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A Review of Pediatric Radiology

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ABSTRACT In most dental schools, the focus is on teaching students how to treat adults, with little emphasis placed on treating children. The goal of this article is to review some basic concepts in pediatric radiology to help general practitioners have a better understanding of when to take radiographs on children, which radiographs should be taken, what to look for when examining the radiographs and possible ways to treat the problems diagnosed from the radiographs.

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A typical "full-mouth series" on a child with no specific dental issues and who has a complete primary or mixed dentition is an upper and lower anterior occlusal film and two bitewing radiographs. This helps the clinician screen for dental caries, supernumerary or missing teeth in the maxillary and mandibular anterior area, anomalies in the size or shape of the maxillary and mandibular permanent incisors, detect impacted or ectopically erupting teeth and evaluate the amount of space available for the permanent dentition. Some reasons for taking additional periapical films include history of pain, swelling, trauma, mobility of teeth, unexplained bleeding, disrupted eruption patterns or deep carious lesions.[1] X-ray film and plates come in size 0, 1 and 2. Most pediatric dentists use a size 0 or 1 film for bitewings in young patients and a size 2 for anterior occlusal films to view the upper and lower incisors.

In 2012, the American Dental Association (ADA), in collaboration with the U.S. Food and Drug Administration (FDA), released updated recommendations for the prescription of dental radiographic examinations (TABLE). Dentists should use these guidelines, along with their professional judgment, to determine appropriate diagnostic imaging for each individual patient. This requires that the dentist review the patient's health history, note any dental complaint and perform a clinical examination of the patient prior to selecting which diagnostic radiographs are needed.

Limiting Radiation Exposure

Even though radiation exposure from dental radiographs is low, once a decision to obtain radiographs is made, it is the dentist's responsibility to follow the ALARA principle (as low as reasonably achievable) to minimize the patient's exposure. Examples of good radiologic practice include:

TABLE

American Dental Association Recommendations for Prescribing Dental Radiographs *(Revised 2012)*
(In the child with primary or transitional dentition)

Type of Encounter	Patient Age and Dental Developmental Stage	
	Child with Primary Dentition (prior to eruption of first permanent tooth)	**Child with Transitional Dentition** (after eruption of first permanent tooth)
New patient being evaluated for oral disease	Individualized radiographic exam consisting of selected periapical/occlusal views and/or posterior bitewings if proximal surfaces cannot be visualized or probed. Patients without evidence of disease and with open proximal contacts may not require a radiographic exam at this time.	Individualized radiographic exam consisting of posterior bitewings with panoramic exam or posterior bitewings and selected periapical images.
Recall patient with clinical caries or at increased risk for caries	Posterior bitewing exam at 6-12 month intervals if proximal surfaces cannot be examined visually or with a probe.	
Recall patient with no clinical caries and not at increased risk for caries	Posterior bitewing exam at 12-24 month intervals if proximal surfaces cannot be examined visually or with a probe.	

These recommendations are subject to clinical judgment and may not apply to every patient. They are to be used by dentists only after reviewing the patient's health history and completing a clinical examination. Once a decision is made to obtain radiographs, it is the dentist's responsibility to follow the ALARA Principle (As Low As Reasonably Achievable) to minimize the patient's exposure.

- Use of the fastest image receptor compatible with the diagnostic task (F-speed film or digital);
- Collimation of the beam to the size of the receptor whenever feasible;
- Proper film exposure and processing techniques;
- Use of protective aprons and thyroid collars when appropriate; and
- Limiting the number of images obtained to the minimum necessary to obtain essential diagnostic information.[2]

Switching from D to E speed can produce a 30–40 percent reduction in radiation exposure.[3] The use of F-speed film can reduce exposure 20–50 percent compared to the use of E-speed film.[4] Digital imaging provides an opportunity to further reduce the radiation dose by 40-60 percent.[5] In digital radiography, there are three types of receptors that take the place of conventional film: charge-coupled device (CCD), complementary-metal-oxide-semiconductor (CMOS) and photo-stimulable phosphor (PSP) plates. Systems that use CCD- and CMOS-based solid-state detectors are called "direct." When these sensors receive energy from the X-ray beam, the CCD or CMOS chip sends a signal to the computer and an image appears on the monitor within seconds. Systems that use PSP plates are called "indirect." When these plates are irradiated, a latent image is stored on them. The plate is then scanned and the scanner transmits the image to the computer.

While some pediatric dentists utilizing digital radiography are able to use the CCD or CMOS "hard" sensors on young patients, many choose to use PSP plates because they are very much like regular film and are less objectionable for young children.

Panoramic Radiograph

A panoramic film is one of the most useful films in pediatric dentistry. It is typically taken in the mixed dentition (between 7 and 9 years old) to screen for extra or missing teeth, eruption problems (e.g., ectopic eruption, impaction, transposition, ankylosis, primary failure of eruption), root resorption, cysts or any other anomalies that might have gone undetected with a routine periapical series of radiographs.

While panoramic radiographs provide a wealth of information, other radiographs may be necessary to help confirm the diagnosis. Ectopic eruption of incisors and canine impaction are often diagnosed from panoramic radiographs, but can be erroneously evaluated in this manner if only a panoramic radiograph is used.[6,7] Labial or palatal positioning of the canine is best determined using the panoramic radiograph in conjunction with an occlusal radiograph, particularly if the canines cannot be palpated on the facial aspect of the alveolus at approximately 9 to 10 years of age. The occlusal radiograph will provide a better estimate of the position of the canine to the lateral incisor.[8] Cone beam computed tomography is an incredible tool that can also be used to help diagnose all of these potential problems. While it is becoming more widespread, it is not commonly used in the pediatric population.

Impacted Teeth

One of the more commonly encountered anomalies when examining radiographs on children are impacted teeth. Dental impaction has been

reported to affect as much as 25-50 percent of the population.[9] The most commonly impacted permanent teeth in decreasing order of frequency are mandibular third molars, maxillary third molars, maxillary cuspids, mandibular second bicuspids, maxillary second bicuspids, maxillary central incisors and mandibular second molars.[10] Because third molar impaction isn't usually a problem until late adolescence, one of the earliest encountered impacted teeth in young children is the permanent maxillary canine.

Permanent Maxillary Canine Impaction

Maxillary canine impaction occurs in approximately 1-3 percent of the population with a 2:1 female to male ratio,[11,12] and they are more commonly impacted than the mandibular canine.[13] Other teeth may be impacted but much less frequently.[14] Of the individuals with maxillary impacted canines, it is estimated that 8 percent have bilateral impactions.[15] Approximately one-third of impacted maxillary canines are located labially and two-thirds are located palatally.[16-17] Potential factors related to impaction include arch-length deficiency, maxillary transverse deficiency, missing or peg lateral incisors, cystic lesions of the follicle, trauma, early loss of primary teeth, ankylosed or over-retained primary teeth and physical impediments such as mesiodens, odontomas or supernumerary teeth.[18-22]

Impacted canines are usually asymptomatic. Therefore, most patients and parents are unaware of the impacted canine's existence. An impacted maxillary canine can be diagnosed clinically through delayed eruption of the permanent canine, over retention of the primary canine, absence of a labial bulge, presence of a palatal bulge and distal crown tipping of the lateral incisor. It is important for the clinician to utilize both visualization and palpation.[23] A bulge in the canine buccal area will be palpable approximately 18 months before oral eruption.[24] Impacted canines can also be diagnosed through multiple periapical films (SLOB rule), occlusal radiographs, lateral cephalometry and panoramic radiographs. Localization of impacted teeth is important for surgical exposure and for planning of appropriate orthodontic force vectors. Eighty-five percent of all palatal impactions have sufficient space for eruption (no arch-length deficiency) and 83 percent of labial impactions are associated with an arch-length deficiency.[25]

Ericson and Kurol found that early removal of primary maxillary canines could result in normal eruption of ectopically displaced permanent maxillary canines. They proposed that extracting the primary canine before the patient is 11 years of age would normalize the erupting position of the permanent canine in 91 percent of the cases if the crown were distal to the midline of the lateral incisor root. However, the success rate decreases to 64 percent if the permanent canine crown is mesial to the midline of the lateral incisor root[26] (**FIGURE 1**). If this is unsuccessful, the patient will need to have the tooth repositioned orthodontically.

Bonetti et al. found that primary canine and first primary molar extractions were more effective as a preventive approach to promote eruption of permanent maxillary canines that were positioned centrally or palatally.[27] The decision to extract primary teeth unilaterally or bilaterally should be decided on a case-by-case basis. If there is a unilateral ectopic permanent canine and no arch-length deficiency, you may extract only the primary tooth or teeth on the affected side. If there is moderate to severe arch-length deficiency, extract primary teeth on both sides. You must have a minimum of one-half root formation on the premolar if you choose to extract the first primary molar or there may be a delay in the premolar's eruption.[28]

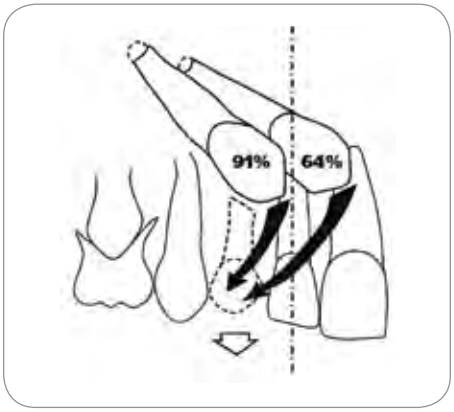

FIGURE 1. Illustration showing the normalization rates of the maxillary canine after extraction of the primary canine when the permanent maxillary canine is located mesially and distally to the midline of the lateral incisor.

Permanent First Molar

Ectopic eruption of permanent first molars occurs in 3-4 percent of children with the maxillary arch usually being affected.[29] Etiological factors include a sibling with ectopic eruption;[30] shorter, smaller maxilla;[31-32] larger mesiodistal width of the first permanent molar with increased mesial inclination;[33] cleft lip and/or palate[34] and association with other dental anomalies.[35]

They are usually identified between 5 and 7 years of age on a radiographic exam, with the first permanent molar impacted in the distobuccal root of the second primary molar (**FIGURE 2**). Of these teeth, 69.4 percent spontaneously correct and 14.3 percent result in pulpal exposure of the second primary molar.[36]

Early correction of ectopically erupting permanent molars is important for

FIGURE 2. Ectopic eruption of permanent first molars.

FIGURE 3. Ankylosed teeth are locked in position and cannot continue to erupt or be moved orthodontically.

development of a stable occlusion.[37] If left untreated, ectopic eruption of the first permanent molar may cause serious sequel, including early loss of the second primary molar, space loss, impaction of second premolars and super-eruption of the opposing first permanent molar. Treatment options for minimally impacted molars include disking the second primary molar, the brass wire technique,[38] a spring-type deimpactor[39] or elastic separators.[40] When the impaction is severe, options include extraction of the second primary molar and space maintenance or distal tipping appliances can be utilized, such as the Halterman appliance,[41,42] a removable appliance with a finger spring,[43] a sectional wire with open coil spring[44] or the Cetlin appliance/headgear.[45]

Ankylosis

Another common condition found in the pediatric patient, both clinically and on X-ray, is ankylosis. Ankylosis is defined as a fusion of dentin or cementum within the alveolar bone. These teeth are locked in position and cannot continue to erupt or be moved orthodontically (**FIGURE 3**). While the cause of ankylosis is essentially unknown, it is typically attributed to either a local disturbance in metabolism or from trauma, and can occur at any time during the lifetime of a tooth.[46] Evidence suggests that there is a genetic predisposition in primary molars.[47] The incidence of ankylosis in primary teeth is 1-14 percent of children and multiple primary teeth may be affected.[48-51] The following are the most commonly ankylosed teeth in the primary dentition:[52]

- Mandibular primary first molar.
- Mandibular primary second molar.
- Maxillary primary first molar.
- Maxillary primary second molar.

Diagnosis of an ankylosed primary tooth may include any or all of the following: decreased mobility compared to unaffected teeth; a positioning of the affected tooth apical to the plane of occlusion (infraocclusion) possibly without occlusal contact; altered percussion — giving a dull rather than a cushioned sound; radiographic obliteration of the periodontal ligament space suggesting direct approximation of tooth and bone; and the radiographs show a developing vertical defect between the primary and permanent tooth.[53]

Longitudinal studies indicate that most ankylosed primary teeth exfoliate normally and allow normal eruption of succedaneous teeth.[54] Ankylosed teeth should not be removed unless they are impeding the eruption of the succedaneous tooth or unless a large marginal ridge discrepancy develops between it and the unaffected adjacent teeth. If a marginal ridge discrepancy develops, the adjacent teeth may tip into the space occupied by the ankylosed tooth and cause space loss. In cases where there is agenesis of the succedaneous tooth, it must be decided whether to perform early extraction to allow mesial drifting of the posterior teeth or to place occlusal buildups to minimize super-eruption of the opposing tooth and to lessen mesial tipping of the tooth distal.[55]

When evaluating an ankylosed tooth, the clinician must take into account the presence of a permanent successor, the extent of submergence (and potential vertical defects), and the extent of the patient's remaining facial growth. Here are some possible scenarios:

- In a mature female with a missing second bicuspid and mild to moderate submergence of the ankylosed tooth, the tooth can be kept but it may need to be restored and/or reduced mesially and distally to idealize the occlusion.
- In a male with remaining facial growth and a missing second bicuspid, the ankylosed tooth should be extracted to allow the edentulous ridge to move occlusally as the adjacent teeth erupt.[56]
- In a 9-year-old with an ankylosed and submerged primary second molar with a permanent second bicuspid with a one-third root formation, the ankylosed tooth should be extracted and the space maintained. The potential for years of negative effects on the occlusion from the submerged tooth is too great to consider maintaining the tooth.
- In an 11-year-old with an ankylosed and submerged primary second molar with a permanent second bicuspid, the ankylosed tooth can be allowed to exfoliate on its own if the ankylosis is mild to moderate with minimal changes in the occlusion.

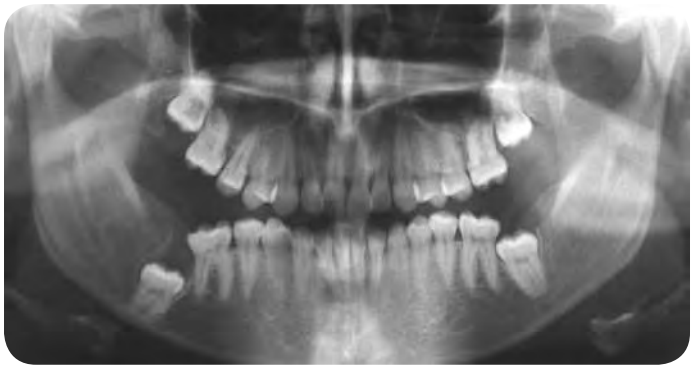

FIGURE 4. Primary failure of eruption or PFE.

FIGURE 5. A mesiodens refers to a supernumerary tooth present in the midline of the maxilla between the two central incisors.

Primary Failure of Eruption

When teeth do not erupt normally, another possible cause is primary failure of eruption or PFE. Profitt and Vig described the condition as one in which "nonankylosed teeth fail to erupt fully or partially because of malfunction of the eruption mechanism" (**FIGURE 4**). This is an unusual eruption problem that affects the posterior teeth. It is diagnosed when a tooth fails to erupt despite the presence of adequate space and the absence of overlying hard tissue that prevents eruption. Furthermore, all teeth distal to the affected tooth also fail to erupt. The cause is unknown but appears to have a genetic component.

Profitt and Vig identified several key characteristics in their study:

1. Posterior teeth were more frequently involved and the teeth distal to the first affected tooth were also affected to some degree.
2. Capacity for eruption of affected teeth varied.
    a. Involved teeth may have erupted partially and then ceased to erupt and are relatively submerged but not ankylosed.
    b. Involved teeth may have completely failed to erupt with an uncoupling of the eruption and resorption mechanisms. In these cases, the resorption appeared to be normal but the tooth failed to follow the path created.
3. Deciduous molars were likely to be involved.
4. The condition was rarely symmetric and was frequently unilateral but it could be bilateral.
5. Involved permanent teeth tended to become ankylosed at some point.
6. Orthodontic forces led to ankylosis rather than normal tooth movement.
7. Patients did not seem to have similarly affected close relatives.[57]

The management of PFE is difficult, not least because diagnosis of this condition relies principally upon exclusion, where all possible causative factors have been considered and eliminated. Active orthodontic force will most likely result in localized ankylosis and failure to extrude an affected tooth into occlusion, a finding that is essentially diagnostic. Where the condition is a localized problem affecting only one tooth, management may include extraction of the affected tooth, followed either by orthodontic space closure or by prosthetic replacement. Alternatively, a localized bony osteotomy and orthodontic extrusion of the whole segment would seem to be the only option if an occlusal position of the tooth or teeth is to be obtained. If some eruption of the tooth has occurred, a coronal buildup may be the treatment of choice, in this case accepting the vertical position of the affected tooth but achieving occlusion via the restoration.[58] Cases where multiple teeth are involved are more difficult to manage; the only available method of bringing them into occlusion is a segmental osteotomy.[59] Careful planning in these cases is essential to ensure that no damage is caused to adjacent teeth. While surgical repositioning may not move teeth into an entirely acceptable position, it will certainly aid prosthetic management.

Mesiodens

A mesiodens refers to a supernumerary tooth present in the midline of the maxilla between the two central incisors. The incidence of mesiodens has been estimated at 0.15–1 percent of the population. It occurs more frequently in boys than in girls with the ratio being approximately 2:1. In one study, 66 percent of the mesiodens were conical in shape and 52 percent were in the upward (inverted) position (**FIGURE 5**).[60]

Mesiodens are usually found close to the crowns of the unerupted permanent central incisors in a palatal position but occasionally they erupt in the middle.[61] In children, 85 percent of anterior supernumeraries are unerupted and 65 percent interfere with the normal eruption of the maxillary permanent incisors.[62] Of the 15 percent that do erupt, most come in between the ages of 3 and 7. The mesiodens may emerge in the palate or may resorb the roots of the primary central incisors and erupt in their place.[63]

Common problems associated with mesiodens include over retention of primary teeth, impaction or delayed eruption of permanent teeth, dilacerations or abnormal root development, and abnormal crowding

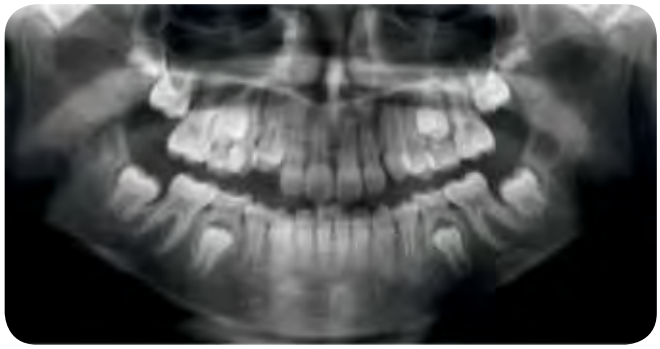

FIGURE 6. Transposition of the maxillary right first bicuspid and canine transposed.

or spacing of the anterior teeth.[64] The accurate location of supernumerary teeth is critical in determining the proper treatment approach. Clinical examination, including labial and palatal palpation, along with proper radiographs, can be used with high accuracy to determine the mesiodens' location in the premaxilla. Both vertical and horizontal shift radiographic techniques using periapical films are helpful in localizing midline mesiodens. Panoramic and lateral occlusal films can also be used.[65]

Opposing views exist as to when supernumerary teeth should be treated, if at all. Some recommend early removal of supernumerary teeth especially if they are inverted or are unlikely to erupt.[66] This may prevent the need for orthodontic treatment and/or additional surgical procedures. Advocates of early treatment feel that this will improve the chance of spontaneous eruption of the permanent incisors and increase the potential for self-correction with the optimal time being 6 and 7 years of age.[67,68] Some believe that the best time for removal of mesiodens is 8 and 9 years of age when the upper incisors erupt. At this age, the child's behavior may be easier to manage and there may be less need for sedation.[69] Another treatment approach calls for late extraction of mesiodens when the adjacent permanent incisors have completed their root formation.[70,71]

Transposition

Transposition occurs when there is "a positional interchange of two adjacent teeth, especially their roots or the development or eruption of a tooth in a position occupied normally by a nonadjacent tooth."[72] While transposition is typically first observed in the late mixed-dentition stage, it can be diagnosed in the early mixed-dentition stage. This is usually a transposition of the mandibular lateral incisor and canine.[73] The lateral incisor will show distal tipping, resorption of the primary canine (and sometimes the primary first molar) and rotation as it migrates. Other transpositions that are observed later in the transitional years are likely to be the mature mandibular lateral and canine, and the more prevalent transpositions of the maxillary canine/first premolar and maxillary canine/lateral incisor[74] (**FIGURE 6**).

Serial Extraction

When children have little to no spacing in the primary dentition, they are almost assuredly going to have crowding in the permanent dentition. Radiographs can be very useful in determining whether there will be enough room to maintain all of the teeth or whether serial extraction should be considered. Serial extraction is a planned sequence of tooth removal to reduce crowding and eruption problems during the transition from the primary to the permanent dentition. While it may make later comprehensive orthodontic treatment easier, it is not viewed as a substitute for orthodontic treatment. Serial extraction is intended for severe dental crowding. It is best used when no skeletal problems exist and the crowding is greater than 10 mm per arch. If the initial discrepancy is smaller, more residual space should be expected.

Treatment begins in the early mixed dentition (usually between 6 and 8 years old) when the primary incisors are removed to make room for the permanent incisors. This may include the extraction of the primary canines as necessary. There is usually some lingual tipping of the lower incisors and overbite often increases.

In the middle mixed dentition (usually between 8 and 10 years old), it is advisable to take a panoramic radiograph. The goal of serial extraction is to influence the permanent first premolars to erupt ahead of the canines so that they can be extracted and the canines can move distally into this space. The maxillary bicuspids usually erupt before the canines so the eruption sequence is rarely a problem. However, the lower canines often erupt before the first bicuspids, which may cause the canines to erupt facially. One technique to avoid this is to remove the lower primary first molar when there is one-half to two-thirds the root formation of the first bicuspid. This usually helps speed up the eruption of the first bicuspid, allowing it to be removed before the canine erupts. One problem that can occur is when the lower primary first molar is removed and the permanent canine still erupts ahead of the first bicuspid. This can lead to impaction of the bicuspid that requires later surgical removal.

After the first bicuspid has been removed, the second primary molars should exfoliate normally. The first bicuspid extraction space closes by mesial drift of the second bicuspid and first molar along with distal eruption of the

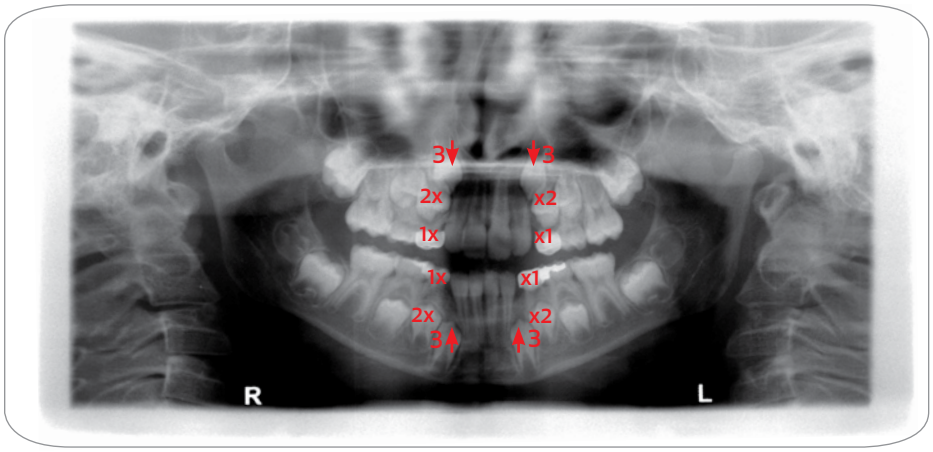

FIGURE 7. Here is an example of a serial extraction patient. The maxillary and mandibular primary incisors and cuspids have already been removed to accommodate the maxillary and mandibular permanent incisors. The sequence goes as follows: (1) Remove the first primary molars (2) Remove the first permanent bicuspids (3) Allow the permanent cuspids to occupy the space of the first permanent bicuspids and complete orthodontics as needed.

canine. Ideal alignment of the teeth is usually not achieved without subsequent orthodontic treatment[75] (see **FIGURE 7**).

X-ray Techniques for Young Children

The following are some techniques that may be useful when taking X-rays on children:

- Use a "tell, show, do" technique with an unexposed packet of film. You may want to use a camera analogy.
- Match the size of the film to the size of the child. Size 2 films are fine for anterior occlusal X-rays but size 0 or 1 films should be used to take bitewings on small children.
- Take the least difficult radiograph first to acquaint the child with the procedure. Anterior occlusal films are usually the easiest to take.
- Be sure that all settings are made on the machine and that the X-ray head is positioned before inserting the film. Some children can only hold a film for a short period of time because of their gag reflex, discomfort or short attention span.
- Consider placing alginate flavoring on the X-ray film to make it more fun and palatable for children.
- Work quickly with constant reinforcement.
- A Snap-a-Ray can be used as an anterior film stabilizer or to aid in taking bitewing radiographs.
- Be patient!

Conclusion

Because of the dynamic changes that occur in a child's developing dentition, it is very important for dentists to recognize when to take radiographs, which radiographs to take, how to evaluate them and how to treat the problems. Clinicians should be checking for anomalies such as extra/missing teeth, tooth impaction, ankylosis, primary failure of eruption, transposition and crowding. Early detection and treatment can help prevent larger problems as the child grows older. It is important for dentists to learn techniques enabling them to take radiographs on a child of any age. ■■■■

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