maturity determinations as it inputs into dental treatment planning.

Learn the roles of panoramic, cephalometric, and hand-wrist radiographic studies in biological age determinations.

Learn the factors acting as determinants of relative dental and skeletal maturity findings.

Provided as a professional service by:

Panoramic Corporation

In conjunction with

The Richmond Institute for Continuing Dental Education

A division of Young Innovations, Inc.

Assessing Growth and Development with Panoramic Radiographs and Cephalometric Attachments: A critical tool for dental diagnosis and treatment planning

By Dr. Allan G. Farman

It is recommended that radiographs be made periodically including both during the mixed dentition (8-9 year old) and adolescence (12-14 year old) to evaluate growth and development, and to look for asymptomatic dental disease [1-3]. Substantial differences in the assessed biological and the known chronological age can be indicators of a variety of inherited and congenital conditions. Further, local failure in dental eruption within the normal time range can be evidence of dental impaction and possibly of a pathological process such as a hamartoma, cyst, or tumor. Failure to remove causes of impaction prior to cessation of the normal eruption time can lead to otherwise unnecessary surgical orthodontics, a poorer outcome prognosis, and perhaps to a sequence of time consuming, expensive, and less than ideal replacement strategies [4]. The dental panoramic radiograph is a quick, simple, and relatively safe way to achieve the goal of evaluating the whole dentition in a manner that is easy to explain to the patient or concerned parent.

Eruption Sequence and Timing

There is some controversy as to the precision with which tooth development and eruption predict chronological age; however, most reports suggest that there is a good correlation. One key indicator of age is that the three permanent molar teeth in each quadrant erupt approximately at six-year intervals. The first permanent molar erupts around 6 years, the second permanent molar around 12 years, and the third molars around 18 years. Root formation for permanent teeth is completed roughly three years following eruption. The first major attempt at developing a chronology for human tooth development was that of Logan and Kronfeld (1933) and with minor modification is still usable as a rough and ready guide. Using this Table, eruption times for permanent teeth usually are within 2 years of the actual chronological age (Table 1; Fig. 1-5) [5].

Demirjian and Levesque (1980) studied dental development of a genetically homogeneous French-Canadian group of children ranging in age from 2.5-19 years using 5,437

TABLE 1: Approximate Dental Maturation Schedule (after Logan & Kronfeld[5])

Dentition/ Arch	Tooth	Calcification Commences	Enamel Complete	Eruption	Root Complete
Primary Maxillary	Cent. Incisor	4 mth IU	1.5 mth	7.5 mth	18 mth
	Lat. Incisor	4.5 mth IU	2.5 mth	9 mth	24 mth
	Canine	5 mth IU	9 mth	18 mth	39 mth
	1st Molar	5 mth IU	6 mth	14 mth	2.5 y
	2nd Molar	6 mth IU	11 mth	24 mth	3 y
Primary Mandibular	Cent. Incisor	4.5 mth IU	2.5 mth	6 mth	18 mth
	Lat. Incisor	4.5 mth IU	3 mth	7 mth	18 mth
	Canine	5 mth IU	9 mth	16 mth	39 mth
	1st Molar	5 mth IU	5.5 mth	12 mth	27 mth
	2nd Molar	6 mth IU	10 mth	20 mth	3 y
Permanent Maxillary	Cent. Incisor	3-4 mth	4-5 y	7-8 y	10 y
	Lat. Incisor	10-12 mth	4-5 y	8-9 y	11 y
	Canine	4-5 mth	6-7 y	11-12 y	13-15 y
	1st Premolar	18-21 mth	5-6 y	10-11 y	12-13 y
	2nd Premolar	24-27 mth	6-7 y	10-12 y	12-14 y
	1st Molar	At Birth	2.5-3 y	6-7 y	9-10 y
	2nd Molar	2.5-3 y	7-8 y	12-13 y	14-16 y
	3rd Molar	7-9 y	12-16 y	17-21 y	18-25 y
Permanent Mandibular	Cent. Incisor	3-4 mth	4-5 y	6-7 y	9 y
	Lat. Incisor	3-4 mth	4-5 y	7-8 y	10 y
	Canine	4-5 mth	6-7 y	9-10 y	12-14 y
	1st Premolar	21-24 mth	5-6 y	10-12 y	12-13 y
	2nd Premolar	27-30 mth	6-7 y	11-12 y	13-14 y
	1st Molar	At Birth	2.5-3 y	6-7 y	9-10 y
	2nd Molar	2.5-3 y	7-8 y	11-13 y	14-15 y
	3rd Molar	8-10 y	12-16 y	17-21 y	18-25 y

" Up to 5-6 years of age, no difference was found in the timing of dental development between boys and girls, in contrast to the older ages where girls were always more developed dentally than boys."

panoramic radiographs [6-8]. The maturity of each mandibular tooth was evaluated individually. For each stage of each tooth, the developmental curves of boys and girls were compared. Up to 5-6 years of age, no difference was found in the timing of dental development between boys and girls, in contrast to the older ages where girls were always more developed dentally than boys. Elsewhere, Hegde and Sood (2002) evaluated dental age in 197 children of known chronological age (6-13 years) in Belgaum, India [6,9]. When the method of Demirjian *et al.* [6-8] was applied to Belgaum children, mean difference between true and assessed age for males showed overestimation of 0.14 years (51 days) and females showed overestimation of 0.04 years (15 days); hence, the method of Demirjian *et al.* showed high accuracy in this population group.

In contrast, Teivens *et al*. (1996) studied the developmental stages of the mandibular teeth according to the method by Demirjian *et al.* and reported discrepancies in staging where children of ages 5 and 12 years were found to fit the same developmental stage [7,8,10]. Their study involved analysis of 197 panoramic radiographs of children aged 5, 6, 9, and 12 years collected and examined by each of 13 independent pedodontists, radiologists and forensic odontologists. It was concluded that any method for age determination of children with aid of tooth development will suffer from a rather wide range of uncertainty owing to individual variations. In a separate paper from the same institution, it was found that different observers could vary to an extreme degree in age assessments made on the same radiographs, thus baseline standardization of observers rather than the assessment *per se* could well have contributed to finding a lack of reliability [11].

Dental age was studied by Nykanen *et al.* in a sample of 261 Norwegian children (128 boys and 133 girls) by using panoramic radiographs with the same maturity standards [7,12]. Reliability was analyzed by repeated

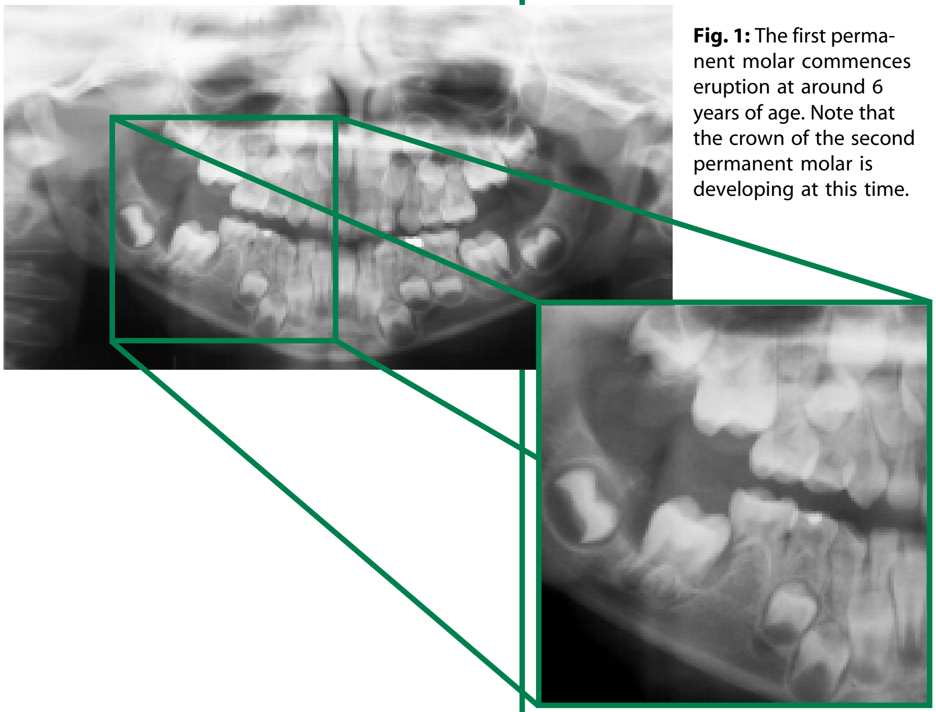


Fig. 1: The first permanent molar commences eruption at around 6 years of age. Note that the crown of the second permanent molar is developing at this time.

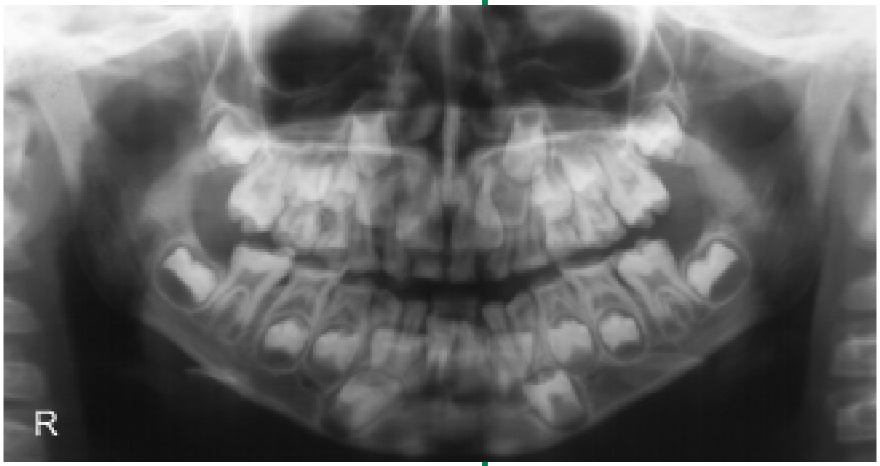


Fig. 2: The first permanent molar is generally fully erupted by 7 years; however the roots are still developing. Note that the root apices are wide open ("blunderbuss" shape). Root completion is approximately 3 years following eruption.

Fig. 3: At 10 years in the mixed dentition all permanent first molars and permanent incisors are erupted. The mandibular first premolars are in process of eruption. The roots of the first permanent molars are complete. This case shows a mesiodens in the maxilla that is displacing the central incisors and, left unattended, might complicate eruption of the permanent maxillary canines due to consequent dental crowding.

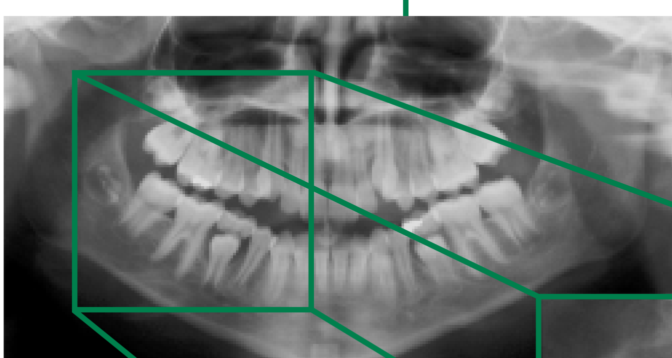


Fig. 4: At 12 years, the second permanent molars erupt. All premolars are erupted save for the mandibular second premolars that are still in process of eruption. The permanent maxillary canines are in process of completion of eruption. The mandibular third molars have commenced calcification.

assessments of 134 of the radiographs, and the overall mean difference between duplicate dental age determinations was 0.5 months for intra- and 1.8 months for inter-examiner comparisons. The Norwegian children were generally somewhat advanced in dental maturity compared with the French-Canadian reference sample. Among the boys the mean difference between dental age and chronologic age varied in the different age groups from 1.5 to 4.0 months. Among the girls the difference increased with age, varying from 0 to 3.5 months in the younger age groups (5.5 to 9.0 years) and from 4.5 to 7.5 months in the age groups 9.5 years and above. The variability in individual dental age was sometimes marked and increased with age. For the older age groups 95% of the individual age estimates were within ± 2 years of the real chronological age.

Normal Variations in Eruption Timing

Gender: As indicated earlier, the dental development of a genetically homogeneous French-Canadian group of children ranging in age from 2.5 to 19 years was evaluated from 5,437 panoramic radiographs by the method of Demirjian *et al.* [7,8] Up to 5-6 years of age, no difference was found in the timing of dental development between boys and girls, in contrast to the older ages where girls were always more developed than boys. A close relation was established between the stage of formation of all teeth and their emergence.

In a study of dental maturity in 903 healthy Chinese children (boys: 465, girls: 438) aged 3-16 years, at 3-5 years old, boys had dental maturity slightly earlier than girls but the gender difference was not statistically significant [13]. In the age range of 7-14 years, girls were more advanced than boys ($p < 0.05$), with girls being on average 0.45 years more advanced than boys. The maximum average difference was 0.85 years for the permanent canine tooth. The time that each developmental stage took was shorter in 50% of girls, but longer in

28% of girls compared to the average for boys. There was no difference between boys and girls in the remaining 22% of cases.

In a study of 929 female and 686 male Japanese subjects aged between 12 and 30 years, a total of 1,615 panoramic radiographs were examined [14]. The mineralization stages of third molars were evaluated on the basis of the Demirjian *et al.* stages, modified in accordance with Mincer's model [7,8]. No statistically significant differences in the chronology of third molar mineralization between maxilla and mandible and between sides were observed. A comparison between genders did not reveal any substantial differences with respect to third molar development.

Skeletal Pattern: In a Japanese population, Sasaki, *et al.* (1990) examined variations in dental maturity between girls having skeletal Class II and Class III malocclusions. Using panoramic radiographs and lateral cephalograms, they found that the timing of dental eruption was not significantly affected by jaw skeletal type [15].

In Brazil, Janson *et al.* carried out a double blind determination of dental maturation, expressed by dental age, for each of 20 subjects (10 male and 10 female for each group) selected from 400 subjects by virtue of representing the extremes in open and deep bite. Given the same chronological age, the open bite group had a mean dental age 6 months greater than that determined for the deep overbite group [16]. This difference proved to be statistically significant ($p < 0.05$) [16].

Ethnicity: Prabhakar *et al.* (2002) used the standard Demirjian *et al.* (1973) dental maturation system for 151 healthy Indian children in Davangere and found that this ethnic group was on average more dentally advanced than the standard by slightly more than one year for boys (1.20 ± 1.02 years) and just less than one year for girls (0.90 ± 0.87) [6,17].

Davidson and Rodd (2001) used a cross-sectional study to compare dental age with chronological age in Somali children under 16 years of age and age-and-gender-matched white Caucasian children, resident in Sheffield, England [18]. Dental age was determined for each subject using existing panoramic radiographs. Comparisons of the difference between dental age and chronological age were made for gender and ethnic group, using independent sample t-tests and setting significance at $p = 0.05$. The sample group comprised 162 subjects: 84 Somali and Caucasian boys (mean age 10.6 years) and 78 Somali and Caucasian girls (mean age 11.2 years). The mean difference between dental and chronological age was 1.01 years for Somali boys, 0.19 years for Caucasian boys; 1.22 years for Somali girls, and 0.52 years for Caucasian girls. The difference between dental and chronological age was significantly greater in Somali subjects than in Caucasian children, and some Somali subjects showed a marked discrepancy between ascribed chronological age and dental age (range -1.75 to +5.42 years), which was most evident in 8- to 12-year-old children. These findings suggest that there is a need for population-specific dental development standards to improve the accuracy of dental age assessment.

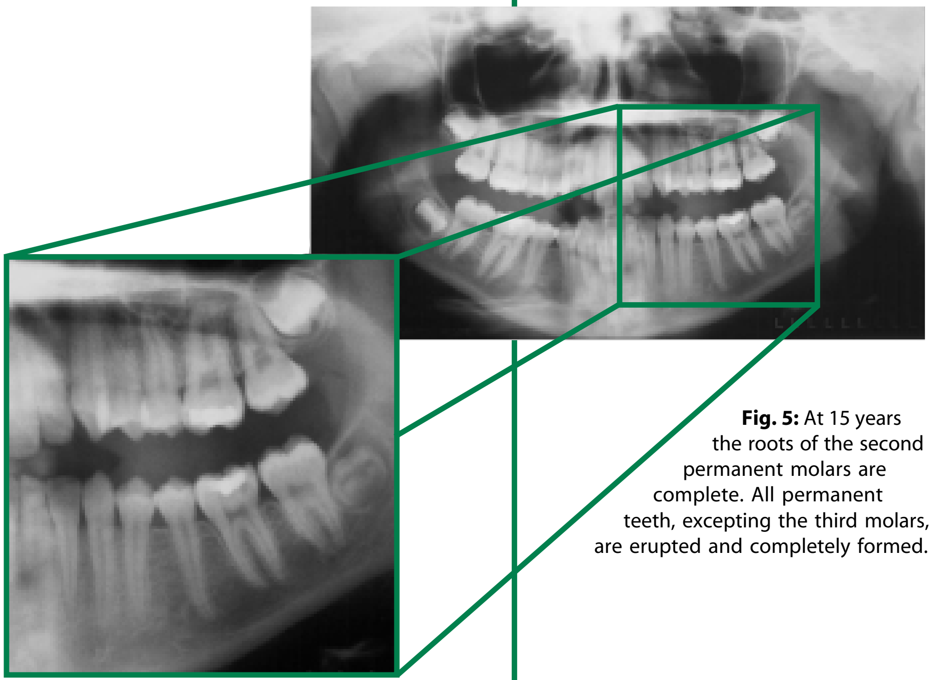


Fig. 5: At 15 years the roots of the second permanent molars are complete. All permanent teeth, excepting the third molars, are erupted and completely formed.

Local Causes of Delayed Dental Eruption

Individual or multiple teeth in a jaw segment can fail to erupt in a timely manner due to impaction against a "mechanical" obstruction commonly caused by inappropriate tooth orientation during development (especially maxillary permanent canine or third molar teeth in either jaw), crowding (impaction against a regular tooth or teeth), supernumerary tooth or teeth, retained primary teeth, or tooth roots, with or without ankylosis. Primary teeth most likely to be involved are those that have inflamed pulps or periapical lesions, and those that have been treated by pulpotomy. Other fairly common obstructions to dental eruption are follicular cysts (eruption or dentigerous cyst) and hamartomas (complex or com-

" Several syndromes are associated with delay or failure in dental eruption."

pound odontomas) [19]. For tumors or cysts to prevent or delay tooth eruption locally, the lesion needs to arise in childhood or adolescence. Benign tumors that can envelop or overlie a developing tooth include adenomatoid odontogenic tumor, ameloblastoma (usually unicystic), ameloblastic fibroma, ameloblastic fibro-odontoma, odontogenic myxoma, and cemento-ossifying fibroma. Other conditions that can locally delay tooth eruption include cherubism (usually bilaterally) and fibrous dysplasia (unilateral) [19]. Obviously teeth that are absent cannot erupt so hypodontia also needs to be excluded radiographically. Regional odontodysplasia can also result in failure of eruption of a segment of teeth, and again requires radiographic study. Fibromatosis gingivae may either delay eruption or simply hide the teeth from clinical view.

Systemic Conditions Delaying Dental Eruption

Low birthweight: Seow (1996) studied the development of the permanent dentition in very low birthweight (< 1500 g) Caucasian children in Australia [20]**.** 55 very low birthweight children (mean age at dental examination 7.7 +/- 2.2 years, mean birthweight 1203 +/- 240 g, and mean gestational age 29.8 +/- 2.4 weeks) were compared to 55 normal birth weight children matched for race, sex, and age. Dental maturity determined from panoramic radiographs found very low birthweight children to experience a delay in dental maturation of 0.29 +/- 0.54 years compared with normal birthweight children ($p < 0.02$). Very low birthweight children < 6 years of age showed the greatest delay of 0.31 +/- 0.68 years ($p < 0.001$). In contrast, children aged 9 years and older showed no difference in dental maturity compared to controls ($p > 0.01$), suggesting that "catch-up" growth had occurred.

In a separate study carried out in Finland, comparing dental development in preterm versus matched control children, premature birth also had no appreciable late effects on tooth-maturation by age 9 years [21].

Second hand smoke: For evaluation of the effects of second hand smoke on dental development, panoramic radiographs of 203 children between the ages of 7-10 years were studied [22]. Four groups were separated: a control group in which neither parent had smoked during the pregnancy, a group exposed to tobacco smoke from the mother only, a group exposed to smoke from the father only, and a group exposed to tobacco smoke from both parents. Maximum differences between chronological and dental ages were found in children subjected to cigarette smoke from both parents (35% reduction in dental maturation).

Syndromes: Several syndromes are associated with delay or failure in dental eruption. One of the most common of these is cleidocranial dysplasia, in which there are multiple supernumerary teeth, with delayed or arrested eruption of the permanent teeth (however, the primary dentition erupts normally) [23,24].

Trisomy 21 (Down's syndrome) and juvenile hypothyroidism (cretinism) have also been attributed as causes of delayed eruption. Other, less common, syndromes associated with delayed or failed dental eruption include: hypopituitarism, osteomatosis intestinal polyposis syndrome (Gardner's syndrome in which there is a high propensity for development of intestinal cancer), chondroectodermal dysplasia (Ellis-van Crevald syndrome), progeria (Hutchinson-Gilford's syndrome), osteopetrosis, pyknodysostosis, acrocephalysyndactyly (Apert's syndrome), focal dermal hypoplasia (Goltz syndrome), vitamin D deficiency syndromes, and dystrophic epidermolysis bulosa [25,26]. Drug induced gingival hyperplasia, such as that related to use of Phenytoin (Dilantin) in prevention of seizures, can either delay eruption, or simply hide the teeth from clinical view. Radiation therapy for treating malignancies in childhood has also been associated with failed tooth development and either delayed or premature dental eruption.

Delayed Puberty: Gaethofs *et al.* (1990) compared the dental age of boys with constitutional delay in growth and puberty with that of normal healthy boys [27]. The Demirjian *et al.* method was found to be accurate for the Belgium control subjects examined. Boys with delayed puberty had significant delay in dental development ($p < 0.01$).

Factors in Premature Dental Eruption

Individual teeth can erupt in advance as a sporadic variant (*i.e.* natal teeth). Premature eruption of a permanent tooth quite frequently occurs following early loss of its primary antecedent. More generalized premature eruption has been reported in juvenile rheumatoid arthritis [28], Turner's syndrome [29,30], hyperthyroidism, pituitary giantism, hypergonadism, Cushing's syndrome, and adrenogenital syndrome. Local premature dental eruption has been found in association with adjacent benign vascular (hemangioma) or neural tumors, or due to pressure from growing subjacent jaw neoplasms (*e.g.* osteogenic sarcoma).

Hass AD, *et al.* studied 28 subjects aged 4 to 19 years having Turner's syndrome using serial panoramic and cephalometric radiographs. They found dental development to be advanced in all of the subjects and the administration of growth hormone had no effect on this finding [30].

Kotilainen and Pirinen investigated dental maturity in 28 Fragile X affected boys and 3 girl carriers of this condition [31]. The mean relative dental age was advanced in Fragile X males, based both on formation and on emergence, with more pronounced advancement seen in younger

" Skeletal development is an important maturity indicator during childhood."

children. Dental maturity was advanced in heterozygous carrier girls as well. Height and skeletal maturity did not show a similar trend toward advanced development.

Assessment of Biologic Age Using Hand-Wrist Radiographs

Skeletal development is an important maturity indicator during childhood [32]. In clinical practice, determination of skeletal age is helpful for the diagnosis of disorders of growth and development. Typical disharmonic patterns in the appearance of bone centers of hand and wrist have been found in certain disorders of development [32].

Fishman developed a widely-used system of hand-wrist skeletal maturation indicators (SMI), using four stages of bone maturation (initial ossification, width, capping, and fusion) at six anatomic sites [33]. Table 2 details specific criteria to be used with the Fishman system. The various anatomic features that need to be recognized are annotated in Figure 6 and detailed in examples in Figures 7 & 8. Using this system, it is possible to judge the remaining potential of the jaws, an important issue for orthodontic treatment planning (Figs. 7 & 8). Hand-wrist radiographs can be made using a standard cephalometric extension to a panoramic machine.

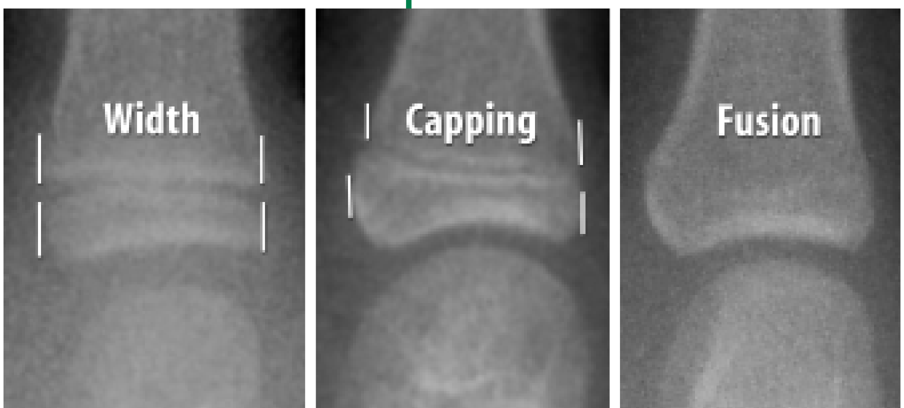
Assessment of Biologic Age Using Lateral Cephalograms

Lateral cephalometric and left hand-wrist radiographs from the Bolton-Brush Growth Center at Case Western Reserve University were reviewed to develop a cervical vertebrae maturation index [34]. By using the lateral profiles of the second, third, and fourth cervical vertebrae, it was possible to develop a reliable ranking of patients in terms of the potential for future adolescent growth (Table 3, Fig. 9 & 10). A subsequent study evaluated lateral cephalometric and left hand-wrist radiographs of 180 untreated subjects (99 girls and 81 boys) aged from 8 to 18 [35]. The results of this study indicated that cervical

TABLE 2: Hand-Wrist Maturation Schedule (after Fishman[33])

Stage	Bone	Age (y) Female	Age (y) Male
Ossification	Hamate/Capitate	0.5	0.5
	Radius Distal Epithysis	1	1
	Thumb Phalynx Distal Epithysis	1	1.5
	Metacarpal Epithysis (All 4 Fingers)	1	1.5
	Thumb Metacarpal Epithysis	1.5	2.5
	Triquetral	1.5	2.5
	Thumb Phalynx Proximal Epithysis	2	3
	Lunate	4	4
	Trapezium	4	5
	Scaphoid	4.5	5.5
	Trapezoid	4	6
	Ulna Distal Epithysis	5	6
	Pisiform	9	11
	Adductor	11	12
Width	Proximal Phalynx Middle Finger	10	11
	Middle Phalynx Middle Finger	11	12
	Middle Phalynx Little Finger	11	12
Capping	Proximal Phalynx Middle Finger	12	13
	Middle Phalynx Middle Finger	12	14
	Middle Phalynx Little Finger	12	14
Fusion	Proximal Phalynx Middle Finger	13	15
	Middle Phalynx Middle Finger	14	16
	Middle Phalynx Little Finger	15	16
	Radius Distal Epithysis	16	17
	Ulna Distal Epithysis	17	19

Fig. 6: Annotated hand-wrist radiograph indicating the landmarks needed to assess skeletal age using the Fishman method.



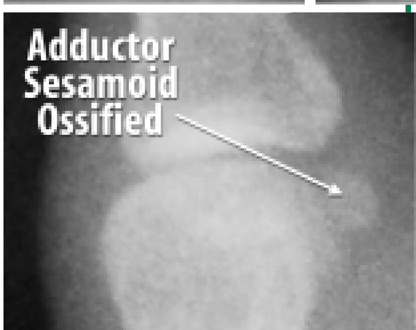


Fig. 7: Details of epiphyseal "width," "capping" and "fusion" at phalynx base, and of ossification of the adductor bone. These are key indicators of skeletal age.

Pre-Pubertal

(Note: Adductor sesamoid not ossified.)

Post-Pubertal

(Note: Adductor sesamoid is ossified.)

Fig. 8: Comparison of hand-wrist radiographs from pre-pubertal patient having significant growth potential (left), and of post-pubertal individual with little growth potential (right).

vertebral maturation and hand-wrist skeletal maturation were significantly related. A study in Italy by Franchi *et al.* concurred that cervical vertebral maturation is an appropriate method for the appraisal of mandibular skeletal maturity in individual patients on the basis of a single cephalometric observation [36]. They concluded that the accuracy of the cervical vertebral method in the detection of the onset of the pubertal spurt in mandibular growth provides helpful indications for orthodontic treatment timing of patients having mandibular deficiencies. The accuracy of cervical vertebral maturation in determining skeletal age during the circum-pubertal period was found to be valid and reliable in children of Chinese ethnicity [37]. Minars M *et al.* (2003) used repeated evaluations of 30 randomly selected, pretreatment lateral cephalometric radiographs and found the accuracy of determining skeletal maturity and growth potential with lateral cephalograms to be R=0.98 (highly accurate) [38].

Biological Age and Orthodontic Intervention

In Australia, Grave *et al.* constructed velocity curves for stature and mandibular growth for 47 boys and 27 girls, and plotted maturation events on the curves [39]. For the majority of children, peak velocity in mandibular growth coincided with peak velocity in stature increments. Particular radiologic maturation events occurred consistently before, during, or after the adolescent growth spurt, contributing to a positive, purposeful, and more confident approach to the management of orthodontic patients, particularly those with a Class II malocclusion.

Kopecky GR *et al.* (1993) treated 41 patients with clinically diagnosed Class II, Division I malocclusions with midface prognathism using Kloehn-type cervical headgear [40]. All cases included longitudinal series both of lateral cephalometric radiographs and of hand-wrist films made before, during, and after treatment. Skeletal and dental changes were related to specific maturational periods and compared with their related chronologic age to evaluate optimum timing for maximum treatment response. This study found timing of cervical headgear treatment on the basis of skeletal maturation is preferable to use of chronologic age. The most favorable results were demonstrated during maturational periods associated with a high degree of incremental growth velocity.

Baccetti *et al.* (2001) evaluated the short-term and long-term treatment effects of rapid maxillary expansion in two groups of subjects treated with the Haas appliance [41]. Treatment outcomes were evaluated before and after the peak in skeletal maturation, as assessed by the cervical vertebral maturation method, in a sample of 42 patients compared to a control sample of 20 subjects. The group receiving early treatment had not passed the pubertal peak in skeletal growth when treatment commenced, whereas the late treatment subjects had (See Table 3). Rapid maxillary expansion treatment before the peak in skeletal growth velocity was able to induce more pronounced transverse craniofacial changes at the skeletal level. Biological age determination is important in treatment planning effective rapid palatal expansion.

Age and Identity

In Belgium, Van Erum *et al.* evaluated 48 patients aged 2-32 years with short stature of prenatal origin. They observed tooth development and craniofacial growth using panoramic and cephalometric radiographs [42]. While craniofacial growth was closely related to general growth and skeletal age, dental maturation closely correlated with chronologic age.

In the United States, an immigrant's age can be critical to his or her effort to gain entry to and residence in the country. Minors who enter the United States illegally are, unlike adults, exempt from immediate deportation. Minors are permitted to remain in the United States if they are granted political asylum or "special immigrant juvenile status,"

TABLE 3: Cervical Vertebral Maturation Schedule (after Hassel & Farman[34])

Stage	Vertebral Indicators	Growth Potential
Initiation	C2, C3 & C4 inferior vertebral body borders flat. Superior vertebral bodies tapered posterior to anterior.	Very significant adolescent growth expected.
Acceleration	C2 & C3 lower body borders developing concavities. C4 body inferior border flat. C3 & C4 more rectangular in shape.	Significant adolescent growth expected.
Transition	Distinct concavities in C2 & C3 lower borders. C4 develops concavity in body lower border. C3 & C4 bodies rectangular in shape.	Moderate adolescent growth expected.
Deceleration	Distinct concavities in lower borders of bodies of C2, C3 & C4. C3 and C4 bodies nearly square in lateral profile.	Small amount of adolescent growth expected.
Maturation	Accentuated concavities of inferior vertebral body borders of C2, C3 & C4. C3 and C4 vertebra; bodies are square in lateral profile.	Insignificant amount of adolescent growth expected.
Completion	Deep concavities of inferior vertebral body borders of C2, C3 & C4. C3 and C4 vertebral body heights greater than widths.	Adolescent growth completed.

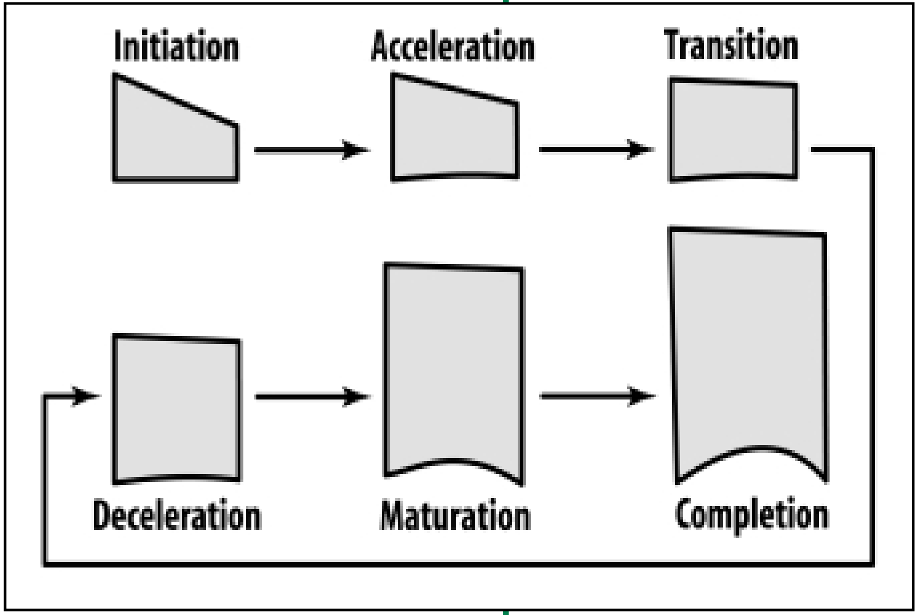


Fig. 9: Schematic of maturation sequence of third cervical vertebra (C3) after Hassel & Farman[34]

“There seems to be a closer association between dental development as viewed on a panoramic radiograph and chronological age, than between chronological age and skeletal maturity.”

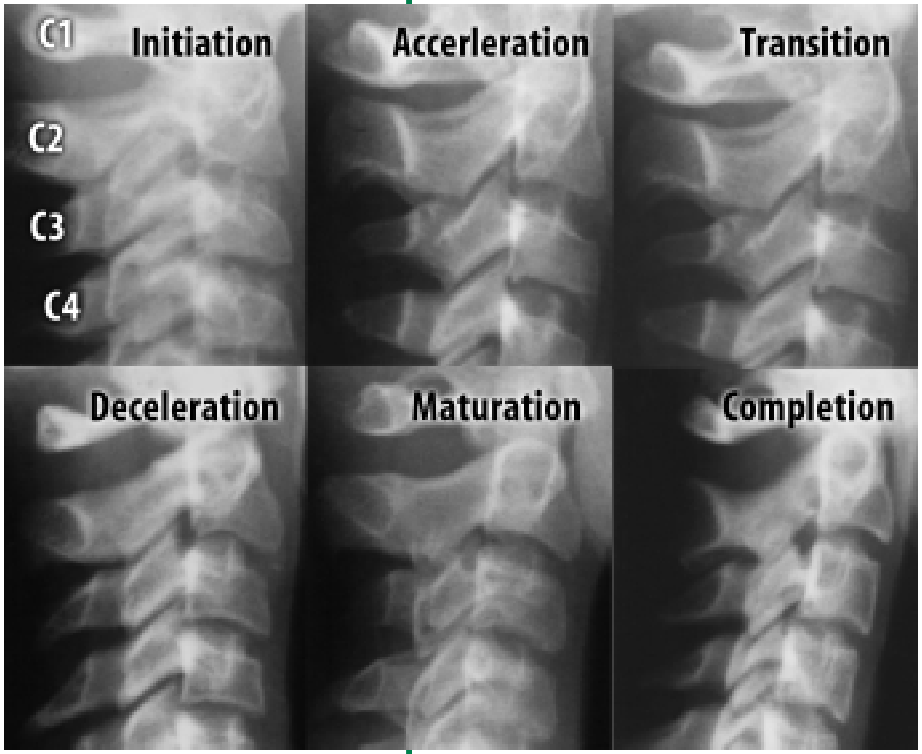


Fig. 10: Maturation sequence for cervical vertebra (C2-4) used for skeletal growth potential determination after Hassel & Farman[34].

given when a child is the victim of abuse or neglect. If denied asylum, minors cannot be sent home until relatives in their home country are contacted. In the view of the federal immigration authorities, dental and bone radiographs are one of the most reliable ways of determining age [43]. Trager, a US dentist with a dental office directly above Customs and Immigration at Kennedy Airport, NY, and another office in LaGuardia, noted that the eruption of third molars and the fusion of bones in the wrist usually signify that a person is over 18 years of age [43]. Detainee’s challenges to this means of age determination have apparently been dismissed in federal court [44]. Nevertheless, there can be no precision in correlation of biological (skeletal or dental) age and the chronological age that is so important in law. One can only specify the likelihood of age given a population sample, not the exact age of a specific individual. Biological age is important for dental treatment planning and can be assessed with some utility using dental, cephalometric and hand-wrist radiographs. Precise chronological age correlations can never be guaranteed. The most accurate determinant of being over 18 years of age, however, according to Friedrich *et al.* is the presence of filled wisdom teeth. The correlation was reported as being 100% [44].

Concluding Remarks

The literature points to there being close correlation between growth potential and skeletal maturity as demonstrated from morphological evaluation of the cervical spine on lateral cephalograms, or of the bones of the hand and wrist. It is this skeletal growth potential that is important for orthodontic assessment. As the lateral cephalogram is standard for orthodontic assessment presently, evaluation of the spine obviates an additional radiograph being made of the hand and wrist. Even when a thyroid shield is worn by the patient, C3 is usually included in the cephalogram.

There seems to be a closer association between dental development as viewed on a panoramic radiograph and chronological age, than between chronological age and skeletal maturity. This is particularly the case if ethnic variability is taken into account. Nevertheless, population standards are not precise when it comes to evaluation of the individual. Kjaer *et al.* found that while skeletal maturation was delayed by more than four years in four siblings with Seckel syndrome, tooth maturity progressed normally [45]. While there are many local and systemic causes of delayed and premature dental eruption, tooth development is perhaps the best radiographic indicator of chronological age during childhood and adolescence.

It may be necessary to make adjustments over time to any reference chart as it appears that the rate of dental maturation might be accelerating. Nadler (1998) compared 1970 and 1990 Caucasian patient samples, age 8.5-14.5 years old, and demonstrated dental age reductions of 1.2 years for males and 1.5 years for females, giving a combined mean reduction of 1.4 years [46]. Further, it has been established that there is a variation of ± 15 months at the 95% confidence interval using dental age to estimate chronological age among Chinese children [47]. Perhaps like in aging horses, the use of dental aging for humans is to best be considered as being a “respected imprecise science” [48].

Knowledge of the normal sequence and timing of dental eruption provides useful information regarding the selection of radiographic proce-

" When there is a local cause of failed eruption, early intervention can save much time, effort, cost, and discomfort with respect to the patient."

dures to evaluate the patient who falls outside the normal range, or who shows asymmetry in tooth eruption patterns. When there is a local cause of failed eruption, early intervention can save much time, effort, cost, and discomfort with respect to the patient. A most comprehensive overview of the dentition, providing ready bilateral comparisons, is the panoramic radiograph. Diligent use of the panoramic radiography at key stages of growth and development is advocated as a basic standard of care.

References

1. FDA Dental Radiographic Selection Panel, Joseph LP. The Selection of Patients for X-Ray Examinations: Dental Radiographic Examinations. HHS Publication FDA 88-8273; 1987.
2. Espelid I, Mejare I, Weerheijm K. EAPD guidelines for use of radiographs in children. Eur J Paediatr Dent 2003;4:40-48.
3. Langland OE, Langlais RP, Preece JW. Principles of Dental Imaging, ed 2. Lippincott Williams & Wilkins: Philadelphia; 2002.
4. Farman AG, Eloff J, Joubert JJdeV, Nortjé CJ. Clinical absence of the permanent maxillary central incisor: A study of 30 cases. Rhodesian J Dent 1979;8:4-6.
5. Logan WHG, Kronfeld R. Development of the human jaws and surrounding structures from birth to the age of fifteen years. J Amer Dent Assoc 1933;20:379-427.
6. Demirjian A, Goldstein H, Tanner JM. A new system of dental age assessment. Human Biol 1973;45:211-227.
7. Demirjian A, Goldstein H. New systems for dental maturity based on seven and four teeth. Ann Hum Biol 1976;3:411-421.
8. Demirjian A, Levesque GY. Sexual differences in dental development and prediction of emergence. J Dent Res 1980 59,1110-1122.
9. Hegde RJ, Sood PB. Dental maturity as an indicator of chronological age: radiographic evaluation of dental age in 6 to 13 years children of Belgaum using Demirjian methods. J Indian Soc Pedod Prev Dent 2002;20:132-138.
10. Teivens A, Mornstad H, Reventlid M. Individual variation of tooth development in Swedish children. Swed Dent J 1996;20:87-93.
11. Reventlid M, Mornstad H, Teivens AA. Intra- and inter-examiner variations in four dental methods for age estimation of children. Swed Dent J 1996;20:133-139.
12. Nykanen R, Espeland L, Kvaal SI, Krogstad O. Validity of the Demirjian method for dental age estimation when applied to Norwegian children. Acta Odontol Scand 1998;56:238-244.
13. Zhao J, Ding L, Li R. Study of dental maturity in children aged 3-16 years in Chengdu. Hua Xi Yi Ke Da Xue Xue Bao. 1990;21:242-246.
14. Olze A, Taniguchi M, Schmeling A, Zhu BL, Yamada Y, Maeda H, Geserick G. Studies on the chronology of third molar mineralization in a Japanese population. Leg Med (Tokyo) 2004;6:73-79.
15. Sasaki M, Sato K, Mitani H. Tooth formation and eruption in skeletal Class II and Class III malocclusions. Nippon Kyosei Shika Gakkai Zasshi. 1990;49:435-442.
16. Janson GR, Martins DR, Tavano O, Dainesi EA. Dental maturation in subjects with extreme vertical facial types. Eur J Orthod 1998;20:73-78.
17. Prabhakar AR, Panda AK, Raju OS. Applicability of Demirjian's method of age assessment in children of Davangere. J Indian Soc Pedod Prev Dent 2002;20:54-62.
18. Davidson LE, Rodd HD. Interrelationship between dental age and chronological age in Somali children. Community Dent Health 2001;18:27-30.
19. Farman AG, Nortjé CJ, Wood RE. Oral and maxillofacial diagnostic imaging. St Louis: Mosby-Year Book 1993.
20. Seow WK. A study of the development of the permanent dentition in very low birthweight children. Pediatr Dent 1996;18:379-384.
21. Backstrom MC, Aine L, Maki R, Kuusela AL, Sievanen H, Koivisto AM, Ikonen RS, Maki M. Maturation of primary and permanent teeth in preterm infants. Arch Dis Child Fetal Neonatal Ed 2000;83:F104-108.
22. Kieser JA, Groeneveld HT, da Silva P. Delayed tooth formation in children exposed to tobacco smoke. J Clin Pediatr Dent 1996;20:97-100.
23. Jensen BL, Kreiborg S. Development of the dentition in cleidocranial dysplasia. J Oral Pathol Med 1990;19:89-93.
24. Shaikh R, Shusterman S. Delayed dental maturation in cleidocranial dysplasia. SDC J Dent Child 1998;65:325-329, 355.
25. Myllarniemi S, Lenko HL, Perheentupa J. Dental maturity in hypopituitarism, and dental response to substitution treatment. Scand J Dent Res 1978;86:307-312.
26. Kostara A, Roberts GJ, Gelbier M. Dental maturity in children with dystrophic epidermolysis bullosa. Pediatr Dent 2000;22:385-388.
27. Gaethofs M, Verdonck A, Carels C, de Zegher F. Delayed dental age in boys with constitutionally delayed puberty. Eur J Orthod 1999;21(6):711-715.
28. Lehtinen A, Oksa T, Helenius H, Ronning O. Advanced dental maturity in children with juvenile rheumatoid arthritis. Eur J Oral Sci 2000;108:184-188.
29. Hass AD, Simmons KE, Davenport ML, Proffit WR. The effect of growth hormone on craniofacial growth and dental maturation in Turner syndrome. Angle Orthod 2001;71:50-59.
30. Midtbo M, Halse A. Skeletal maturity, dental maturity, and eruption in young patients with Turner syndrome. Acta Odontol Scand 1992;50:303-12.
31. Kotilainen J, Pirinen S. Dental maturity is advanced in Fragile X syndrome. Am J Med Genet 1999;83:298-301.
32. Heinrich UE. Significance of radiologic skeletal age determination in clinical practice. Radiologe 1986;26:212-215.
33. Fishman LS. Maturational patterns and prediction during adolescence. Angle Orthod 1987;57:178-193.
34. Hassel B, Farman AG. Skeletal maturation evaluation using cervical vertebrae. Am J Orthod Dentofacial Orthop 1995;107:58-66.
35. Kucukkeles N, Acar A, Biren S, Arun T. Comparisons between cervical vertebrae and hand-wrist maturation for the assessment of skeletal maturity. J Clin Pediatr Dent1999;24:47-52.
36. Franchi L, Baccetti T, McNamara JA Jr. Mandibular growth as related to cervical vertebral maturation and body height. Am J Orthod Dentofacial Orthop 2000;118:335-340.

37. Chang HP, Liao CH, Yang YH, Chang HF, Chen KC. Correlation of cervical vertebra maturation with hand-wrist maturation in children. Kaohsiung J Med Sci 2001;17:29-35.

38. Minars M, Burch J, Masella R, Meister M. Predicting skeletal maturation using cervical vertebrae. Today's FDA 2003;15:17-19.

39. Grave K, Townsend G. Hand-wrist and cervical vertebral maturation indicators: how can these events be used to time Class II treatments? Aust Orthod J 2003;19:33-45.

40. Kopecky GR, Fishman LS. Timing of cervical headgear treatment based on skeletal maturation. Am J Orthod Dentofacial Orthop 1993;104:162-169.

41. Baccetti T, Franchi L, Cameron CG, McNamara JA Jr. Treatment timing for rapid maxillary expansion. Angle Orthod 2001;71:343-350.

42. Van Erum R, Mulier M, Carels C, de Zegher F. Short stature of prenatal origin: craniofacial growth and dental maturation. Eur J Orthod. 1998;20:417-425.

43. Hedges C. Airport dentist crucial to INS gatekeeping. NY Times on the web, July 22, 2000.

44. Friedrich RE, Ulbricht C, von Maydell LA. Dental caries and fillings in wisdom teeth as an aid in forensic dentistry for determining chronologic age over 18. Radiologic studies of orthopantomography images of children and adolescents Arch Kriminol 2003;212:74.

45. Kjaer I, Hansen N, Becktor KB, Birkebaek N, Balslev T. Craniofacial morphology, dentition, and skeletal maturity in four siblings with Seckel syndrome. Cleft Palate Craniofac J 200138:645-651.

46. Nadler GL. Earlier dental maturation: fact or fiction? Angle Orthod 1998;68:535-538.

47. Anonymous. Aging horses by examining the teeth—a centuries-old inexact science. Special report. J Vet Dent 1997;14:97-98.

In The Recent Literature:

Implantology: Panoramic radiography was proven to be equal to intraoral radiography for the assessment of peri-implant bone loss in the anterior mandible.

Zechner W, Watzak G, Gahleitner A, Busenlechner D, Tepper G, Watzek G. Rotational panoramic versus intraoral rectangular radiographs for evaluation of peri-implant bone loss in the anterior atrophic mandible. Int J Oral Maxillofac Implants 2003;18:873-878. [From the Department of Oral Surgery, University of Vienna, Austria.]

In patients with atrophic mandibles, elevation of the floor of the mouth often prevents intraoral rectangular radiography for longitudinal follow-up studies, while extraoral techniques such as panoramic radiographs have been perceived to produce distorted views of the interforaminal region. In this study, intraoral and panoramic radiographs were compared for their accuracy in evaluating peri-implant bone loss. In a recall program, 22 patients with 88 screw-type implants (44 MKII and 44 Frios) were followed. Interforaminal marginal bone loss was evaluated by panoramic radiography and by using intraoral radiographs. In addition, pocket depth, Periotest readings, and bleeding on probing were recorded. For statistical analysis, the Spearman coefficient of correlation was used. The effects on bone loss and clinical variables were computed with a mixed model and the Bland and Altman method. Computed as least square means, the mean difference between panoramic radiographs (2.4 +/- 0.2 mm for MKII implants and 1.6 +/- 0.2 mm for Frios implants) and intraoral radiographs (2.6 +/- 0.2 mm and 1.4 +/- 0.2 mm, respectively) was 0.2 mm (range, 0.1 to 0.8 mm). In this study, the two imaging techniques were comparable clinically in terms of the precision with which they could be used to measure marginal bone loss. Hence, for highly atrophic mandibles with unfavorable imaging conditions, rotational panoramic radiographs can be a useful alternative to intraoral radiographs for evaluating peri-implant bone loss.

Lateral cephalograms: Cervical vertebral morphology can be used to accurately assess skeletal maturity.

San Roman P, Palma JC, Oteo MD, Nevado E. Skeletal maturation determined by cervical vertebrae development. Eur J Orthod 2002;24:303-311. [From the Department of Orthodontics, Complutense University, Madrid, Spain.]

This study investigated the validity of using cervical vertebral radiographic assessment to predict skeletal maturation. Left hand-wrist and lateral cephalometric radiographs of 958 Spanish children from 5 to 18 years of age were studied. The classification of Grave and Brown was used to assess skeletal maturation from the hand-wrist radiograph. Cervical vertebrae maturation was evaluated with lateral cephalometric radiographs using the stages described by Hassel and Farman and by Lamparski. A new method to evaluate the cervical maturation by studying the changes in the concavity of the lower border, height, and shape of the vertebral body was created. Correlation coefficients were calculated to establish the relationship between skeletal maturation values obtained by the three classifications of vertebral and skeletal maturation measured at the wrist. All correlation values obtained were statistically significant ($p < 0.001$). In the population investigated, the new method was as accurate as the Hassel and Farman classification and superior to the Lamparski classification.

Impacted third molars: An intimate association between the tooth and the inferior alveolar canal often resulted in a darkening of the root of the affected tooth when viewed with panoramic radiography.

Bell GW. Use of dental panoramic tomographs to predict the relation between mandibular third molar teeth and the inferior alveolar nerve. Radiological and surgical findings,

and clinical outcome. Br J Oral Maxillofac Surg 2004;42:21-27. [From the Oral and Maxillofacial Surgery, Dumfries and Galloway Royal Infirmary, Dumfries, United Kingdom]

Preoperative radiological observations from dental panoramic tomographs were compared with surgical findings at removal of third molars with respect to relationship of the tooth to the inferior alveolar nerve. One surgeon viewed the radiographs of 219 patients and recorded the radiological observations of the mandibular third molar tooth and the inferior alveolar nerve. The same surgeon removed the teeth and made detailed records of morphology of the root and its relation to the inferior alveolar nerve. Patients were reviewed postoperatively. A total of 300 teeth were removed and the neurovascular bundle observed during surgery. The roots were grooved or deflected due to their proximity to the neurovascular bundle in 12% of the cases (n=35). There was an intimate relation between the mandibular third molar tooth and the inferior alveolar nerve in 51% of cases when darkening of the root was observed (n=12), but only in 11% of cases (n=11) when there appeared to be interuption of the radiopaque outline of the inferior alveolar canal radiographically.

Calcified stylohyoidal chain: Stylohyoidal ossifications show age-related increases in prevalence, length, and topographical location in panoramic radiographs.
Krennmair G, Piehslinger E. Variants of ossification in the stylohyoid chain. Cranio 2003;21:31-37. [From the Dental Clinic, Department of Removable and Fixed Prosthodontics, University of Vienna, Austria]

This study evaluated the age-related differences in the incidence, length, and topographic location in ossifications of the stylohyoid chain. Panoramic radiographs of 420 patients (795 reviewed stylohyoid-chains), subdivided into four age groups (≤ 20 y, 21-40 y, 41-60 y, > 60 y) were examined for the incidence, length, and topographic location of stylohyoidal ossification. Two hundred forty-five (30.8%) out of 795 stylohyoidal chains showed radiological variabilities (elongation of the styloid process or ossification of the stylohyoid ligament). With increasing age, there was an increase in prevalence and length of stylohyoidal ossifications ($p < 0.01$). A significant linear correlation between the length of the stylohyoidal ossifications and age was only found in the young age group (≤ 20 y., $p < 0.01$). There was also a higher prevalence of isolated locations in the superior stylohyoidal segment in this age group (≤ 20 yrs). With increasing age, there was a pronounced presence of ossifications in the middle and inferior stylohyoid segments and combinations of ossified variabilities. Stylohyoidal ossifications show age-related increases in prevalence, length, and topographical location.

Jaw fracture and third molar impaction: This study did provide evidence that patients with retained or impacted third molars are significantly more susceptible to angle fracture than those without third molars.
Meisami T, Sojat A, Sandor GK, Lawrence HP, Clokie CM. Impacted third molars and risk of angle fracture. Int J Oral Maxillofac Surg 2002;31:140-144. [From the Department of Oral and Maxillofacial Surgery, The University of Toronto Faculty of Dentistry, Ontario, Canada.]

This investigation assessed the influence of the presence, position, and severity of impaction of the mandibular third molars on the incidence of mandibular angle fractures. A retrospective cohort study was designed for patients presenting to the Division of Oral and Maxillofacial Surgery, Toronto General Hospital, Canada, for treatment of mandibular fractures from January 1995 through June 2000. The study sample comprised 413 mandibular fractures in 214 patients. Demographic data collected included age, sex, mechanism of injury, and number of mandibular fractures. Independent variables studied were the presence, position, and severity of impaction of third molars; the outcome variable was the incidence of mandibular angle fractures. Panoramic radiographs and hospital records were used to determine and classify these variables. The incidence of angle fractures was found to be significantly higher in the male population and was most commonly seen in the third decade of life. Assault was the most frequent causative factor. This study did provide evidence that patients with retained or impacted third molars are significantly more susceptible to angle fracture than those without third molars. Patients with third molars had a three times increased risk of angle fractures when compared to patients without ($p < 0.001$), and impaction of third molars significantly increased the incidence of mandibular angle fractures ($p < 0.001$). The severity and angulation of third molar impactions did not prove to be significantly associated with angle fractures.

PANORAMIC Imaging News
Volume 4, Issue 4

CE TEST: Assessing Growth and Development with Panoramic Radiographs and Cephalometric Attachments: A critical tool for dental diagnosis and treatment planning

1. Panoramic radiography provides a better assessment of growth potential of the jaws than does the lateral cephalogram.
   ❑ True ❑ False

2. Panoramic radiography provides a better assessment of patient chronological age than does the lateral cephalogram.
   ❑ True ❑ False

3. Failure to detect causes of impaction until after the normal eruption sequence of an affected tooth can complicate treatment planning and reduce the prognosis for successful intervention.
   ❑ True ❑ False

4. Using the Classification of Hassel & Farman, the most significant growth potential is found in patients designated as being in the Transition Stage
   ❑ True ❑ False

5. The adductor bone usually commences calcification at a younger age in girls than in boys.
   ❑ True ❑ False

6. Second hand smoke has been indicated as a possible cause of delayed dental development.
   ❑ True ❑ False

7. Whereas individual variation can make accurate assessment of chronological age using radiographs somewhat problematic, the presence of filled third molars is a good predictor of the person concerned being 18 years or older.
   ❑ True ❑ False

8. When assessing growth potential of the mandible, dental maturity is a better indicator than skeletal maturity using hand-wrist radiographs.
   ❑ True ❑ False

9. Root completion for the first permanent molar occurs around 6 years of age.
   ❑ True ❑ False

10. Excepting the third molars, by age 16 years all permanent teeth should be erupted and have completed root formation.
   ❑ True ❑ False

How to Obtain CE Credit:

Successful completion entitles respondent to 1 hour Continuing Education Credit from The Richmond Institute for Continuing Dental Education.

1. Complete questions and required personal information.
2. RENTAL CUSTOMERS:
   CE fee is included in rental cost. Simply FAX completed form to (847) 458-0063 . Do not send payment.
3. ALL OTHERS:
   A. Mail completed form with $10 processing fee to Richmond Institute, 2260 Wendt St., Algonquin, IL 60102

   Mail or FAX completed form with credit card information to (847) 458-0063
   B. Make checks payable to Richmond Institute.

Name: ____________________

Address: ____________________

City: ____________ State: _____ Zip: __________

Telephone: ____________ Date: __________

Email: ____________________

Credit Card Number: ____________ Expiration Date: ________

For $10 Processing Fee: ____________________
Signature

Provided as a professional service by:

Panoramic Corporation
4321 goshen road, fort wayne, in 46818 • 800.654.2027

In conjunction with
The Richmond Institute for Continuing Dental Education
A division of Young Innovations, Inc.

ADA C·E·R·P®
CONTINUING EDUCATION RECOGNITION PROGRAM
The Richmond Institute for Continuing Dental Education is an ADA CERP Recognized Provider.

Academy *of General Dentistry*
PACE
Program Approval for Continuing Education
Approved PACE Program Provider
FAGD/MAGD Credit
10/19/03 to 10/18/07