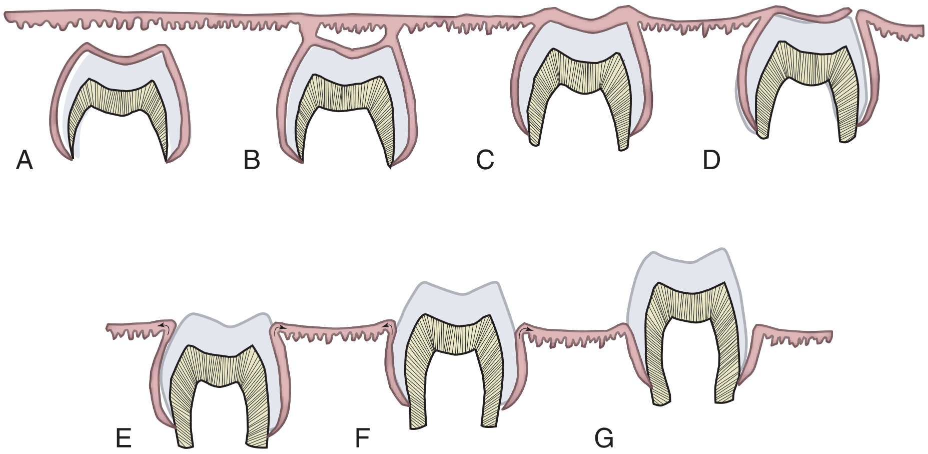

Fig. 6.19 Stages of tooth eruption. A, Tooth crown approaching oral epithelium in preeruptive stage. **B,** Contact of reduced enamel epithelium including the developmental cuticle fusing with oral epithelium. **C,** Fusion of reduced enamel epithelium including the developmental cuticle and oral epithelia. **D,** Thinning of fused epithelia. **E,** Rupture of oral epithelium, formation of the attached gingiva, and emergence. **F,** Clinical crown appearance into the oral cavity (prefunctional stage). **G,** Tooth erupting into functional occlusion.

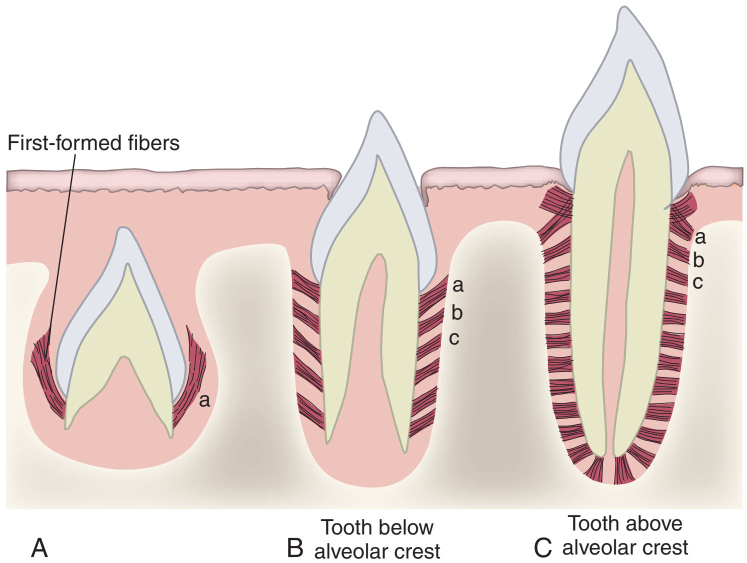

Fig. 6.20 Principal fiber development during tooth eruption. A, Origin of fibers at the cervical root area of crown. **B,** Fiber development with root growth. *a,* Initial fiber formation; *b,* development of secondary fibers; *c,* further fiber development. **C,** Change in orientation of the fibers with occlusal function. Initial fiber groups (*a, b,* and *c*) change direction with function.

attach in rapid succession. Some fibers may detach and reattach later while the tooth moves occlusally as new bone forms around it. Gradually the fibers organize and increase in number and density as the tooth erupts into the oral cavity. Blood vessels then become more dominant in the developing ligament and exert additional pressure on the erupting tooth (**Fig. 6-21**).

CLINICAL COMMENT

Teeth are considered submerged when eruption is prevented because of crowding or tipping of the adjacent teeth into the space created by the missing primary tooth. Retained primary teeth may be caused by the lack of development of the permanent successor.

Underlying the Teeth

As the crown of a tooth begins to erupt, it gradually moves occlusally, providing space underlying the tooth for the root to lengthen (**Fig. 6-22**). In the fundic region, these changes in the soft tissue and the bone surrounding the root apex are believed to be largely compensatory for the lengthening of the root. During root formation, the dentin of the root apex tapers to a fine edge that terminates in the epithelial diaphragm (**Fig. 6-23**). Fibroblasts form collagen around the root apex, and these fiber bundles become attached to the cementum as it begins to form on the apical dentin. Fibroblasts appear in great numbers in the fundic area, and some of these fibers form strands that mature into calcified trabeculae. These trabeculae form a network, or bony ladder, at the tooth apex. This is believed to fill the space left behind as the tooth begins eruptive movement (see Fig. 6-23). Gradually, this delicate bone ladder becomes denser as additional bony plates appear (**Fig. 6-24**). The

Fig. 6.21 Histology of erupting tooth with vascular injection. An outline of the blood vessels in the periodontium and tooth pulp is shown.

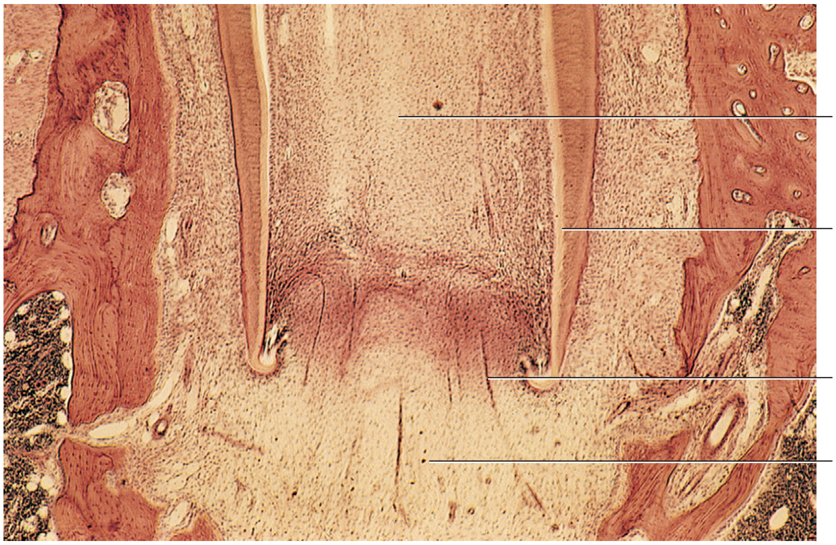

Fig. 6.22 Histology of erupting tooth with immature roots and open apex. As the tooth erupts, the roots will develop and fill in the wide pulpal tooth apex.

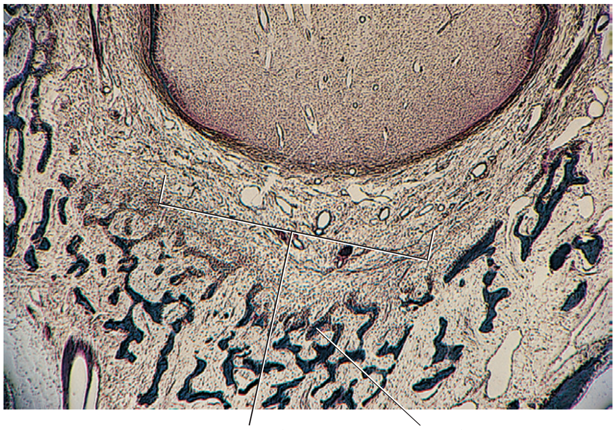

Fig. 6.23 Histology of changes in fundic region during tooth eruption. Fine trabeculae of new bone appear near tooth apices that will aid in stabilizing the tooth during eruption.

bony plates remain until the teeth are in functional occlusion at the end of this phase. Dense bone then forms around the tooth's apex, and bundles of fibers attach to the apical cementum and extend to the adjacent alveolar bone to provide more support **(Fig. 6-25)**.

CLINICAL COMMENT

Tooth eruption is a complex and multistep process that includes different types of tooth growth and movements within the bony crypt in order for the tooth to erupt into the genetically designated area of the maxilla or mandible. To accomplish eruption, bone remodeling by osteoclasts (resorption of bone) and osteoblasts (bone deposition) must take place in a coordinated manner. Most important is the removal of bone overlying the crypt, which forms the eruption pathway. In experimental studies, it has been shown that without formation of the eruption pathway, the tooth will not erupt.

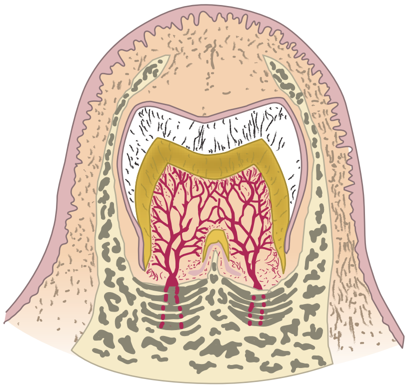

Fig. 6.24 Diagram of a later stage of tooth eruption. The fundic region further develops a bony ladder.

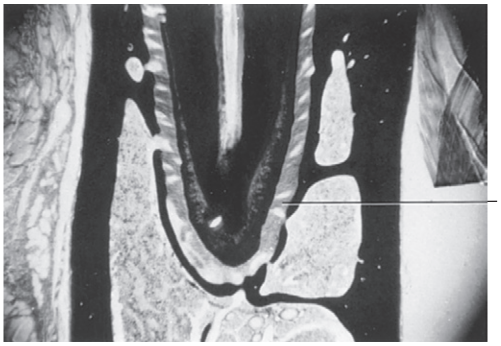

Fig. 6.25 Histology of tooth in functional occlusion to show density of functioning periodontal fibers. Areas between fiber bundles are for blood vessels and nerves.

FUNCTIONAL ERUPTIVE PHASE

The final eruptive phase takes place after the teeth are functioning and continues as long as the teeth are present in the mouth. During this period of root completion, the height of the alveolar process undergoes a compensating increase. The fundic alveolar plates resorb to adjust for formation of the root tip apex. The root canal narrows as a result of root tip maturation, during which the apical fibers develop to help cushion the forces of occlusal impact. Root completion continues for a considerable length of time, even after the teeth begin to function. This process takes about 1 to 1.5 years for deciduous teeth and 2 to 3 years for permanent teeth.

The most marked changes occur as occlusion is established. At that time, the mineral density of the alveolar bone increases, and the principal fibers of the periodontal ligament increase in dimension and change orientation to their mature state. These fibers separate into groups oriented about the gingiva, the alveolar crest, and the alveolar surface around the root. Such fibers stabilize the tooth to a greater degree, and the blood vessels become more highly organized in the spaces between the bundles of fibers (see Fig. 6-25). Later in life, attrition and abrasion may wear down the occlusal or incisal surface of the teeth, causing the teeth to erupt slightly to compensate for this loss of tooth structure. Any such change results in deposition of cementum on the root's apex **(Fig. 6-26)**. Cementum is also deposited in the furcation area of a two- or three-rooted tooth.

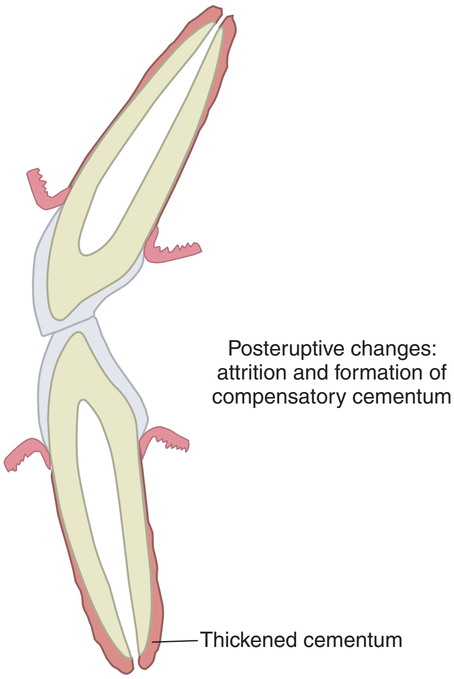

Fig. 6.26 Functional eruptive changes illustrating attrition of the incisal surface of enamel. Observe the compensatory deposition of cementum on the apical region of the root surface.

> **CLINICAL COMMENT**
>
> Lack of eruption resulting from failure of root formation may be caused by crowding of teeth, crown-to-root fusion, and lack of development of the pulp proliferative zone.

POSSIBLE CAUSES OF TOOTH ERUPTION

Of the numerous causes of tooth eruption, the most frequently cited are root growth and pulpal pressure. Other important causes are cell proliferation, increased vascularity, and increased bone formation around the teeth. Additional possible causes that have been noted are endocrine influence, vascular changes, and enzymatic degradation. Probably all these factors have an influencing role, not necessarily independent of one another.

Although not all factors associated with tooth eruption are known, elongation of the root and modification of the alveolar bone and periodontal ligament are thought to be the most important ones. These events are coupled with changes overlying the tooth that produce the eruption pathway. Blood vessels in this area are compressed by the influence of the advancing crown and become nonfunctional. Connective tissue in the eruption pathway gradually disappears as the tooth epithelium and the oral epithelium fuse. In summary, the erupting tooth moves from an area of increased pressure to an area of decreased pressure.

> **CLINICAL COMMENT**
>
> The 6/4 rule for primary tooth emergence means that from birth, 4 teeth emerge for each 6 months of age. Thus, 6 months, 4 teeth; 12 months, 8 teeth; 18 months, 12 teeth; 24 months, 16 teeth; and 30 months, 20 teeth.

SEQUENCE AND CHRONOLOGY OF TOOTH ERUPTION

The formula for the eruptive sequence of the primary and permanent dentition appears in **Box 6-3**. **Table 6-1** shows the chronologic development and eruption of the primary dentition, and **Table 6-2** shows the development and eruption of the permanent dentition.

> **CLINICAL COMMENT**
>
> A lack of eruption may be related to fusion of tooth roots to the bony socket or to the crown of a permanent tooth. The condition is known as ankylosis (**Fig. 6-27**), because the cementum of the tooth root fuses with the alveolar bone proper surrounding the alveolus (socket).

> **CONSIDER THE PATIENT**
>
> A patient complains about a retained primary tooth. She notes the absence of the permanent successor. How could you determine what has occurred?

Box 6-3 Sequence of Tooth Eruption

Primary

CI	LI	$_1M$	Cu	$_2M$
L	U	U	U	L
U	L	L	L	U

Permanent

U_1M	LCI	UL	LCU	U_1Pre	U_2Pre	UCu	L_2M	L_3M
L_1M	UCI	LL		L_1Pre	L_2Pre		U_2M	U_3M

Table 6.1 Chronology of development of the primary dentition*

Primary teeth listed in order of eruption (sequence)	Beginning calcification (Mo in utero)	Crown completed postnatally (Mo)	Appearance in the oral cavity (eruption time) (Mo)	Root completed (Yr)
Lower central incisor	3-4	2-3	6-8	1-2
Upper central incisor	3-4	2	7-10	1-2
Upper lateral incisor	4	2-3	8-11	2
Lower lateral incisor	4	3	8-13	1-2
Upper first molar	4	6	12-15	2-3
Lower first molar	4	6	12-16	2-3
Upper canine	4-5	9	16-19	3
Lower canine	4-5	9	17-20	3
Lower second molar	5	10	20-26	3
Upper second molar	5	11	25-28	3

*The normal range of eruption times indicates a wide variation in eruption times. It is important to know that a difference of 1 or 2 months either side of the normal range does not necessarily indicate that a child's eruption time schedule is abnormal. Only deviations considerably out of this range should be considered abnormal.

Table 6.2 Chronology of development of the permanent dentition

Permanent teeth listed in order of eruption (sequence)	Beginning calcification	Crown completed (Yr)	Appearance in the oral cavity (eruption time) (Yr)	Root completed (Yr)
Lower first molar	Birth	3-4	6-7	9-10
Upper first molar	Birth	4-5	6-7	9-10
Lower central incisor	3-4 mo	4	6-7	9
Upper central incisor	3-4 mo	4-5	7-8	10
Lower lateral incisor	3-4 mo	4-5	7-8	9-10
Upper lateral incisor	10-12 mo	4-5	8-9	10-11
Lower canine	4-5 mo	5-6	9-10	12-13
Upper first premolar	1-2 yr	6-7	10-11	12-14
Lower first premolar	1-2 yr	6-7	10-11	12-14
Upper second premolar	2-3 yr	7-8	10-12	13-14
Lower second premolar	2-3 yr	7	11-12	14-15
Upper canine	4-5 mo	6-7	11-12	14-15
Lower second molar	2-3 yr	7-8	11-12	14-15
Upper second molar	2-3 yr	7-8	12-13	15-16
Lower third molar	8-10 yr	12-16	17-20	18-25
Upper third molar	7-9 yr	12-16	18-20	18-25

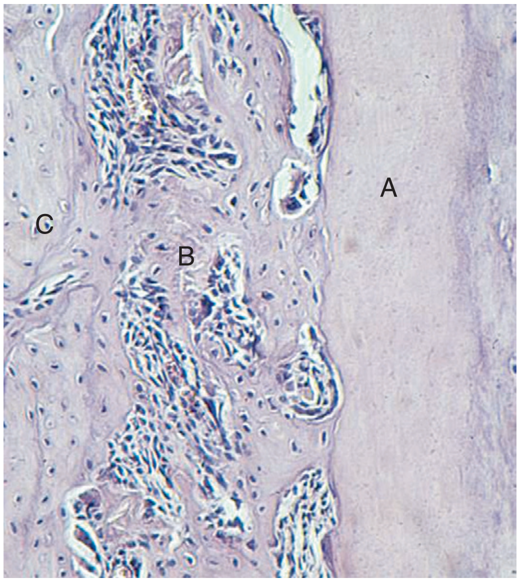

Fig. 6.27 Ankylosis. This photomicrograph demonstrates ankylosis between the cementum on the root surface **(A),** the alveolar bone proper **(C),** and the area that was the periodontal ligament **(B),** which is now filled in with bone and connective tissue and fused with the cementum and the alveolar bone proper.

SHEDDING OF PRIMARY TEETH

Humans are considered **diphyodonts** because they possess two dentitions, primary and permanent. Teeth in the primary dentition are smaller and fewer in number than the permanent dentition to conform to the smaller jaws of the young person. Teeth in the permanent dentition are larger, longer, and more numerous, which the larger jaws of the adult can accommodate.

The primary dentition functions from about 2 to 8 years of age. Teeth from both dentitions are present in the **mixed dentition period,** which extends from about 8 to 12 years of age. This is an interesting period, because only part of the primary teeth roots are present while they undergo resorption, and only part of the permanent roots are present while they are in the formative stage. In this way, nearly 50 teeth can be accommodated in the jaws during this 4-year span (see Fig. 6-12).

The period of tooth shedding follows the mixed dentition period. **Shedding** is the loss of the primary dentition caused by the physiologic resorption of the roots, the loss of the bony supporting structure, and therefore the inability of these teeth to withstand the masticatory forces.

The degeneration of primary pulp tissue is similar to that of the tissues in the eruption pathway with a loss of cells, nerves, and blood vessels. When a primary tooth is extracted, blood is still likely to be in the crown, although only the oral epithelium holds the tooth in the socket. **Fig. 6-28** shows the correlation between root growth and eruption. It illustrates changes that occur in the preeruptive (Fig. 6-28**,** *A* and *B*),

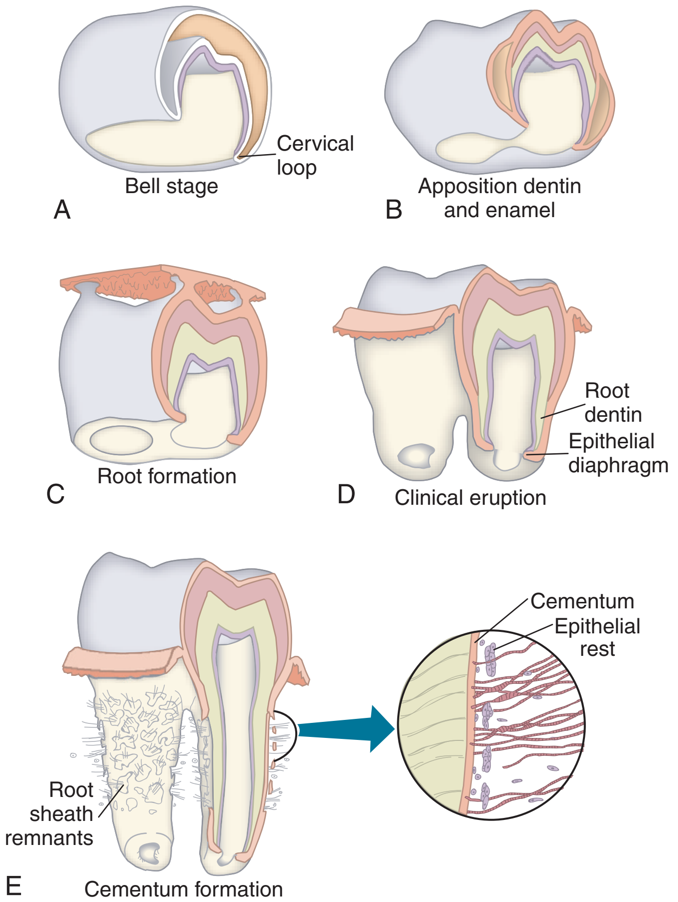

Fig. 6.28 Summary of tooth eruption. A, Early preeruptive changes in enamel organ at the bell stage. **B,** Late preeruptive changes as enamel and dentin form. **C,** Early prefunctional changes as the tooth moves to oral epithelium. **D,** Late prefunctional changes as the tooth emerges into the oral cavity. **E,** Functional eruptive phase with clinical contact. Root growth is shown with the root sheath detaching from the root surface. Epithelial rests and cementum formation by cementoblasts are now occurring.

prefunctional (Fig. 6-28**,** *C* and *D*), and functional eruptive (Figure 6-28**,** *E*) stages of the tissues overlying and around the root surface as the tooth develops functionally.

COMPARISONS OF THE PRIMARY AND PERMANENT DENTITIONS

This section compares the morphology and histology of the primary and permanent dentition and describes some clinical problems in the developing jaw of the growing child as compared with the jaw in the adult and related characteristics of the developing primary and permanent teeth and their supporting structures (**Table 6-3**).

Tooth Number and Size

The main difference between the primary and permanent dentitions is the number of teeth—20 in the primary dentition, and 32 in the permanent dentition. The permanent teeth replacing the primary teeth are called *successional.* There are 12 permanent teeth, the permanent molars, that have no predecessors. They are called *accessional.* As the permanent molars are added, arch length and occlusal surface are increased (see Fig. 6-18). Primary and permanent teeth differ in size and form. Several of these differences influence decisions about clinical treatment. Crowns of primary teeth are smaller than the crowns of their successors, with only a few key exceptions. Crowns of permanent incisors and canines are larger than their primary counterparts in all dimensions (see Fig. 6-3). The difference between the cumulative mesiodistal diameters of the primary molars and canines and those of the permanent molars and canines is called the *leeway space,* which totals 1.3 mm in the maxillary arch and 3.1 mm in the mandibular arch.

Primary teeth resemble permanent teeth. Both permanent and primary incisors have single roots and incisal edges. Both primary and permanent canines also have single roots and a single cusp. Primary molars, however, bear no resemblance to the premolars that will succeed them. The crowns of the permanent molars are larger than crowns of primary molars; the latter have a larger mesiodistal diameter than crowns of the succeeding premolars. This difference has clinical significance in caries patterns on approximal surfaces and in cavity design for caries removal. Interproximal lesions will be cervical to the contact areas and of similar shape.

Roots

The roots of primary teeth are shorter than roots of permanent teeth and are more divergent. The flat curved roots of primary teeth permit development of the crown of the permanent successor (see Fig. 6-18). As the permanent teeth erupt, the roots of the primary teeth are resorbed. Root shape dictates the shape of the root pulp and is correlated with two important

Table 6.3 Brief outline of the comparison of primary and permanent teeth

	Primary	Permanent
Number of teeth	20	32
Enamel and dentin	Thinner	Thicker
Lifespan	Develop quicker: span ≈ 8½ yrs	Develop slower: span ≈ 6 yrs to ?
Size	Smaller, except MD width of molars	Larger
Crown shape	Greater contour, especially at cervical area	Curved M/D/B/L
Contact areas	Flat	Point
Root shape	Curved molar roots	Straighter roots
Pulp chamber	Larger in relation to rest of tooth Ribbon-like pulp in root MB pulp horn large in molars	Smaller Oval shape in root
Accessory canals	More in bifurcation area than permanent teeth	More in apical area
MD width of incisors (difference is named *incisors liability*)	Smaller (incisors are more erect)	Larger (incisors have greater angulation)
MD width of primary molars and permanent premolars (difference is named *leeway space*)	Larger	Smaller (1.3 mm in maxillary, 3.1 mm in mandibular)
Root resorption	Normal	Pathological
Dentin hardness	Peripheral dentin ≈Same	≈Same
Central dentin	Softer	Harder
Pulpal dentin	Softer	Harder

MB, Mesiobuccal; *MD,* Mesiodistal; *M/D/B/L,* Mesial/Distal/Buccal/Lingual.

clinical considerations. First, curved roots with thin walls make mechanical access of root canals more difficult in primary molars than in permanent molars. Second, the flat ribbon-shaped root canals of the primary teeth are in sharp contrast to the tubelike canals of the permanent teeth. Significant developmental differences occur in the root canals of the primary molars; the root canal fills in unevenly with secondary dentin, which leaves calcified bridges, making endodontic instrumentation difficult.

Tooth Structure

Primary and permanent teeth have a similar enamel prism structure, except at the tooth surface. Primary teeth are more likely to have a prismless surface, and this reflects on the clinician's ability to etch the surface and provide an interface for attachment of sealants and other restorative procedures. Enamel is about twice as thick in permanent teeth as in primary teeth and is more highly pigmented. Primary tooth dentin is slightly softer than the permanent teeth.

Pulp Shape and Size

The coronal pulps of primary teeth are relatively larger than in permanent teeth. The largest pulp horn in primary molars is the mesiobuccal pulp horn and the second largest is the mesiolingual pulp horn. These differences are used in the design of dental restoration. Primary and permanent teeth are similar in basic histological architecture and the vasculature; connective tissue and odontoblastic and subodontoblastic zones are similar in appearance. Permanent teeth have a larger number of nerves than primary teeth. The usual location of accessory canals in primary teeth is in the furcation zone and in permanent teeth at the apical one third of the completed root.

Arch Shape

Arch shape is similar in the anterior portion of the two dentitions, but the permanent dentition extends further distally. Tooth-size differences are critical in assessment of potential space for permanent teeth to erupt into alignment.

The succession of smaller primary incisors with larger permanent incisors is called *incisor liability,* and the difference in the mesial distal dimension between the primary molars and permanent premolars is called the *leeway space.*

Root Resorption and Pulp Degeneration

The primary tooth roots have a higher susceptibility to resorption than permanent teeth. The process of resorption is accompanied by gradual changes in the pulp. The first sign is a reduction in the number of cells in the pulp; nerve trunks degenerate and some fibrosis occurs. Blood vessels remain until the tooth is exfoliated.

During root formation, the primary tooth pulp is highly cellular. As the roots are completed, fewer cells and more fibers are evident. The proliferation of fibers continues during the root resorption phase with fiber bundles becoming more prominent.

CONSIDER THE PATIENT

Discussion: To answer this question, the dentist takes a radiograph of the area to determine whether the permanent tooth is missing or displaced. In either case, the primary tooth is retained in position while the dentist determines the status of the permanent tooth and, if the tooth is present, aids its eruption into the proper place.

Nerve fibers gradually organize in the pulp chamber of the primary tooth. As the tooth reaches functional occlusion, the nerve fibers form a parietal plexus. These nerve fibers are lost during resorption of the primary tooth roots, which makes teeth insensitive to pulpal pain at the time of exfoliation.

The periodontal support of primary and permanent teeth is similar in basic architecture.

Self-Evaluation Questions

1. Define tooth eruption and each of its phases.
2. Describe the changes overlying the tooth during eruption.
3. Describe the changes occurring around the tooth during eruption.
4. Describe the significant changes in the area underlying the teeth that relate to eruption.
5. What are the three fundamental causes of tooth shedding?
6. Give the sequence of eruption of the primary and permanent teeth.
7. What is the origin of osteoclasts?
8. Give the sequence of events that occur in hard tissue resorption.
9. Give the chronology of eruption for the primary teeth.
10. Give the chronology of eruption for the permanent teeth.

ACKNOWLEDGEMENTS

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QUANDARIES IN SCIENCE

The processes of tooth eruption and shedding of the primary teeth are almost as much a mystery now as they were in the distant past when scientists first started to hypothesize about the biologic sequence of events culminating in a functional tooth. Many theories have been suggested and are under active investigation, but none have been proven. Because the entire process requires many steps including tooth development, bone remodeling, tooth movement, and induction of many cell types, and because each step is both complicated and intricate and exquisitely timed, it is extremely difficult to form a complete picture of this multifactorial event. This chapter discusses the theories, but ultimately why, how, and when teeth erupt is still to be scientifically determined. Maybe scientists should be asking different questions to get to the right answer; for example, why don't teeth erupt?

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