PART

1

Comparative Tooth Anatomy

The six chapters in this part of the book provide a detailed description of each type of tooth in an adult and in a child.

CHAPTER 1

Basic Terminology for Understanding Tooth Morphology

The background terminology and tooth morphology concepts presented in this chapter are divided into 10 sections as follows:

I. Naming teeth based on location within the normal, complete human dentition
- **A.** Complete primary dentition
- **B.** Complete permanent dentition

II. Tooth identification systems: Universal, World Dental Federation (International), and Palmer Numbering Systems

III. Terminology used to describe the tissues of a tooth (and definition of anatomic crown and root)

IV. Introduction to the periodontium (and definition of clinical crown and root)

V. Terminology used to define tooth surfaces
- **A.** Terms that identify outer surfaces (toward the cheeks or lips) of anterior versus posterior teeth
- **B.** Terms that identify inner surfaces (toward the tongue) of maxillary versus mandibular teeth
- **C.** Terms that differentiate biting surfaces of anterior versus posterior teeth
- **D.** Terms that differentiate approximating surfaces of teeth
- **E.** Terms to denote tooth surface junctions or dimensions
- **F.** Divisions (thirds) of the crown or root (for purposes of description)
- **G.** Root-to-crown ratio

VI. Terminology used to describe the morphology of a tooth
- **A.** Morphology of an anatomic crown
- **B.** External morphology of the anatomic root
- **C.** Cervical line (cementoenamel junction or CEJ) curvature
- **D.** Relative size

VII. Terminology related to the ideal tooth alignment of teeth in dental arches
- **A.** Midroot axis line and tooth alignment
- **B.** Crest of curvature (height of contour) on the facial and lingual surface
- **C.** Contact areas (or proximal crests of curvature)
- **D.** Embrasure spaces

VIII. Ideal occlusion: inter (between) arch relationship of teeth

IX. Tooth development from lobes

X. Interesting variations in animal teeth compared to human teeth using dental formulae

OBJECTIVES

This chapter is designed to prepare the learner to perform the following:

- Based on location in the normal, complete primary dentition, name all 20 teeth by arch, quadrant, type (when applicable), and class.
- Based on location in the normal, complete permanent dentition, name all 32 teeth by arch, quadrant, type (when applicable), and class.

(*Continued*)

- Use the Universal Numbering System to identify permanent and primary teeth.
- Use the Palmer and International Tooth Numbering Systems to identify teeth, and "translate" them to the Universal System.
- Identify and describe the supportive structures of the teeth (periodontium).
- Identify and describe the four tissues of a tooth and their location, mineral content, and function.
- Differentiate an anatomic crown and root from a clinical crown and root.
- Name each tooth surface on anterior and posterior teeth.
- From all views, divide a tooth crown and root into thirds and label each third.
- Define terms used to describe a specific dimension of a tooth.
- Describe and identify (by name) common tooth rounded elevations, ridges, depressions, and grooves for each type of tooth.
- Describe and recognize the parts of a root.
- Describe and identify the attributes of ideal tooth alignment and embrasure spaces relative to other teeth within the arch, including the cusp or incisal edge position relative to the tooth's midroot axis line (proximal views), location of crests of curvature and proximal contacts (facial or lingual views), and relative sizes of embrasure spaces (facial, lingual, or occlusal/incisal views).
- Describe and identify the ideal interarch relationship of teeth in class I occlusion, especially the relationship of first molars and canines.
- Identify the number of developmental lobes that form each tooth, and recognize the anatomic landmarks of a tooth that form from these lobes.

Just as you need to learn a new vocabulary before you can speak a foreign language, you need to learn a new vocabulary before you can begin to understand the "foreign language" of dental anatomy. Therefore, you need to understand each new word defined in this introductory chapter (highlighted in **bold**) in order to be able to discuss and appreciate the numerous traits that differentiate each type of tooth that are presented in the next five chapters. Without this understanding, you can neither understand others nor make yourself understood when discussing teeth. Do you comprehend what is meant when someone says "In ideal class I occlusion, the mesiobuccal cusp of the maxillary first molar occludes with the mesiobuccal groove of the mandibular first molar"? If not, study each term in this chapter, carefully analyze each figure when it is referenced, perform all of the learning exercises, and answer each study question. Then you should be able to comprehend and picture exactly what was said in that statement.

SECTION I NAMING TEETH BASED ON LOCATION WITHIN THE NORMAL, COMPLETE HUMAN DENTITION

This section is designed to introduce you to terms used when naming teeth based on their normal location in the mouth. All of the teeth in the mouth together are referred to as our **dentition** [den TISH un]. Humans have two sets of teeth throughout life: one during childhood, called the **primary dentition**, and one that will hopefully last throughout adulthood, called the **permanent** (also known as **secondary**) **dentition**.

The teeth in the upper jawbones (called the maxillae [mak SIL ee]) collectively form an arch shape known as the **maxillary** [MACK si lair ee] **arch**, and those teeth in the lower jawbone (called the mandible) collectively form the **mandibular** [man DIB yoo ler] **arch**. Each arch can further be divided into the left and right halves, also known as left and right quadrants since each **quadrant** contains one fourth of all teeth in that dentition.

A. COMPLETE PRIMARY DENTITION

There are 20 teeth in the complete primary dentition (shown in *Fig. 1-1*). There are ten in the upper (maxillary) arch and ten in the lower (mandibular) arch. The complete primary dentition has five teeth in each quadrant. The primary teeth in each quadrant are further divided into *three* **classes** based on their unique shape and function during chewing. Incisors [in SI zerz] are shaped to incise and cut off pieces of food, canines are shaped to pierce and hold on to food, and molars are shaped to grind food. Starting on either side of the arch **midline**, that is, the demarcation between the right and left quadrants, the two front teeth in each quadrant of the primary dentition are **incisors**, followed by one **canine**, and then two **molars**.

Two classes of primary teeth, incisors and molars, contain more than one tooth per quadrant and are subdivided into **types** within each class. Each type can be defined by its normal location within the complete quadrant. The type of primary incisor closest to the arch midline separating the right and left quadrants is called a **central incisor.** The type of incisor next to, or lateral to, the central incisor is called a **lateral incisor**. Next in each quadrant is a canine, followed by two types of molars: a **first molar** behind the canine and then a **second molar** (Fig. 1-1).

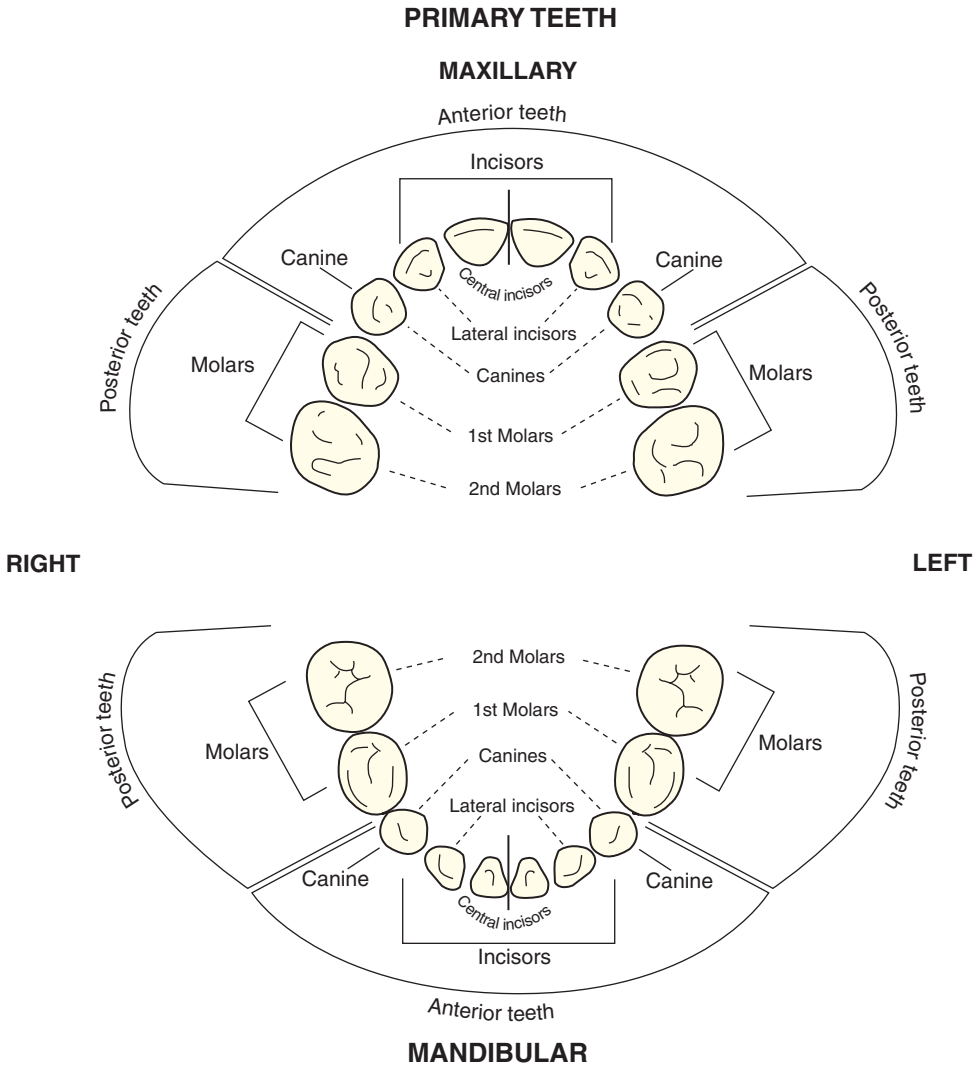


FIGURE 1-1. Maxillary and mandibular **primary** dentition. The midline of each arch is denoted by a line between the right and left central incisors.

The primary dentition is also called the **deciduous** [de SIDJ oo us] **dentition**, referring to the fact that all of these teeth are eventually shed (like a deciduous tree loses its leaves), being replaced by teeth of the permanent dentition. The **mixed dentition** is the term used to describe the dentition where there is a mix of secondary and primary teeth visible in the mouth at the same time, during that time after permanent teeth have begun to replace primary teeth, but before all primary teeth have been lost.

LEARNING EXERCISE

Using either models of the complete primary dentition or Figure 1-1 while covering up the labels, identify each primary tooth based on its location in the arch. Include, in order, the **dentition** (primary), **arch** (maxillary or mandibular), **quadrant** (right or left), **type** (if applicable), and **class**. For example, the tooth next to the midline in the lower left quadrant would be identified as the primary mandibular left central incisor.

B. COMPLETE PERMANENT DENTITION

The complete permanent (or secondary) dentition is present in the adult. It is composed of 32 teeth: 16 in the upper maxillary arch and 16 in the lower mandibular arch (shown in *Fig. 1-2*). The permanent dentition has eight teeth in each quadrant, which are divided into *four* **classes**: incisors that incise food; canines that pierce and hold food; **premolars**, a new class for permanent teeth shaped to chew food; and molars, also shaped to chew food. Based on location, the two permanent front teeth in each quadrant are incisors, followed by one canine, then two premolars, and finally three molars.

The classes of permanent teeth containing more than one tooth per quadrant (namely, incisors, premolars, and molars) are subdivided into **types** within each class. Each type can be identified by its normal location within the quadrant. As in the primary dentition, the permanent incisor closest to the midline between the right and the left quadrants is called a central incisor; the incisor next to, or lateral to, the central incisor is called a lateral incisor. Next in the arch is a canine,

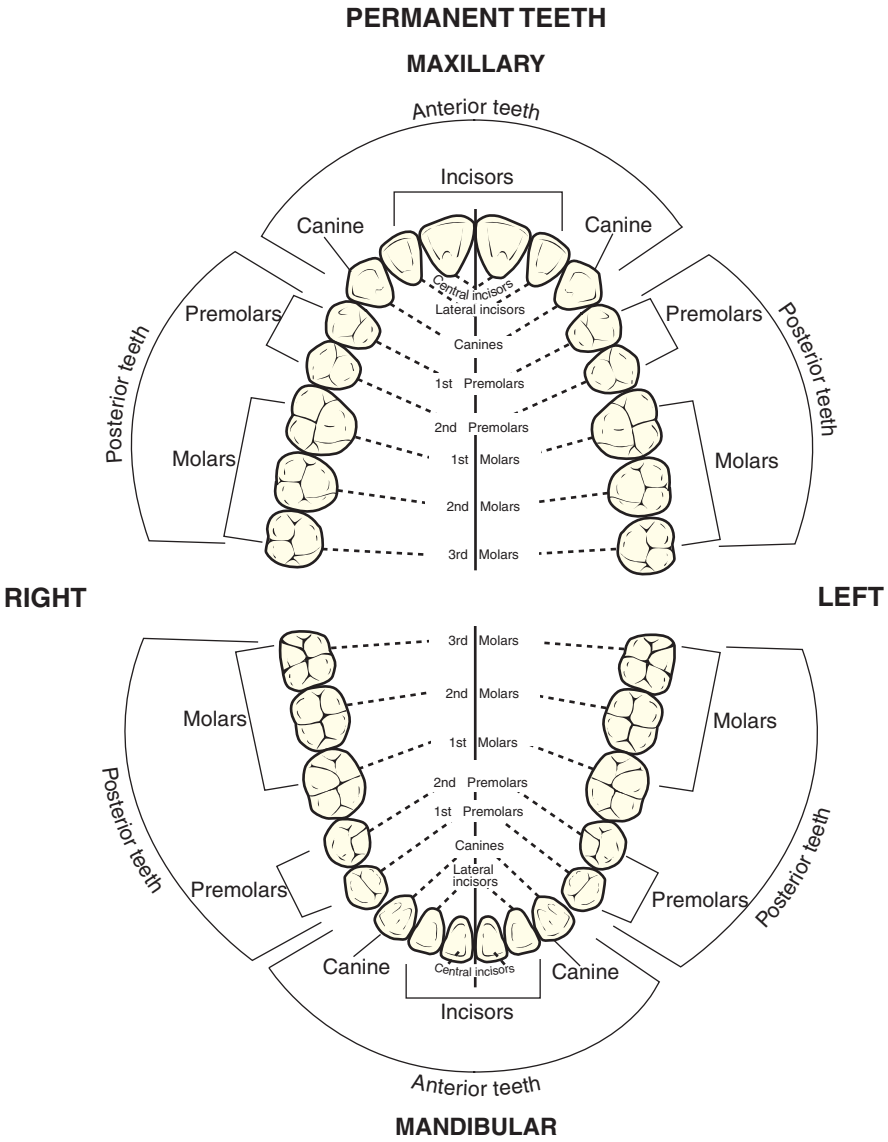


FIGURE 1-2. Maxillary and mandibular **permanent** dentition. The midline of each arch is denoted by a line between the right and left central incisors.

followed by a **first premolar**, and then a **second premolar**. Continuing around toward the back in each quadrant are three molars: a first molar, a second molar, and finally a **third molar** (sometimes referred to as a **wisdom tooth**).

In summary, when comparing the teeth in primary and permanent dentitions, be sure to notice the differences. Although central incisors and lateral incisors and canines are similarly positioned in both dentitions, permanent dentitions have a new class of teeth called **premolars**, which are located between permanent canines and permanent molars. Premolars erupt into the spaces left where the primary molars were located earlier in life. Also, there are three permanent molars in each quadrant, whereas there are only two primary molars in each quadrant. These three permanent molars erupt behind the premolars where no primary teeth were previously located.

There are two other terms used to categorize or distinguish groups of teeth by their location: anterior and posterior teeth. **Anterior teeth** are those teeth in the front of the mouth, specifically, the incisors and the canines. **Posterior teeth** are those in the back of the mouth, specifically, the premolars and the molars.

LEARNING EXERCISE

Using either models of the complete permanent dentition or Figure 1-2 while covering up the labels, identify each permanent tooth based on its location in the arch. To identify each tooth accurately, include, in order, the **dentition** (permanent), **arch** (maxillary or mandibular), **quadrant** (right or left), **type** (if applicable), and the **class**. For example, the last adult tooth in the lower right quadrant is correctly identified as the permanent mandibular right third molar.

REVIEW Questions

These questions were designed to help you confirm that you understand the terms and concepts presented in this section. Select the one best answer.

1. How many teeth are present in one quadrant of a complete adult (permanent) dentition?
   a. 5
   b. 8
   c. 10
   d. 20
   e. 32

2. What class of teeth is present in the permanent dentition that is NOT present in the primary dentition?
   a. Incisors
   b. Canines
   c. Premolars
   d. Molars

3. In a permanent dentition, the fifth tooth from the midline is a
   a. Canine
   b. Premolar
   c. Molar
   d. Incisor

4. The posterior teeth in the permanent dentition include which of the following?
   a. Premolars only
   b. Molars only
   c. Premolars and molars only
   d. Canines, premolars, and molars

5. Which permanent tooth erupts into the space previously held by the primary second molar?
   a. First molar
   b. Second molar
   c. First premolar
   d. Second premolar

6. How many teeth are present in one arch of the adult dentition?
   a. 5
   b. 8
   c. 10
   d. 12
   e. 16

7. How many teeth are present in one arch of the primary dentition?
   a. 5
   b. 8
   c. 10
   d. 16
   e. 20

8. How many incisors are present in the complete adult dentition?
   a. 2
   b. 4
   c. 6
   d. 8
   e. 12

9. How many molars are present in the primary dentition?
   a. 2
   b. 4
   c. 8
   d. 10
   e. 1

10. How many molars are present in each arch of the adult dentition?
    a. 2
    b. 3
    c. 6
    d. 8
    e. 12

11. What is the fourth tooth from the midline in the primary dentition?
    a. Canine
    b. First premolar
    c. Second premolar
    d. First molar
    e. Second molar

ANSWERS: *1–b; 2–c; 3–b; 4–c; 5–d; 6–e; 7–c; 8–d; 9–c; 10–c; 11–d*

SECTION II TOOTH IDENTIFICATION SYSTEMS: UNIVERSAL, WORLD DENTAL FEDERATION (INTERNATIONAL), AND PALMER NUMBERING SYSTEMS

Documenting patient treatment with accurate dental records is an important task in any dental practice. To do so expeditiously, it is necessary to adopt a code or numbering system for teeth. Otherwise, for each tooth being charted, one must record the dentition, arch, side, type (if applicable), and class. For example, describing a permanent maxillary right second molar requires five words, but it can be simplified by using the Universal Numbering System, identifying this same tooth with the number 2 (only one number).

The **Universal Numbering System** was first suggested by Parreidt in 1882 and officially adopted by the American Dental Association in 1975. It is accepted by third-party providers in the United States and is endorsed by the American Society of Forensic Odontology. Basically, the Universal Numbering System uses numbers **1** through **32** for the 32 teeth in the permanent dentition, starting with 1 for the maxillary right third molar, going around the arch to the maxillary left third molar as 16; dropping down on the same side, the left mandibular third molar becomes 17, and then the numbers increase around the lower arch to 32, which is the lower right third molar. This numbering system is used for each permanent tooth in the illustration in *Figure 1-3* and seen in the mouth in *Figure 1-4*.

For the 20 teeth in the primary dentition, 20 letters of the alphabet are used from **A** through **T**. The letter A represents the maxillary right second molar, sequentially around the arch and through the alphabet to J for the maxillary left second molar, then dropping down on the same side to K for the mandibular left second molar, and then clockwise around the lower arch to T for the mandibular right second molar. This system is used to identify each primary tooth in *Figure 1-5* and in the mouth in *Figure 1-6*.

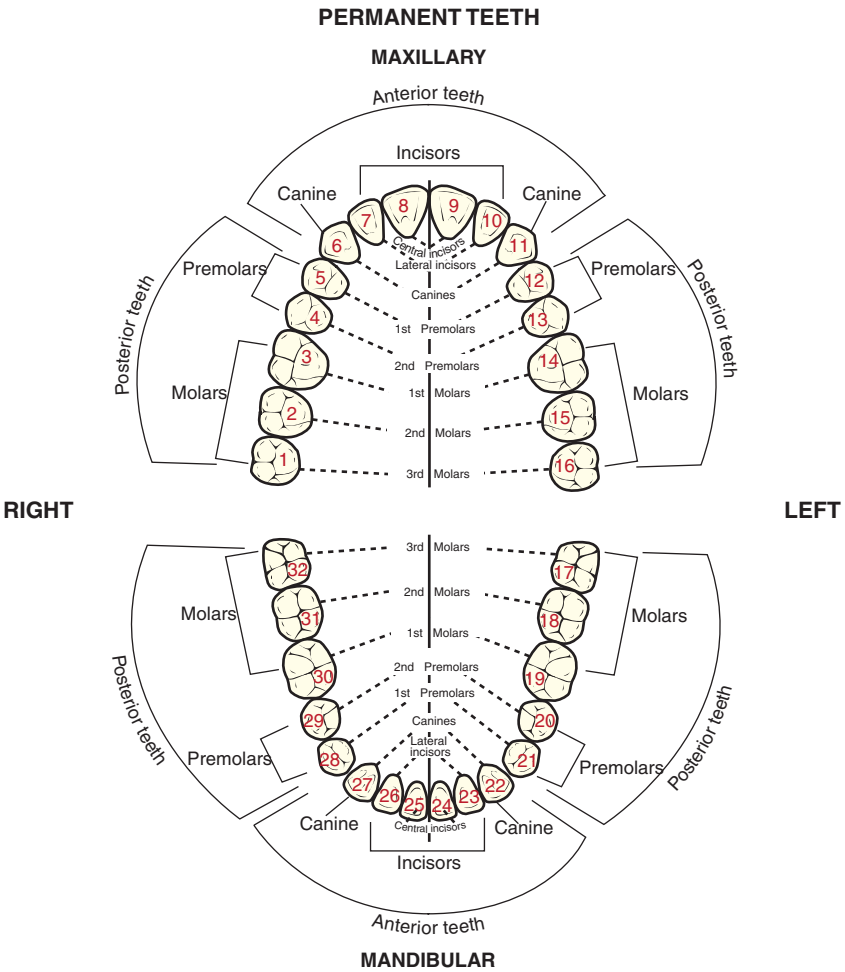


FIGURE 1-3. The numbers 1 through 32 on the *permanent* teeth identify each tooth using the **Universal Numbering System,** which is commonly used for record keeping in the United States and used in this book.

FIGURE 1-4. In the mouth of an adult, the *permanent* teeth that are visible are numbered using the **Universal Numbering System**.

There are also two other numbering systems: the World Dental Federation (International) System used in other countries and the Palmer Tooth Notation System. The **World Dental Federation** notation (also known as the **Federation Dentaire Internationale** or **FDI System**) uses two digits for each permanent or primary tooth. The *first digit* denotes a specific quadrant (right or left), arch (maxillary or mandibular), *and* dentition (permanent or primary) as follows:

PERMANENT DENTITION
1 = Permanent dentition, maxillary, right quadrant
2 = Permanent dentition, maxillary, left quadrant
3 = Permanent dentition, mandibular, left quadrant
4 = Permanent dentition, mandibular, right quadrant

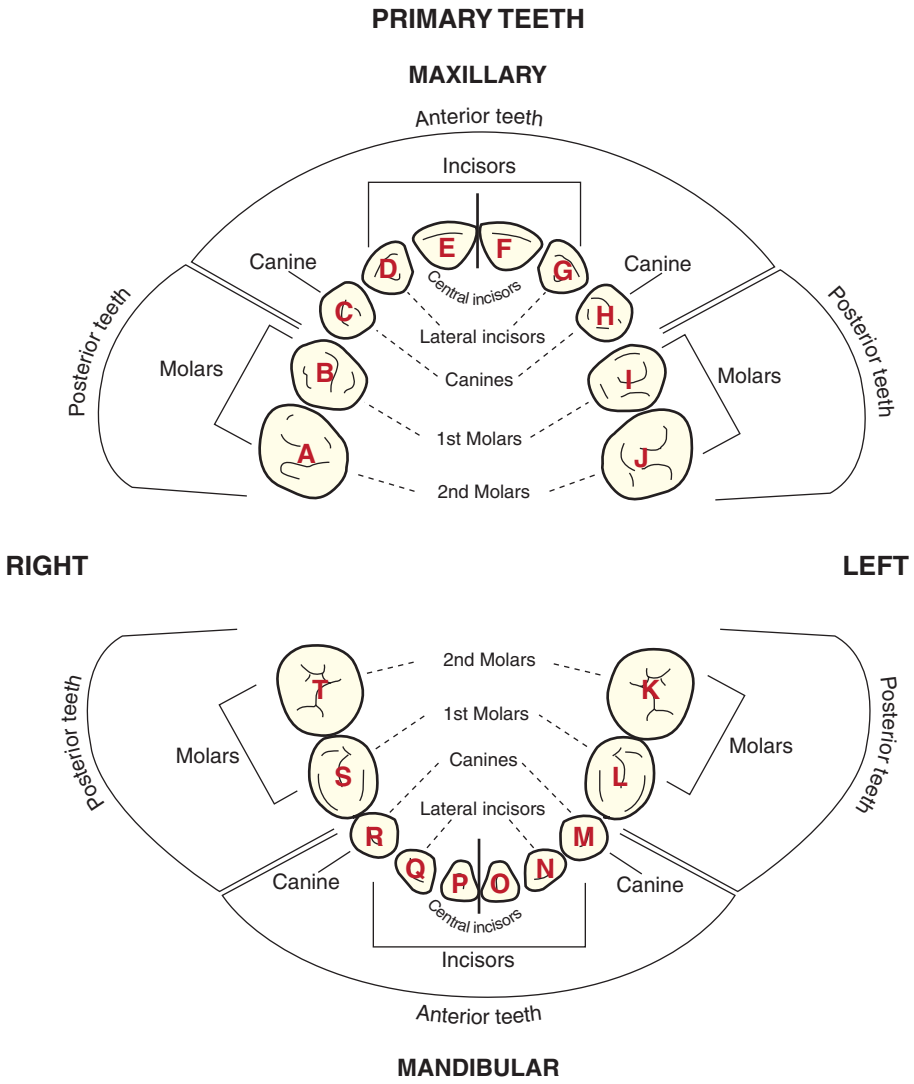


FIGURE 1-5. The letters A to T on the *primary* teeth identify each tooth using the **Universal System,** which is commonly used for record keeping in the United States.

FIGURE 1-6. In the mouth of a child, the *primary* teeth that are visible are identified using letters as used in the **Universal System**.

PRIMARY DENTITION
5 = Primary dentition, maxillary, right quadrant
6 = Primary dentition, maxillary, left quadrant
7 = Primary dentition, mandibular, left quadrant
8 = Primary dentition, mandibular, right quadrant

The *second digit* denotes the tooth position in each quadrant relative to the midline, from closest to the midline to farthest away. Therefore, in the permanent dentition with 8 teeth in each quadrant, 1 is a central incisor closest to the midline, 2 is a lateral incisor, 3 is a canine, and so forth through 8, the permanent third molar, farthest from the midline. In the primary dentition with only 5 teeth in each quadrant, the number 1 represents the tooth closest to the midline or the primary central incisor, and the number 5 represents the tooth farthest from the midline or the primary second molar. In summary, each *adult quadrant* is numbered 1 through 4 and each adult tooth within that quadrant is numbered 1 to 8 (*Fig. 1-7*), while

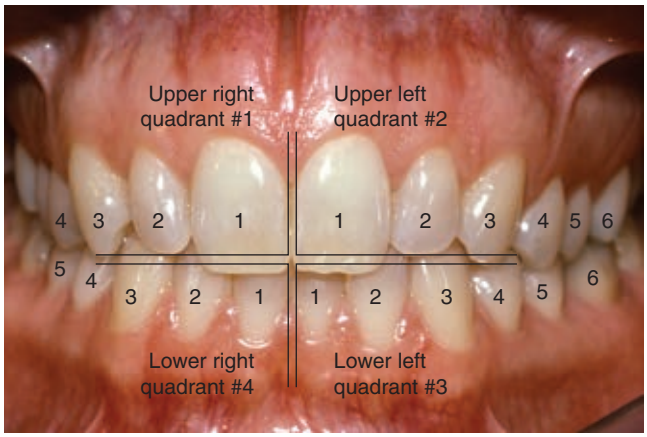


FIGURE 1-7. Two methods are shown for denoting each quadrant in the *permanent* dentition. The **Palmer System** uses a different "bracket" shape for each quadrant as you face the person, whereas the **FDI International System** uses the numbers 1 through 4 to denote each adult quadrant. The numbers on each tooth denote the method for identifying teeth within each quadrant beginning at the midline with number 1 for the central incisors, number 2 for lateral incisors, etc.

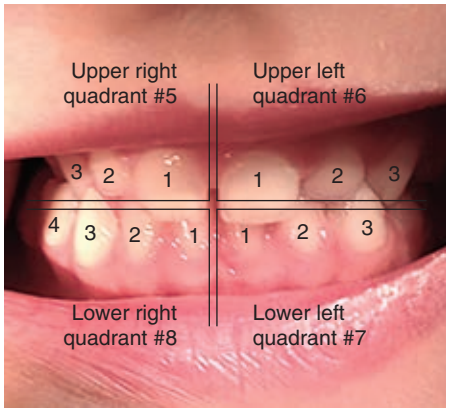


FIGURE 1-8. When identifying each *primary* tooth using the **World Dental Federation** or **FDI International System**, each quadrant is numbered 5 through 8 as indicated, and each tooth within that quadrant is identified using numbers 1 though 5 with number 1 for the central incisors, number 2 for lateral incisors, etc.

each *primary quadrant* is numbered 5 to 8 and each tooth within that quadrant is numbered 1 to 5 (*Fig. 1-8*). (Using this system, tooth numbers within the range 11 through 48 represent permanent teeth, whereas tooth numbers within the range 51 through 85 represent primary teeth.) To cite an example, 45 is a permanent mandibular right second premolar since the first digit, 4, indicates the mandibular right quadrant in the permanent dentition, and the second digit, 5, indicates the fifth tooth from the midline in that quadrant, namely, the second premolar. Using this numbering system for the primary dentition, tooth 63 is a primary maxillary left canine since the first digit, 6, indicates maxillary left quadrant in the primary dentition, and the second digit, 3, indicates the third tooth from the midline, namely, the canine. To cite another example, 51 is a primary maxillary right central incisor since the first digit, 5, indicates the maxillary right quadrant for a primary tooth, and the second digit, 1, indicates the first tooth from the midline in that quadrant, namely, the central incisor. Finally, if the Universal number for a tooth was 32, the World Dental Federation number would be 48. If the Universal letter for a primary tooth was A, the World Dental Federation number would be 55. All tooth numbers and letters using both systems are shown in *Table 1-1*.

The **Palmer Notation System** is used by many orthodontists and other practitioners especially in the United Kingdom. It utilizes four different bracket shapes (⌟, ⌞, ⌝, and ⌜) to denote each of the four quadrants. The specific bracket surrounds a number (or letter), which denotes the specific tooth within that quadrant. The specific brackets are designed to represent each of the four quadrants of the dentition, as if you were facing the patient as seen in Figure 1-7.

⌟ is upper right quadrant.
⌞ is upper left quadrant.
⌝ is lower right quadrant.
⌜ is lower left quadrant.

TABLE 1-1 Major Tooth Identification Systems

		TOOTH	UNIVERSAL RIGHT	UNIVERSAL LEFT	PALMER NOTATION RIGHT	PALMER NOTATION LEFT	INTERNATIONAL (FDI) RIGHT	INTERNATIONAL (FDI) LEFT
PRIMARY DENTITION	MAXILLARY TEETH	Central incisor	E	F	A|	|A	51	61
		Lateral incisor	D	G	B|	|B	52	62
		Canine	C	H	C|	|C	53	63
		First molar	B	I	D|	|D	54	64
		Second molar	A	J	E|	|E	55	65
	MANDIBULAR TEETH	Central incisor	P	O	A|	|A	81	71
		Lateral incisor	Q	N	B|	|B	82	72
		Canine	R	M	C|	|C	83	73
		First molar	S	L	D|	|D	84	74
		Second molar	T	K	E|	|E	85	75
PERMANENT DENTITION	MAXILLARY TEETH	Central incisor	8	9	1|	|1	11	21
		Lateral incisor	7	10	2|	|2	12	22
		Canine	6	11	3|	|3	13	23
		First premolar	5	12	4|	|4	14	24
		Second premolar	4	13	5|	|5	15	25
		First molar	3	14	6|	|6	16	26
		Second molar	2	15	7|	|7	17	27
		Third molar	1	16	8|	|8	18	28
	MANDIBULAR TEETH	Central incisor	25	24	1|	|1	41	31
		Lateral incisor	26	23	2|	|2	42	32
		Canine	27	22	3|	|3	43	33
		First premolar	28	21	4|	|3	44	34
		Second premolar	29	20	5|	|5	45	35
		First molar	30	19	6|	|6	46	36
		Second molar	31	18	7|	|7	47	37
		Third molar	32	17	8|	|8	48	38

The *permanent* tooth in each quadrant is numbered from 1 (nearest to the arch midline) to 8 (farthest from the midline) as in the International System. To record a specific tooth, place the correct number of the tooth in that quadrant within the bracket shape that identifies the correct quadrant (Fig. 1-7). For example, the lower left central incisor would be |1, the lower left second premolar would be |5, and the upper right canine would be 3|. For *primary* teeth, the same four brackets are used to denote the quadrants, but five letters of the alphabet, A through E, represent the primary teeth in each quadrant (with A being a central incisor, B a lateral incisor, C a canine, etc.) (*Fig. 1-9*). For example, the primary upper right first molar would be D|. Comparing the Universal System with the Palmer System, the permanent maxillary right second molar would be tooth 2 using the Universal System, but would be 7| using the Palmer System. If you are confused, study Table 1-1 and the figures that illustrate the quadrant brackets.

Unless otherwise stated, the **Universal System of tooth numbering is used throughout this text.** To master the Universal System, it may be helpful to memorize the number or letters for key teeth, possibly the central incisors (numbers 8, 9, 24, and 25) or the first molars (numbers 3, 14, 19, and 30).

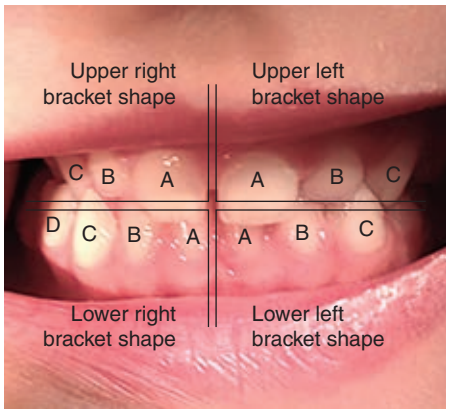


FIGURE 1-9. When identifying each *primary* tooth using the **Palmer System**, each quadrant is denoted by bracket shapes as indicated, and each tooth within that quadrant is identified using letters A though B with letter A for the central incisors, letter B for lateral incisors, etc.

REVIEW Questions about Tooth Notation

These questions were designed to help you confirm that you understand the terms and concepts presented in this section. More than one answer may be correct.

1. If you read an article in a British dental journal that refers to tooth number 48, you would suspect that the authors were using the International Numbering System. What Universal number (or letter) would they be talking about?
   a. 25
   b. J
   c. 30
   d. T
   e. 32

2. Using the Universal Numbering System, what numbers are used to identify maxillary canines?
   a. 6
   b. 8
   c. 10
   d. 11
   e. 27

3. If you read an article in a British dental journal that refers to tooth number 55, you would suspect that the authors were using the International Numbering System. What Universal number (or letter) would they be talking about?
   a. A
   b. 5
   c. E
   d. T
   e. 1

4. If an orthodontist wrote about tooth ⌊5, what would the Universal number be?
   a. 3
   b. 4
   c. 5
   d. 12
   e. 13

5. What are the Universal numbers of the permanent mandibular first molars? _____
   a. 3
   b. 14
   c. 19
   d. 24
   e. 30

6. Fill in the blanks: If you are referring to the Universal tooth 27, what is its position from the midline? _____ What is its arch? _____ In which quadrant is it located? _____

ANSWERS: *1–e; 2–a, d; 3–a; 4–e; 5–c, e; 6–3rd, mandibular, lower right*

SECTION III TERMINOLOGY USED TO DESCRIBE THE TISSUES OF A TOOTH (AND DEFINITION OF ANATOMICAL CROWN AND ROOT)

Each tooth is made up of four tissues: enamel, dentin, cementum, and pulp. The first three of these (enamel, dentin, and cementum) are relatively hard since they contain considerable mineral content, especially calcium (so these tissues can also be described as calcified). Only two of these tissues are normally visible on an intact extracted tooth: enamel and cementum. Enamel covers the portion of the tooth known as the **anatomic crown**, and cementum covers the portion of the tooth known as the **anatomic root**. The other two tissues (dentin and pulp) are usually not visible on an intact tooth. Refer to *Figure 1-10* while reading about each tissue.

Enamel [ee NAM el] is the relatively white, protective external surface layer of the anatomic crown. It is highly calcified or mineralized and is the hardest substance in the body. Its mineral content is 95% calcium hydroxyapatite (which is calcified).

Cementum [se MEN tum] is the dull yellow external layer of the anatomic root. The cementum is very thin, especially next to the part of the root where the crown joins with the root. Its thickness can be compared to the thickness of a human hair (only 50 to 100 µm thick where 1 µm is one millionth of a meter). Cementum is 65% mineralized. (Another

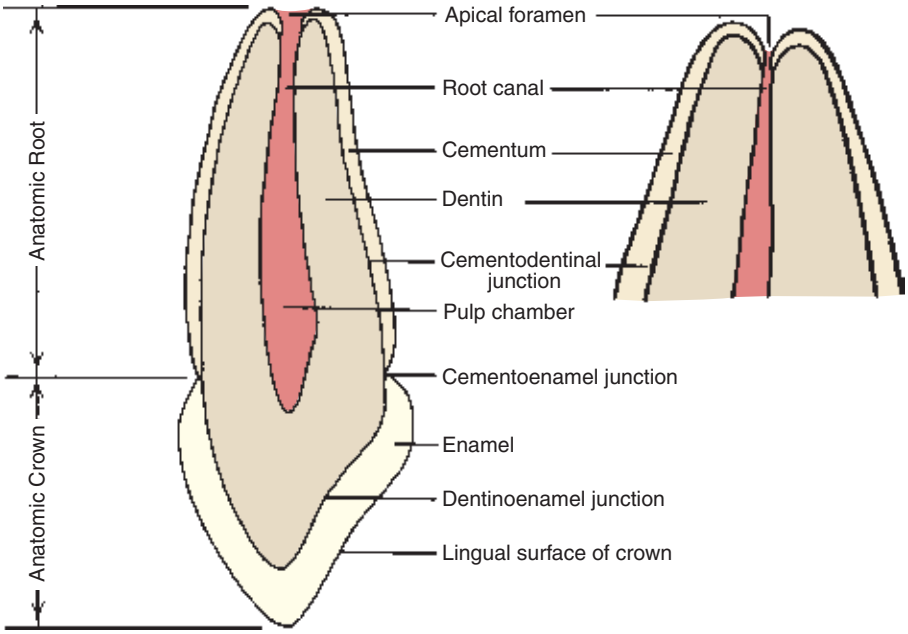


FIGURE 1-10. A maxillary anterior tooth is sectioned faciolingually through the middle to show the distribution of the **tooth tissues** and the shape of the pulp cavity (made up of pulp chamber and root canal). On the right is a close-up of the root tip depicting the usual expected constriction of the root canal near the apical foramen. The layer of cementum covering the root of an actual tooth is proportionately much thinner than seen in these drawings.

author, Melfi, states that the mineral content of cementum is about 50%.) Cementum is about as hard as bone but considerably less hard than enamel.

The **cementoenamel** [se MEN toe ehn AM el] **junction** (also called the **CEJ** or **cervical line**) is the junction between the enamel covering the anatomic crown and the cementum covering the anatomic root. This junction is also known as the **cervical** [SER vi kal] **line**, denoting that it surrounds the neck or **cervix** [SER viks] of the tooth.

Dentin [DEN tin] is the hard yellowish tissue underlying the enamel and cementum, and makes up the bulk of the inner portion of each tooth crown and root. It extends outward from the pulp cavity (located in the center of the tooth) to the inner boundary of the enamel (covering the crown) or cementum (covering the root). Dentin is not normally visible except on a dental radiograph, or when the enamel or cementum has been worn away, or cut away when preparing a tooth with a bur, or destroyed by decay. Mature dentin is composed of about 70% mineralized calcium hydroxyapatite making it less hard (and less brittle) than enamel, but harder than cementum.

The **dentinoenamel** [DEN tin o ehn AM el] **junction** is the inner surface of the enamel where enamel joins dentin. This junction can be best seen on a radiograph (*Fig. 1-11*). The **cementodentinal** [se MEN toe DEN tin al] (or dentinocemental) **junction** is the inner surface of cementum where cementum joins dentin. Cementum is so thin that it is difficult to identify this junction on a radiograph.

Pulp is soft, nonmineralized connective tissue containing a rich supply of blood vessels and nerves located in the cavity or space in the center of the crown and root called the **pulp cavity**. The pulp cavity has a coronal portion toward the crown called a **pulp chamber** and a portion within the roots called a **pulp canal** or **root canal**. The pulp cavity is surrounded by dentin, except at a hole (or holes) near the root tip (apex) called an **apical** [APE i kal] **foramen** [fo RAY men] (plural foramina [fo RAM i na]). Nerves and blood vessels enter the pulp canals through these apical foramina. Like dentin, the pulp is normally not visible, except on a dental radiograph (Fig. 1-11) or on a sectioned tooth. Functions of the dental pulp are as follows:

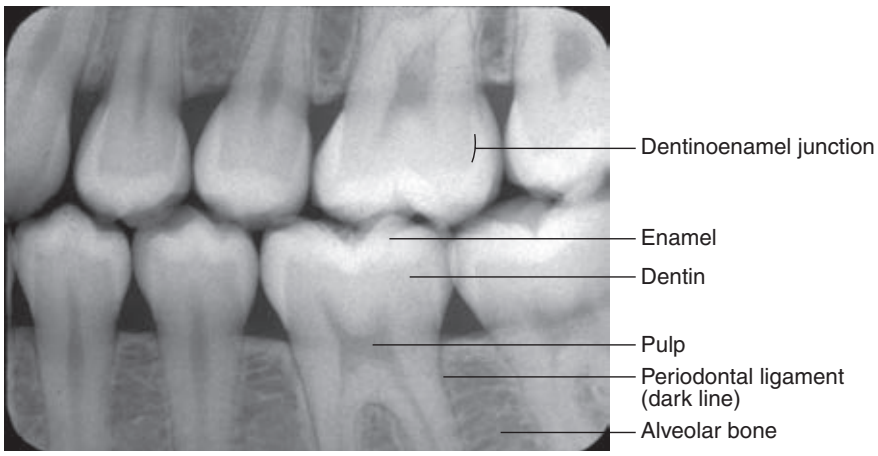


FIGURE 1-11. A radiographs (x-ray) shows tooth crowns covered with enamel, and the tooth roots embedded within the alveolar bone. You can distinguish the whiter outer **enamel** shape from the darker inner **dentin**. The **pulp chamber** in the middle of the tooth is the darkest. The very thin, dark **periodontal ligament** can also be seen between the root and the bone, but the cementum is so thin it cannot be seen.

- **Formative**: Dentin-producing cells (**odontoblasts**) produce dentin throughout the life of a tooth. This normally maturing dentin is called **secondary dentin**.
- **Sensory**: Nerve endings in the pulp relay the sense of pain caused from heat, cold, drilling, sweet foods, decay, trauma, or infection to the brain, so we feel it. However, the nerve fibers in a dental pulp are unable to distinguish the cause of the pain.
- **Nutritive**: Blood vessels transport nutrients from the bloodstream to cells of the pulp and the cells that produce dentin (odontoblasts). Surprisingly, blood being pumped into the tooth pulp had passed through the heart only 6 seconds previously.
- **Defensive or protective**: Pulp responds to injury or decay by forming **reparative dentin** (by the odontoblasts).

Some advanced information on the embryology of tooth tissues that had been included in this chapter in previous editions is now presented at the end of the chapter in a section called "Advanced Topics."

REVIEW Questions about Tooth Tissues

These questions were designed to help you confirm that you understand the terms and concepts presented in this section. More than one answer may be correct.

1. Which tooth junctions are NOT normally visible on a handheld intact tooth?
   a. Cementoenamel junction
   b. Dentinoenamel junction
   c. Dentinocemental junction
   d. Dentinopulpal junction
2. Which mineralized tissue is the hardest?
   a. Cementum
   b. Pulp
   c. Dentin
   d. Enamel
   e. Alveolar bone
3. What tissue forms the outer boundary of almost all of a pulp chamber?
   a. Enamel
   b. Dentin
   c. Cementum
   d. Alveolar bone
   e. Periodontal ligament
4. Which of the following is (are) NOT functions of the pulp?
   a. Taste sweet and sour
   b. Sense pain
   c. Provide nutrition to dentin
   d. Produce new dentin
   e. Produce new enamel

ANSWERS: *1–b, c, d; 2–d; 3–b; 4–a, e*

SECTION IV INTRODUCTION TO THE PERIODONTIUM (AND DEFINITION OF CLINICAL CROWN AND ROOT)

The **periodontium** [pair ee o DON she um] is defined as the supporting tissues of the teeth in the mouth, including surrounding alveolar bone, the gingiva, the periodontal ligament, and the outer, cementum layer of the tooth roots (*Fig. 1-12*). **Alveolar bone** is the portion of the upper (maxillary) or lower (mandibular) bones that surrounds the roots of the teeth. The **gingiva** is the part of the soft tissue in the mouth that covers the alveolar bone of the jaws and is the only part of the periodontium that is visible in a healthy mouth. Part of it is firmly bound to the underlying alveolar bone and is called **attached gingiva**. The other part is **free gingiva** (or marginal gingiva), which is a collar of thin gingiva that surrounds each tooth and, in health, adapts to the tooth but provides access into the potential space between the free gingiva and the tooth, which is called a **gingival sulcus** (crevice). The **gingival margin** (or free gingival margin) is the edge of the gingiva closest to the biting or chewing surfaces of the teeth (*Fig. 1-13*).

The gingival sulcus is not seen visually but can be evaluated with a thin probe (**periodontal probe**), since it is actually a space (or potential space) between the tooth surface and the narrow unattached cervical collar of free gingiva. If you insert a periodontal probe into this sulcus, it should extend only 1 to 3 mm deep in a healthy person (*Fig. 1-14*). The **interdental (interproximal) papilla** [pah PILL ah] (plural is papillae [pa PILL ee]) is that part of the collar of free gingiva that extends between the teeth. A healthy papilla conforms to the space between two teeth (interproximal space), so it is very thin and easy to damage near where the adjacent teeth contact. The papilla also has a hidden sulcus where dental floss can fit once it passes between the teeth (*Fig. 1-15*). The floss must curve around the tooth to avoid cutting into the interdental papilla.

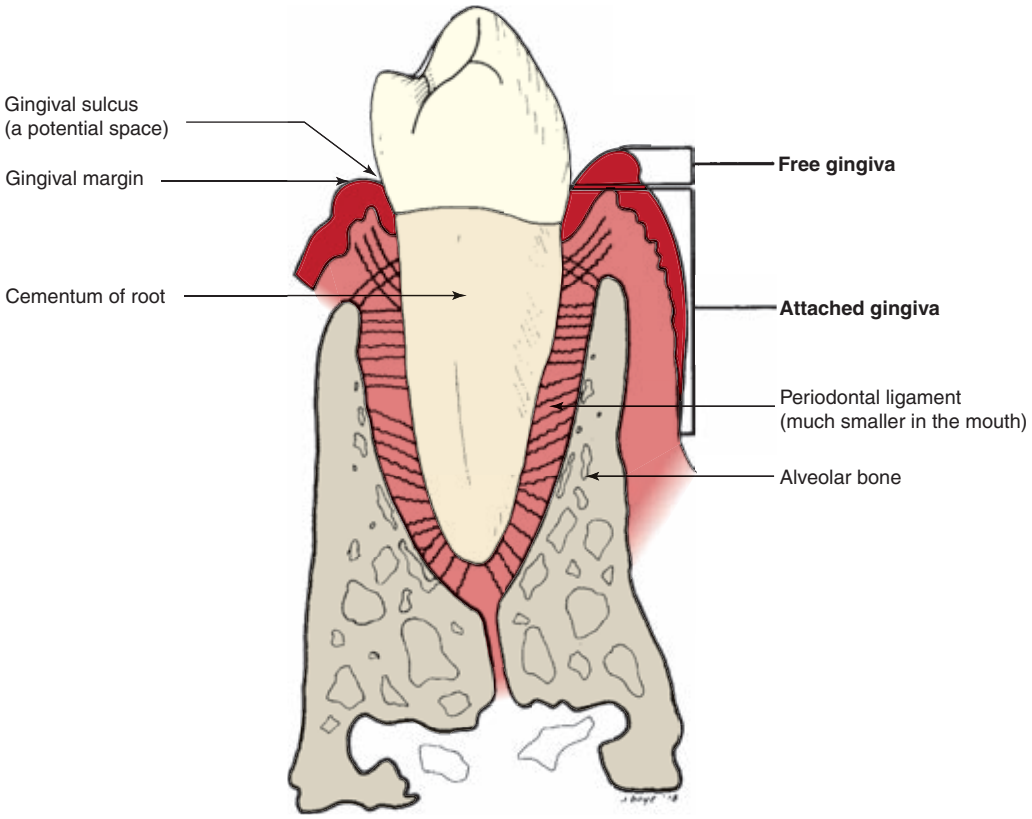


FIGURE 1-12. This diagram is a tooth supported within the **periodontium**. The periodontium is made up of **alveolar bone,** which surrounds the anatomic root; **gingiva** (gum tissue), which covers the bone; **cementum,** which covers the tooth root; and the **periodontal ligament,** which attaches the cementum of the tooth root to the bone.

Although the term ligament is most often defined as a tough fibrous band of tissue that connects two bones, a **periodontal ligament** (abbreviated **PDL**) is a very thin ligament that connects a tooth to its surrounding bone. It is composed of many microscopic tissue fibers that attach the outer layer of the tooth root (covered with **cementum**) to the thin layer of dense **alveolar bone** surrounding each tooth. The fibers of the periodontal ligament represented in Figure 1-12 are greatly enlarged. The average thickness of a healthy periodontal ligament is only about one to four times thicker than the diameter of an average healthy human hair.

CLINICAL CROWN AND ROOT: As mentioned previously, the *anatomic crown* is that part of the tooth (in the mouth or handheld) normally covered by an enamel layer, and the *anatomic root* is the part of a tooth covered by cementum (recall Fig. 1-10). However, when the tooth is in the mouth, the amount of the tooth that is visible in the oral cavity (i.e., not covered with gingiva) is called the **clinical**

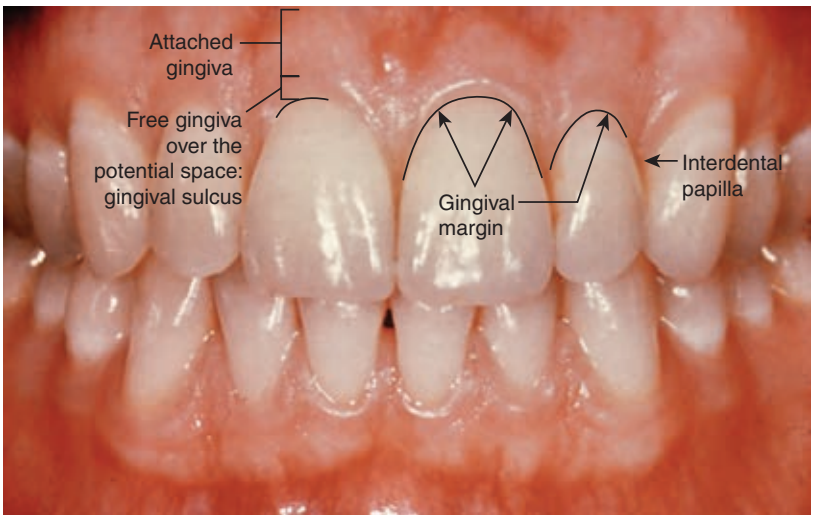


FIGURE 1-13. Healthy gingiva surrounds each tooth forming a characteristic scallop-shaped **gingival margin. Interproximal papillae** fill the spaces between most teeth. The **attached gingiva** is the gingiva that is firmly attached to the underlying bone.

FIGURE 1-14. A periodontal probe is carefully placed into the **gingival sulcus**.

FIGURE 1-15. Dental floss must adapt around the curved surface of each tooth when entering the **gingival sulcus** in order to clean the proximal surface of the tooth and avoid damaging the free gingiva.

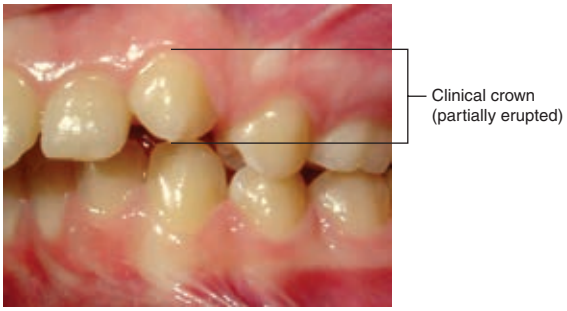
crown, and the portion of the tooth that is not visible since it is covered with gingiva is called the **clinical root**. When the gingival margin in a 25-year-old patient with healthy gingiva approximately follows the curvature of the cervical line, the clinical crown is almost the same as the anatomic crown (*Fig. 1-16A*). However, throughout life, the gingival margin is not always at the level of the cervical line because of the eruption process. For example, the gingiva on a partially erupted tooth of a 10-year-old covers much of the enamel of the anatomic crown of the tooth, resulting in a clinical crown (exposed in the mouth) that is much shorter than the anatomic crown (*Fig. 1-16B*). The clinical root (the part of the tooth not visible in the mouth) would be longer than the anatomic root, since it includes all of the anatomic root plus the part of the anatomic crown covered with gingiva.

In contrast, the gingival margin of an older person may exhibit gingival recession, especially after having periodontal disease or periodontal therapy, exposing more of the anatomic root. In this case, the clinical crown is longer than the anatomic crown since the clinical crown in this mouth consists of the entire anatomic crown plus the part of the anatomic root that is exposed (*Fig. 1-16C*). In this situation, the clinical root is shorter than the anatomic root.

LEARNING EXERCISE

Examine the mouths of several persons of different ages to see if the cervical line of each anatomic tooth is visible or hidden. As the individual grows older, the location of the margin of the gingiva may recede toward the root tip (apically) because of periodontal disease or injury. Of course, the location of the cervical line on the tooth remains the same. In other words, the distinction between the *anatomic* crown and root does not change over a lifetime.

A



B

C

FIGURE 1-16. **A.** On a young adult with healthy gingiva, the entire anatomic crown is all that can be seen, so the **clinical crown** is approximately the same as the **anatomic crown**. **B.** Since this canine is partially erupted, the anatomic crown is only partially exposed, so there is a **short clinical crown**. **C.** This maxillary molar has a very **long clinical crown** since all of the anatomic crown and much of the anatomic root are exposed due to recession of the gingiva and loss of bone.

REVIEW Questions about the Periodontium

These questions were designed to help you confirm that you understand the terms and concepts presented in this section. More than one answer may be correct.

1. Which statement(s) is (are) likely to be true on a person with a barely erupted tooth 9?
   a. The clinical crown is larger than the anatomic crown.
   b. The clinical crown is smaller than the anatomic crown.
   c. The clinical root is larger than the anatomic root.
   d. The clinical root is smaller than the anatomic root.
2. Which statement(s) is (are) true regarding a tooth on a person who has lost most of the bone and gingiva surrounding the tooth?
   a. The clinical crown is larger than the anatomic crown.
   b. The clinical crown is smaller than the anatomic crown.
   c. The clinical root is larger than the anatomic root.
   d. The clinical root is smaller than the anatomic root.
3. Which of the following structures is (are) NOT part of the periodontium?
   a. Alveolar bone
   b. Periodontal ligament
   c. Gingival margin
   d. Cementodentinal junction
   e. Attached gingiva
4. The periodontal ligament attaches the alveolar bone to what tooth tissue?
   a. Dentin
   b. Enamel
   c. Cementum
   d. Pulp

ANSWERS: *1–b, c; 2–a, d; 3–d; 4–c*

SECTION V TERMINOLOGY USED TO DEFINE TOOTH SURFACES

All teeth have surfaces that are named according to their normal, ideal alignment within the dental arch. Refer to *Figure 1-17* when studying the terms to denote tooth surfaces.

A. TERMS THAT IDENTIFY OUTER SURFACES (TOWARD THE CHEEKS OR LIPS) OF ANTERIOR VERSUS POSTERIOR TEETH

The **facial surface** of a tooth is the surface toward the face, that is, the surface of a tooth in the mouth resting against or next to the cheeks or lips. Facial may be used to designate this surface of any tooth, anterior or posterior. Another name for the facial surface of *posterior* teeth is **buccal** [BUCK k'l], located next to the cheek (labeled on tooth 3 in Fig. 1-17). Dental terms that begin with "bucc" refer to a relationship or proximity to the cheek. It is incorrect to use the term buccal when speaking about the incisors or canines because the facial surface of these teeth does not approximate the cheeks. The facial surface of *anterior* teeth is properly called a **labial** [LAY bee al] surface, located next to the lips (labeled on tooth 6 in Fig. 1-17). The term labial should not be used when referring to the premolars or the molars.

B. TERMS THAT IDENTIFY INNER SURFACES (TOWARD THE TONGUE) OF MAXILLARY VERSUS MANDIBULAR TEETH

The **lingual** [LIN gwal] **surface** is the surface of a maxillary or mandibular tooth nearest to the tongue (labeled on tooth 5 in Fig. 1-17). In the maxillary arch, this surface can also be called the **palatal surface** due to its proximity with the palate.

C. TERMS THAT DIFFERENTIATE BITING SURFACES OF ANTERIOR VERSUS POSTERIOR TEETH

The **occlusal** [ahk KLOO zal] **surface** is the chewing surface of a posterior tooth (labeled on tooth 2 in Fig. 1-17). Anterior teeth (incisors and canines) do not have an occlusal surface but do have a cutting **incisal edge** or **ridge** (labeled on tooth 8 in Fig. 1-17).

D. TERMS THAT DIFFERENTIATE APPROXIMATING SURFACES OF TEETH

The **proximal** [PROCK se mal] **surfaces** are the sides of a tooth next to an adjacent tooth. Depending on whether the proximal tooth surface faces toward the arch midline between the central incisors or away from the midline, it is either a **mesial** [MEE zi al] surface (closer to the midline) or a **distal** [DIS tal] surface (farther from the midline). Mesial and distal surfaces are labeled on tooth 1 in Figure 1-17. Note that the mesial surface of a tooth touches, or is closest to, the distal surface of an adjacent tooth EXCEPT between the central incisors where the mesial surface of the right central incisor faces the mesial surface of the left central incisor. Also, the distal surface of the last (third) molar in each arch does not approximate another tooth.

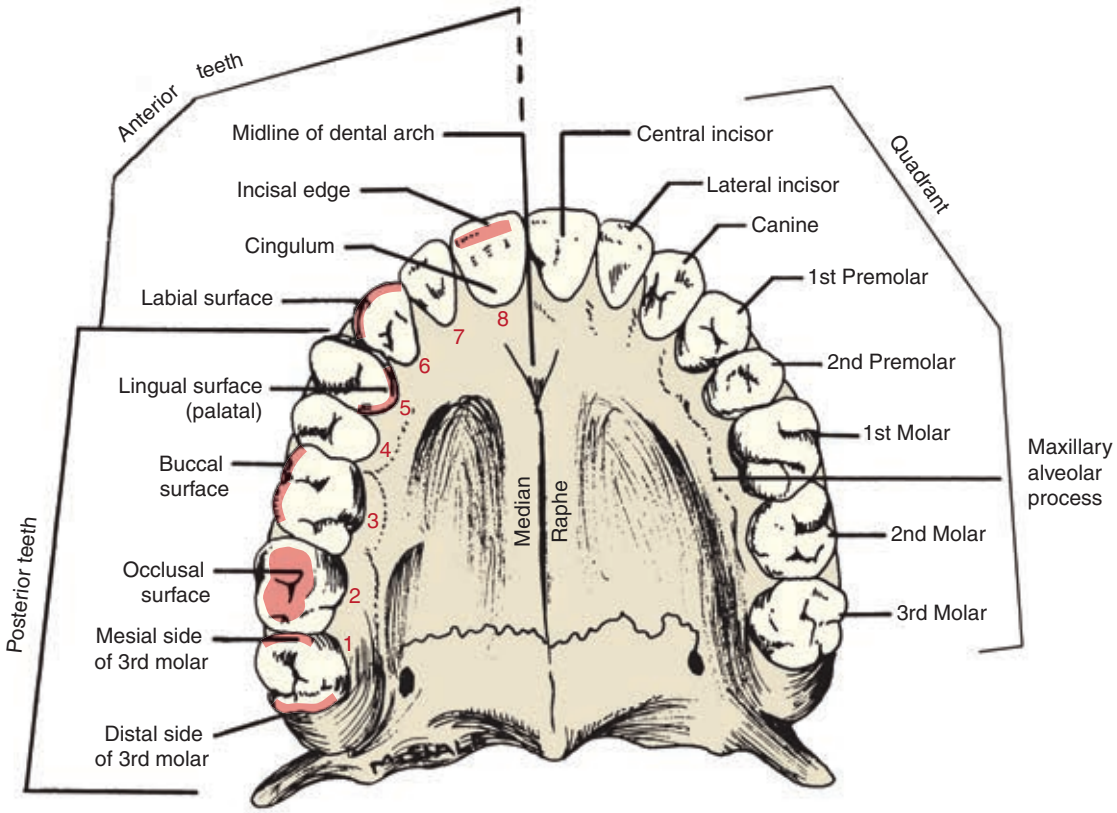


FIGURE 1-17. Maxillary dental arch of teeth with various **tooth surfaces** labeled. Remember that the labial surface of an anterior tooth and the buccal surface of a posterior tooth are both referred to as facial surfaces. Also, the mesial and distal sides or surfaces are both correctly called proximal surfaces.

Soft debris and food particles on proximal surfaces are not easily cleaned by the action of the cheeks, lips, and tongue when compared to most of the facial or lingual surfaces, which are considered more **self-cleansing**, that is, more easily able to be cleaned by the rubbing action of the cheeks, lips, and tongue.

E. TERMS TO DENOTE TOOTH SURFACE JUNCTIONS OR DIMENSIONS

The junction line where two tooth surfaces meet is called an external **line angle**. To name a line angle, combine the names of the two surfaces, but change the "al" ending of the first surface to an "o." (A guideline has been suggested for the order used when combining terms. Use the following order: mesial is used first; then distal, facial, [buccal or labial] or lingual; and lastly occlusal or incisal. Using this guideline, it is better to say mesio-occlusal than occlusomesial, and it is better to say distolingual than linguodistal.) Examples of external line angles of a molar crown include mesio-occlusal, mesiolingual, mesiofacial, disto-occlusal, distolingual, disto-facial, bucco-occlusal, and linguo-occlusal. **Point angles** are the junctions of three tooth surfaces at a point, such as a mesiobucco-occlusal point angle. Examples of these external line angles and point angles are seen in *Figure 1-18*.

To describe a **dimension of a tooth**, terms can be combined to denote the direction over which a dimension is taken. For example, the length of an incisor crown from the incisal edge to the cervical line is called the incisocervical dimension or the dimension incisocervically, and the width of the buccal surface of a molar crown from the mesial surface to the distal surface is the mesiodistal dimension (Fig. 1-18). Other examples of terms used to describe a crown dimension include mesiodistal, faciolingual or buccolingual, and occlusocervical. The length of a root could be described as its cervicoapical dimension.

REVIEW Questions about Dimensions

1. What surface(s) of a tooth would you be looking at in order to determine the mesiodistal dimension of a molar?
2. What surface(s) of a tooth would you be looking at when measuring the buccolingual dimension of a molar?

ANSWERS: *1–Buccal, lingual, or occlusal surfaces; 2–Mesial, distal, or occlusal surfaces*

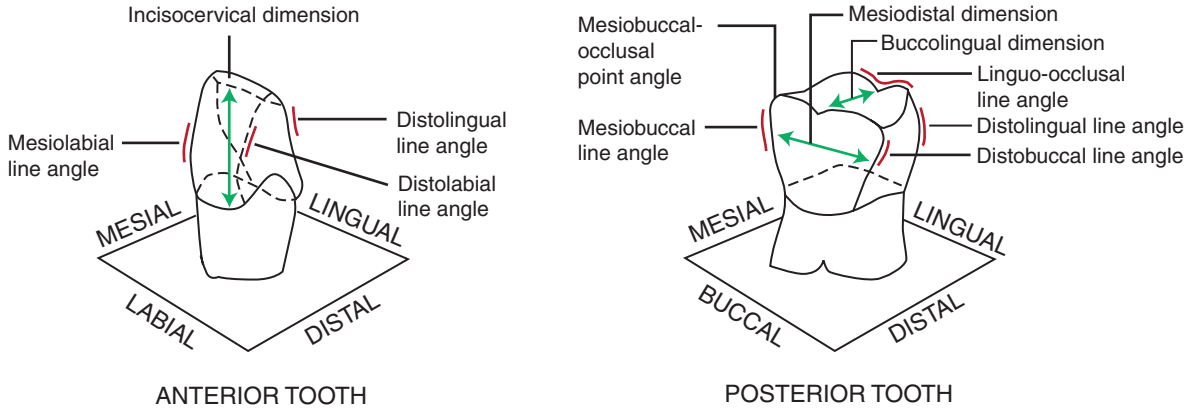


FIGURE 1-18. Diagrammatic representations of an incisor and a molar crown have several examples of **line angles** and **point angles** labeled in *red*. Three examples describing **dimensions** are labeled in *green*.

F. DIVISIONS (THIRDS) OF THE CROWN OR ROOT (FOR PURPOSES OF DESCRIPTION)

A tooth can be divided into **thirds** in order to define more precisely the location of its specific landmarks such as proximal contacts. When viewing a tooth from the facial, lingual, mesial, or distal surface, *horizontal* lines can divide the tooth *crown* into the following thirds: cervical, middle, and occlusal (or incisal) (*Fig. 1-19*). Similarly, *horizontal* lines can divide the *root* into thirds: cervical, middle, and apical (toward the root tip or apex).

When viewing the facial or lingual surfaces of a tooth, *vertical* lines can be used to divide the crown or root into mesial, middle, and distal thirds. When viewing proximal (mesial or distal) surfaces, *vertical* lines can be used to divide the crown or root into facial, middle, and lingual thirds. When viewing a tooth from the occlusal (or incisal) surface, lines running mesiodistally can be used to divide the crown into facial, middle, and lingual thirds, and lines running faciolingually can be used to divide the tooth into mesial, middle, and distal thirds.

G. ROOT-TO-CROWN RATIO

If we know the length of a tooth root from the cervical line to the tip of the root, and the length of the crown (as defined at the end of this chapter in Dr. Woelfel's original research data), we can calculate a root-to-crown ratio. The **root-to-crown**

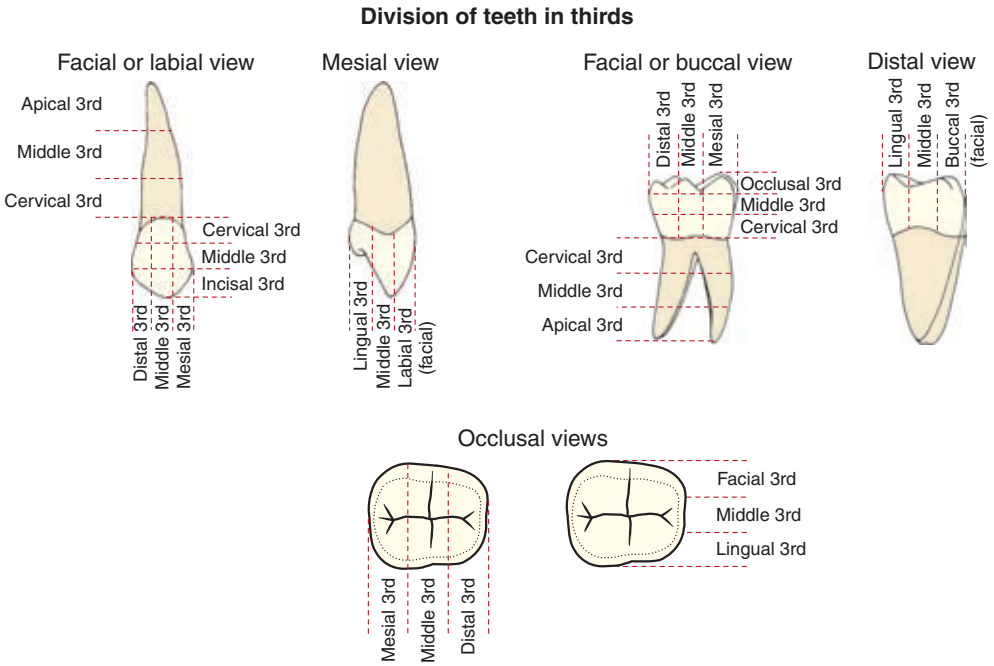


FIGURE 1-19. Diagrams of a maxillary canine and mandibular molars show how a crown or root can be divided into **thirds** from each view.

ratio is the root length divided by crown length. Since almost all tooth roots are longer than their crowns, the root-to-crown ratios for teeth are normally greater than 1.0. For example, the average root length of a maxillary central incisor is only 13.0 mm and the crown length is 11.2 mm. The root-to-crown ratio is 13 divided by 11.2, which equals 1.16. When this number is close to 1, it indicates that the root is not much longer than the crown. Compare this with a maxillary canine, where the average root is much longer, at 16.5 mm, but the crown is only 10.6 mm, for a much larger root-to-crown ratio of 1.56. This larger ratio indicates that the root is over one and a half times (1.56 times) longer than the crown. The obvious difference between the root-to-crown ratio on these two teeth is apparent in *Figure 1-20*. The ratio can be clinically significant, since a tooth with a small root-to-crown ratio (closer to 1) is not the best choice for attaching and supporting false teeth, because the additional attached teeth would apply even more force on a tooth that already has a short root compared to its crown length. Therefore, the long-term success of attaching false teeth to a tooth like the maxillary canine with a large root-to-crown ratio of 1.56 would be better than attaching it to a tooth like the maxillary central incisor with a small root-to-crown ratio of 1.16.

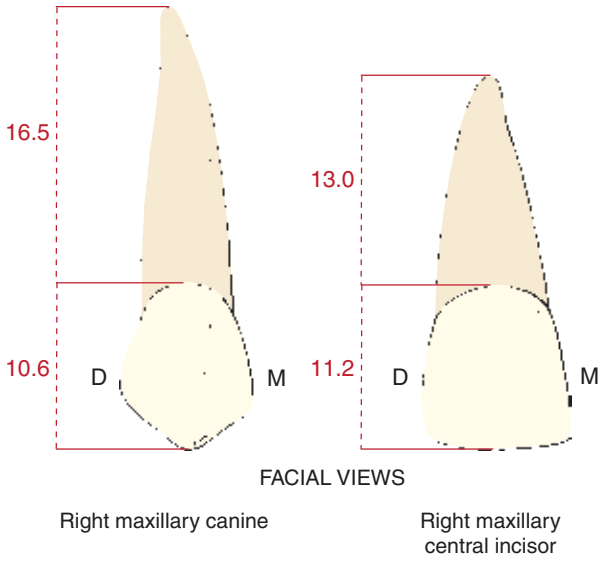


FIGURE 1-20. Compare the **root-to-crown ratio** of a maxillary central incisor where the root is not much longer than the crown and the ratio is 13 mm of crown length divided by 11.2 mm of root length, or only 1.16, with a maxillary canine where the root is considerably longer than the crown so the ratio is much larger: 16.5 mm crown length divided by 10.6 mm root length, or 1.56.

REVIEW Questions about Tooth Terminology

These questions were designed to help you confirm that you understand the terms and concepts presented in this section. More than one answer may be correct.

1. Which tooth surface(s) face(s) the lips or cheeks?
   a. Facial
   b. Distal
   c. Buccal
   d. Occlusal
   e. Labial

2. Which pairs of teeth have a mesial surface touching a mesial surface?
   a. 25 and 26
   b. 16 and 17
   c. 7 and 8
   d. 1 and 32
   e. 8 and 9

3. Which teeth have a distal surface that does not normally contact another tooth?
   a. 1
   b. 3
   c. 8
   d. 17
   e. 24

4. The term labial refers to association with or proximity to the lips, and the term _____ refers to association with or proximity to the cheeks.
   a. Facial
   b. Buccal
   c. Labial
   d. Proximal
   e. Palatal

5. When viewing tooth 8 from the distal view, it can be divided into thirds from the incisal to the cervical and from the facial to the lingual. Which third is NOT possible to see from the distal view?
   a. Facial
   b. Cervical
   c. Middle
   d. Mesial
   e. Incisal

6. When viewing tooth 19 from this one view, it can be divided into thirds from the buccal to lingual and from the mesial to the distal. From which view is this possible?
   a. Buccal
   b. Lingual
   c. Mesial
   d. Distal
   e. Occlusal
7. If you were observing the faciolingual dimension of a tooth, what surface(s) could you be viewing?
   a. Mesial
   b. Occlusal
   c. Proximal
   d. Labial
   e. Distal
8. If the root-to-crown ratio of a maxillary molar (tooth 14) is 1.72 and that of a maxillary incisal (tooth 8) is 1.16, which tooth has the longest root relative to its shorter crown?
   a. Tooth 14.
   b. Tooth 8.
   c. More information is required in order to answer this question.
9. Which of the following phrases are correct?
   a. Buccal surface of tooth 10
   b. Labial surface of tooth 19
   c. Palatal surface of tooth 29
   d. Occlusal surface of tooth 27
   e. Facial surface of tooth 1
10. Which term does NOT refer to a tooth crown line angle?
    a. Mesio-occlusal
    b. Mesiofacial
    c. Mesiodistal
    d. Distofacial
    e. Linguo-occlusal

ANSWERS: *1–a, c, e; 2–e; 3–a, d; 4–b; 5–d; 6–e; 7–a, b, c, e; 8–a; 9–e; 10–c*

SECTION VI TERMINOLOGY USED TO DESCRIBE THE MORPHOLOGY OF A TOOTH

A. MORPHOLOGY OF AN ANATOMIC CROWN

Teeth are made up of many rounded elevations, ridges, depressions, and grooves. Specific tooth structures that occur with some frequency on teeth within a class have been assigned specific names. To identify the following anatomic structures, reference will be made to representative drawings of various teeth seen in figures throughout this book.

1. Elevations: Pointed Cusps and Linear Ridges

a. Cusps: Cusp Names and Numbers

A **cusp** is a pyramidal elevation with a peak called a **cusp tip**. Cusps are located on the occlusal surfaces of molars and premolars and on the incisal surfaces of canines. Canines have one cusp, premolars normally have two or three cusps, and most molars have from three to five cusps. On teeth with multiple cusps, each cusp is named according to its location on the tooth. For example, on a two-cusped premolar, the two cusps are named after the surface adjacent to each cusp: a buccal cusp and a lingual cusp. Three-cusped premolars have one buccal and two lingual cusps, and the two lingual cusps are named after the adjacent line angles, that is, mesiolingual cusp and distolingual cusp. A four-cusped molar has four cusps named after the adjacent line angles: mesiobuccal, distobuccal, mesiolingual, and distolingual. A three-cusped maxillary molar has two buccal cusps (mesiobuccal and distobuccal) and one lingual cusp. On a five-cusped molar, the three buccal cusps are called mesiobuccal, distobuccal, and the smallest distal cusp. Refer to *Figure 1-21* for examples of cusp names on posterior teeth with two, three, four, and five cusps.

b. Cusp Ridges

Many cusps can be thought of as having *four* **cusp ridges** (linear prominences of enamel) converging toward the cusp tip. These four ridges form the shape of a four-sided pyramid with rounded surfaces. If you draw a line along the greatest linear bulge of each of these four ridges, the lines would intersect at the cusp tip indicated by the "X" on *Figure 1-22*. On this example of a buccal cusp on a

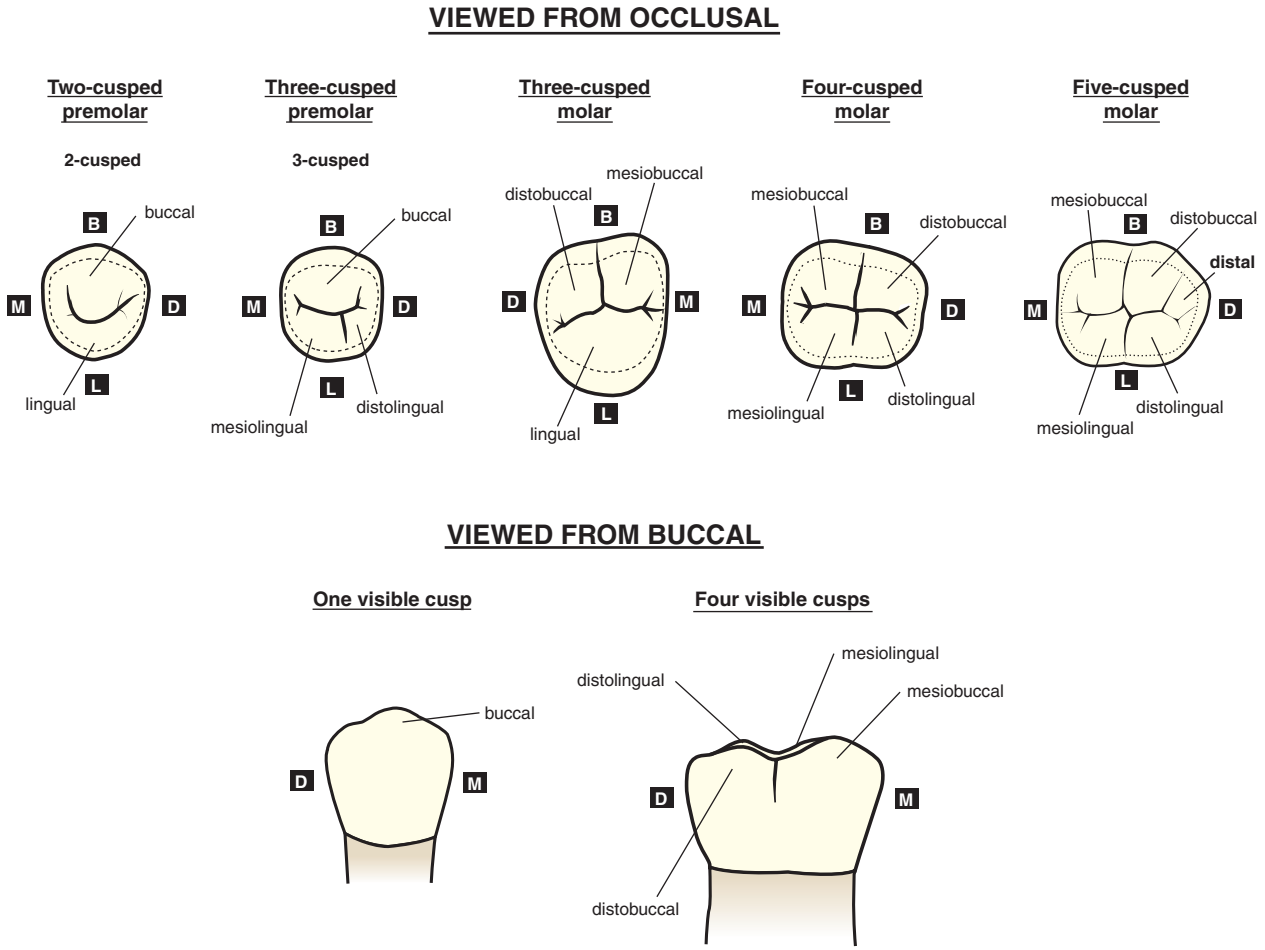


FIGURE 1-21. **Cusp names** on teeth having two, three, four, and five cusps, viewed from the occlusal and buccal views. Notice that the cusps are named after the adjacent surface or line angle EXCEPT on five-cusped mandibular first molars with three buccal cusps. On five-cusped molars, the two larger buccal cusps are named **mesiobuccal** and **distobuccal** cusps, as on the four-cusped molar, but the smallest cusp is called the **distal cusp**.

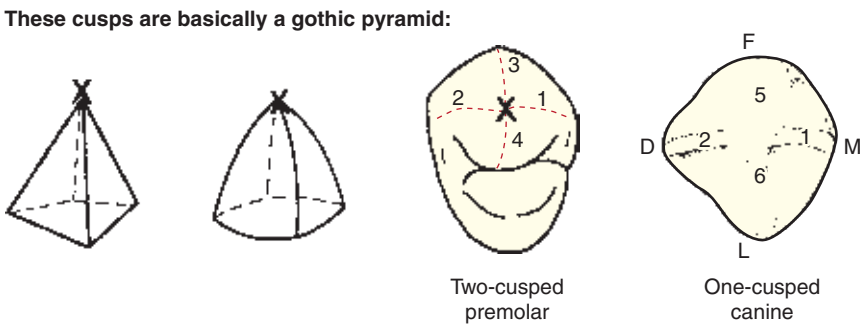


FIGURE 1-22. The **four-cusped ridges** of the buccal cusp of a *two-cusped premolar* have a somewhat pyramidal design (actually, a pyramid with rounded sides called a gothic pyramid). The cusp ridges are numbered 1 to 4 and converge at the cusp tip (at the "X"). Ridge 1 is the **mesial cusp ridge** of the buccal cusp; ridge 2 is the **distal cusp ridge** of the buccal cusp; ridge 3 is the more subtle **buccal ridge** of the buccal cusp; and 4 is the **triangular ridge** of the buccal cusp. (Courtesy of Drs. Richard W. Huffman and Ruth Paulson.) Cusp ridges on the single cusp of a *maxillary canine* also have a mesial cusp ridge labeled 1 and distal cusp ridge labeled 2, the same as on the premolar, but 5 is the **labial ridge** of the canine cusp (similar to a buccal ridge on a premolar), and 6 is the **lingual cusp ridge**.

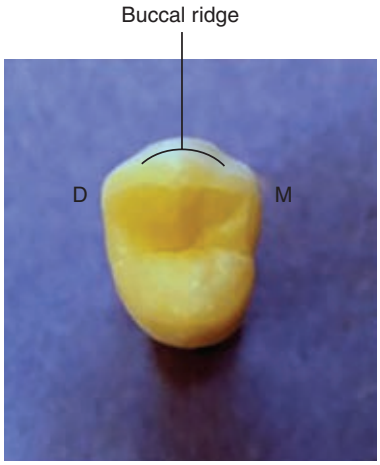


FIGURE 1-23. A rounded **buccal ridge** can be seen on the buccal surface of many premolars.

premolar, three of the ridges are named after the circumferential tooth surface they extend toward: the more subtle **buccal ridge** extends onto the buccal surface, the **mesial cusp ridge** extends from the cusp tip toward the mesial surface, and the **distal cusp ridge** extends from the cusp tip toward the distal surface. The fourth ridge extends from the cusp tip toward the faciolingual middle of the tooth and is called a **triangular ridge**.

The **buccal ridges** that run cervico-occlusally on the buccal surfaces of premolars or molars are often the least distinct of the four ridges that emanate from the cusp tip, although they may be more prominent on some types of teeth (*Fig. 1-23*). Lingual cusps do not normally have prominent lingual ridges running cervico-occlusally from the cusp tips.

The **mesial and distal cusp ridges** are also known as **cusp slopes** or **cusp arms**. They are most evident when viewing teeth from the facial or lingual aspect where they can be seen as inclined ridges that converge toward the cusp tip to form an angle (seen in green on a buccal cusp of a premolar and on a buccal cusp of a molar in *Fig. 1-24*). For some teeth, the sharpness or bluntness of a cusp angle can be an defining trait. These ridges are more difficult to discern when viewing teeth from the occlusal, denoted in green on the two cusps of a premolar in *Figure 1-25*.

Triangular ridges are located on the major cusps of posterior teeth. Each triangular ridge extends from a cusp tip toward the depression (sulcus) near the middle of the occlusal surface faciolingually, most easily identified when viewing a proximal surface as on *Figure 1-26*, but also evident when viewing the occlusal surface as on Figure 1-25. When a triangular ridge from a buccal cusp joins with a triangular ridge from a lingual cusp, these two ridges together form a longer ridge called a **transverse ridge**. A transverse ridge crosses the occlusal surface of posterior teeth in a more or less buccolingual direction, running between the buccal and lingual cusps on a premolar (seen from an occlusal view and a proximal view in Figs. 1-25 and 1-26) or connecting the buccal and lingual cusps that are lined up across from one another on a molar (seen on a mandibular molar in *Fig. 1-27* and on the two-cusped premolar). An **oblique ridge** is found only on maxillary molars. It crosses the occlusal surface obliquely (diagonally) and is made up of one ridge on the mesiolingual cusp joining with the triangular ridge of the distobuccal cusp (seen in Fig. 1-27 on the maxillary molar). According to Ash,[1] the ridge of the mesiolingual cusp that forms the lingual half of the oblique ridge is the *distal cusp ridge* of the mesiolingual cusp.

The single cusp of many canines may also have four ridges emanating from its cusp tip (Fig. 1-22): a mesial cusp ridge and a distal cusp ridge, a **labial ridge** similar to a buccal ridge running cervicoincisally from the cusp tip, and sometimes a fourth ridge called a **lingual ridge** that extends lingually toward the cervical bulge (cingulum). These ridges can be prominent on maxillary canines (*Fig. 1-28A and B*).

C. *Marginal Ridges and Cingulum*

On the lingual of all anterior teeth, a **cingulum** [SING gyoo lum] (plural **cingula**) is the prominence or bulge in the cervical third of the lingual surface of the crown (incisors and canines) (seen on the lingual view in *Fig. 1-29* and seen as a prominence in the cervical third of the crown on the proximal view in *Fig. 1-30*). On *anterior* teeth, mesial and distal

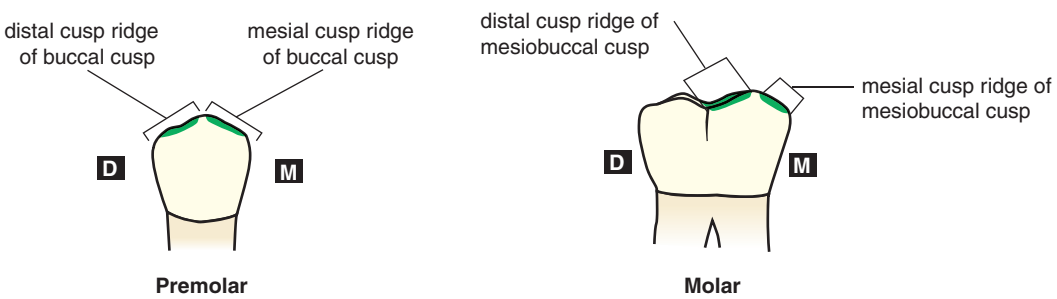


FIGURE 1-24. **Cusp ridges** (cusp slopes) are labeled on the buccal cusp of a mandibular premolar and on the mesiobuccal cusp of a four-cusped mandibular molar.

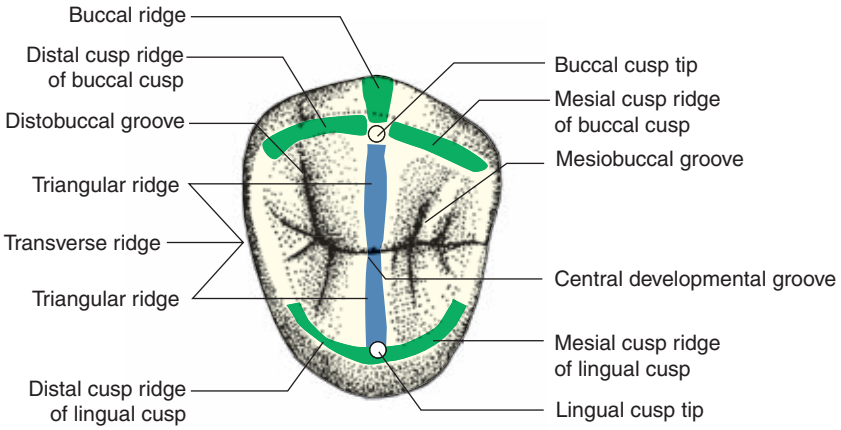


FIGURE 1-25. On this two-cusped maxillary premolar, the **mesial and distal cusp ridges** of the buccal and lingual cusps are shaded *green*. The **triangular ridges** of the buccal and lingual cusps are shaded *blue* and together are called a **transverse ridge**. The **buccal ridge** of the buccal cusp is shaded *green*.

marginal ridges form the mesial and distal borders of the *lingual* surface, and these ridges converge toward a rounded elevation or bulge in the cervical third called a **cingulum**, as seen on an incisor in Figures 1-29 and 1-30. When distinguishing a mesial from a distal marginal ridge on anterior teeth, it can be useful to remember that the mesial marginal ridge is normally longer than the distal. When determining which marginal ridge is longer, think of the length of a marginal ridge as extending from the incisoproximal line angle to its junction with the cingulum (as on Fig. 1-29 where the mesial marginal ridge appears slightly longer than the distal marginal ridge).

On *posterior* teeth, marginal ridges form the mesial and distal borders of the *occlusal* surface. The mesial marginal ridge on a premolar is shaded red in *Figure 1-31*.

d. *Occlusal Table Outline versus Crown Outline*

When viewing posterior teeth from the occlusal view, it is important to distinguish the entire crown outline of the tooth from the occlusal table of that tooth. The **occlusal crown outline** is the outer outline of the entire tooth crown from the occlusal view, whereas the **occlusal table** is the occlusal surface that is bounded by the continuous cusp ridges and marginal ridges. On the premolar in Figure 1-31, the occlusal table is bounded by a mesial marginal ridge joined with the mesial and distal cusp ridges of the buccal cusp, then the distal marginal ridge, and the cusp ridges of the lingual cusp.

This would be a good time to refer to *Figure 1-32* and perform the learning exercise to test your knowledge of cusp ridges.

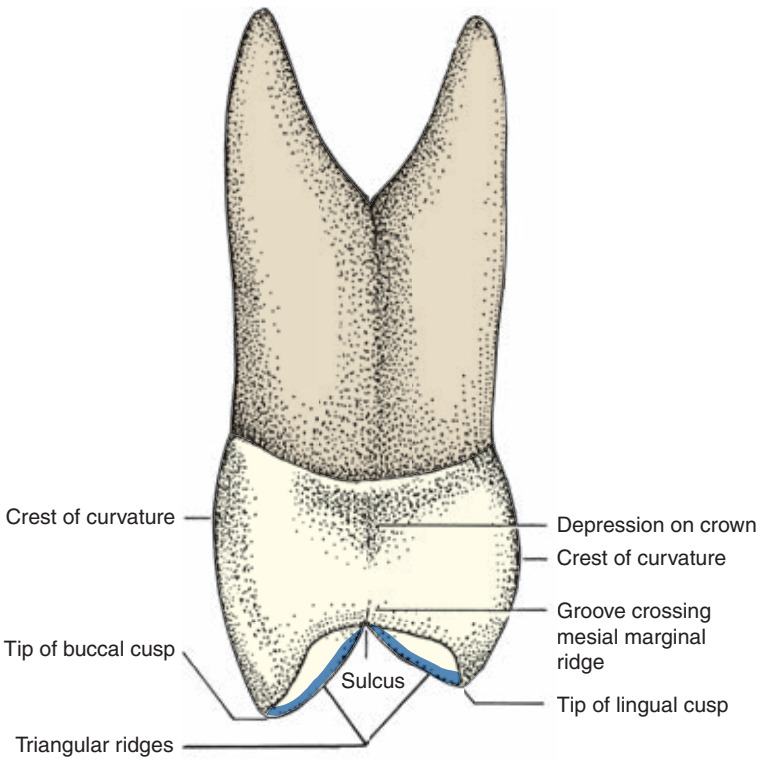


FIGURE 1-26. When seen from the mesial view on this maxillary two-cusped premolar, the outlines of two **triangular ridges** form a "V" shape and join at the depth of the occlusal **sulcus** to form one **transverse ridge**.

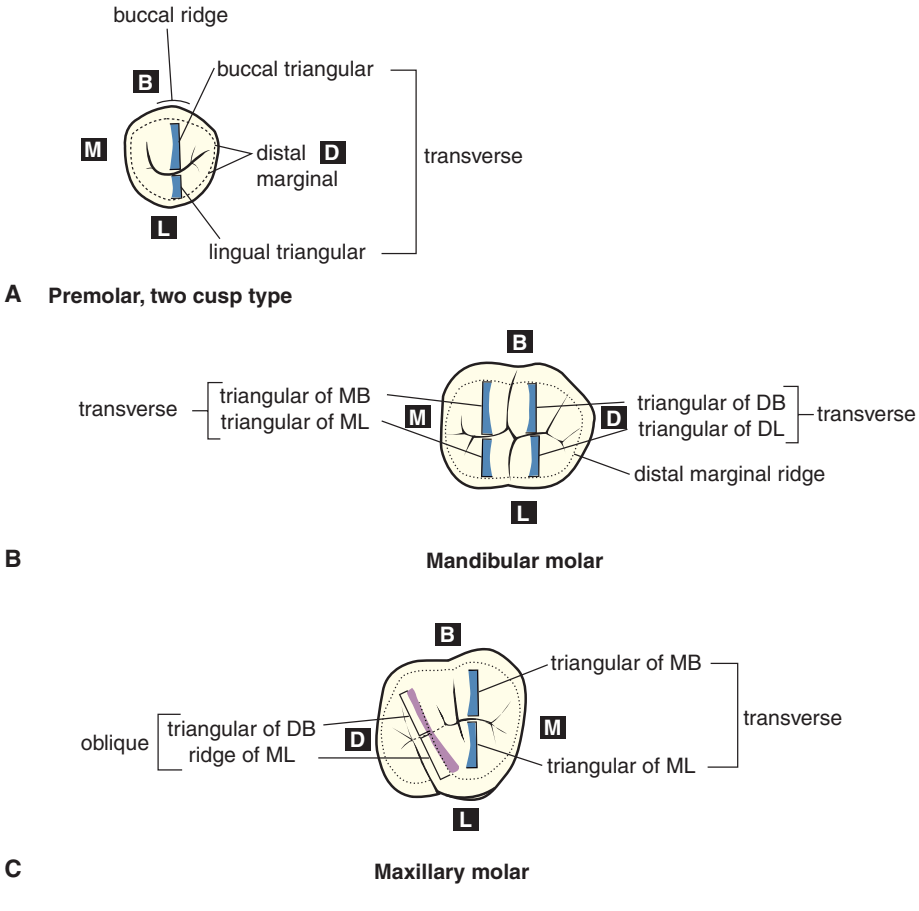


FIGURE 1-27. Three posterior teeth show **transverse** and **oblique ridges**. **A.** Two triangular ridges on a two-cusped premolar form *one* **transverse** ridge. **B.** Two pairs of triangular ridges on a *mandibular* molar join to form *two* **transverse** ridges. **C.** One pair of triangular ridges on a *maxillary* molar is aligned buccolingually and forms *one* **transverse** ridge in *blue*, and another pair of ridges is aligned obliquely (diagonally) to form an **oblique** ridge in *purple*.

LEARNING EXERCISE

The diagram in this Figure 1-32 the ridges seen from the occlusal view that bound the occlusal table of a two-cusped premolar. Name each ridge next to its corresponding number. (Note that ridges labeled 1, 3, 4, 5, 6, and 7 form a continuous outline on the occlusal surface. The area inside of this line is called the **occlusal table**.)

e. *Other Bulges and Ridges*

Other bulges or ridges can be seen on the cervical third of certain teeth facially or lingually. On the facial surface of permanent molars, the ridge or bulge running mesiodistally in the cervical one third of the facial surface of a crown is called the **cervical ridge**. This ridge forms the greatest bulge on the buccal surface, which is known as the **crest of curvature** (or height of contour) (*Fig. 1-33A and B*). This ridge is most evident on mandibular second molars where the

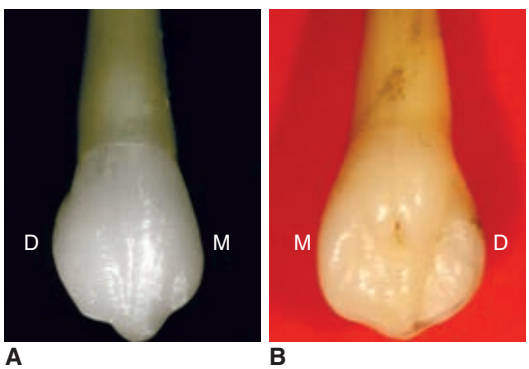


FIGURE 1-28. **A.** On this maxillary canine, a **labial ridge** can be seen running from the cusp tip cervically along the labial surface. **B.** On this maxillary canine, a prominent **lingual ridge** is visible running from the cusp tip cervically to the cingulum.

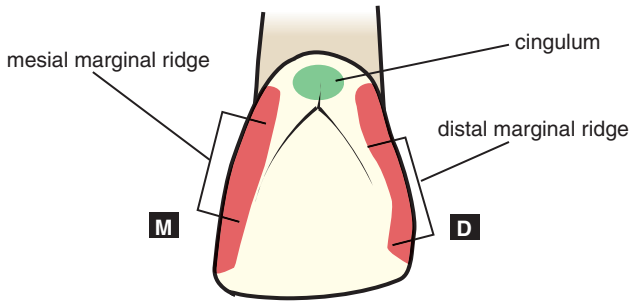


FIGURE 1-29. The mesial and distal **marginal ridges** are shaded *red*, and the **cingulum** is shaded green on the lingual surface of a maxillary incisor. If you think of the length of a marginal ridge as running from the proximal incisal line angles to the cingulum, you can see that this mesial marginal ridge is slightly longer than the distal marginal ridge.

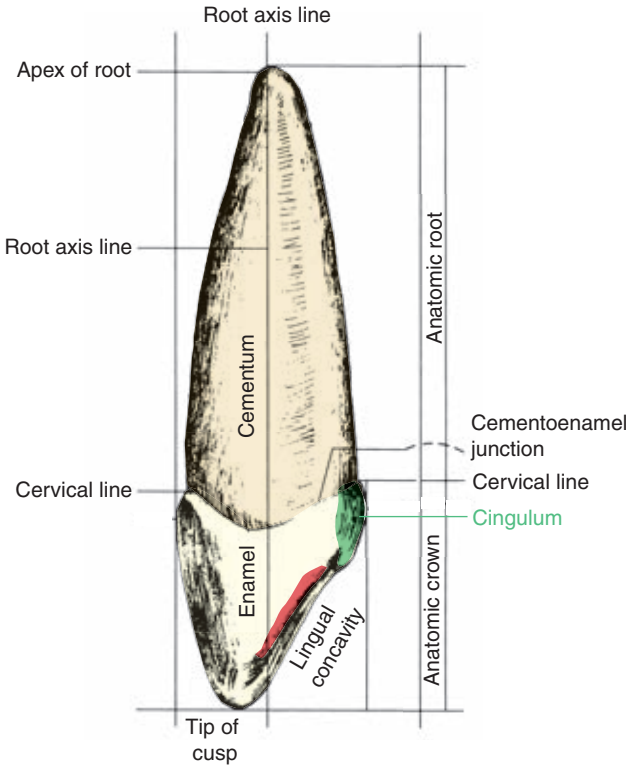


FIGURE 1-30. This maxillary canine demonstrates that the **cingulum** bulge in *green* is located in the cervical third of the lingual surface. One visible marginal ridge is shaded *red*.

occlusal outline of the mesiobuccal cusp appears to bulge (*Fig. 1-33C*).

Mamelons are three small bulges or tubercles on the incisal edges of newly erupted incisors (*Fig. 1-34*). Usually, mamelons are not evident on adult dentition since they are

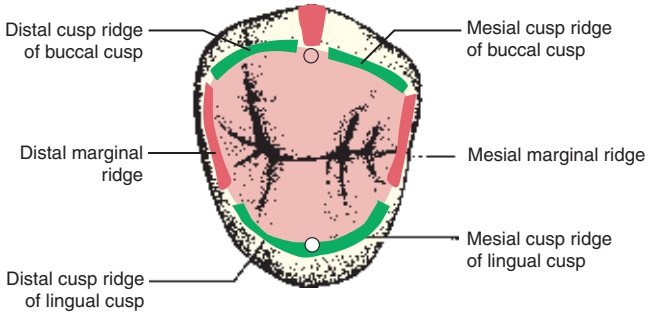
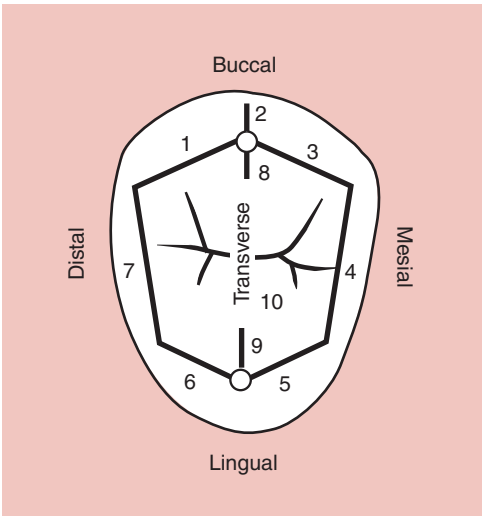


FIGURE 1-31. Occlusal view of a two-cusped premolar shows the difference between the **occlusal outline** of the tooth (the *black* outline surrounding the entire tooth from this view) and the smaller *red* **occlusal table** (or occlusal chewing surface) bounded by six ridges: the two cusp ridges of the buccal cusp (*green*), the two cusp ridges of the lingual cusp (*green*), and the two marginal ridges (*red*).

worn off after the tooth comes into functional contact with its opposing teeth. If you have the opportunity, observe a 7-year-old smile to see these mamelons on newly erupted permanent incisors. When mamelons remain on the incisors of an adult, it is because maxillary and mandibular anterior teeth do not touch together to wear away the enamel. When a patient desires, the dentist can reduce the mamelons to make the incisal edge more uniformly curved.

Finally, **perikymata** [pear i KY mah tah] are the numerous, minute horizontal ridges on the enamel of newly erupted permanent teeth (*Fig. 1-35*). They form from the overlapping of layers of enamel laid down during tooth formation. These lines are closer together in the cervical third of the crown than in the incisal third. Perikymata are more prominent on the teeth of young people than on the teeth of older persons because perikymata, like mamelons, wear away from

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. Transverse



ANSWERS: *1—distal cusp ridge of buccal cusp; 2—buccal (cusp) ridge; 3—mesial cusp ridge of buccal cusp; 4—mesial marginal ridge; 5—mesial cusp ridge of lingual cusp; 6—distal cusp ridge of lingual cusp; 7—distal marginal ridge; 8—triangular ridge of buccal cusp; 9—triangular ridge of lingual cusp.*

FIGURE 1-32. Identify the ridges numbered on this maxillary premolar.

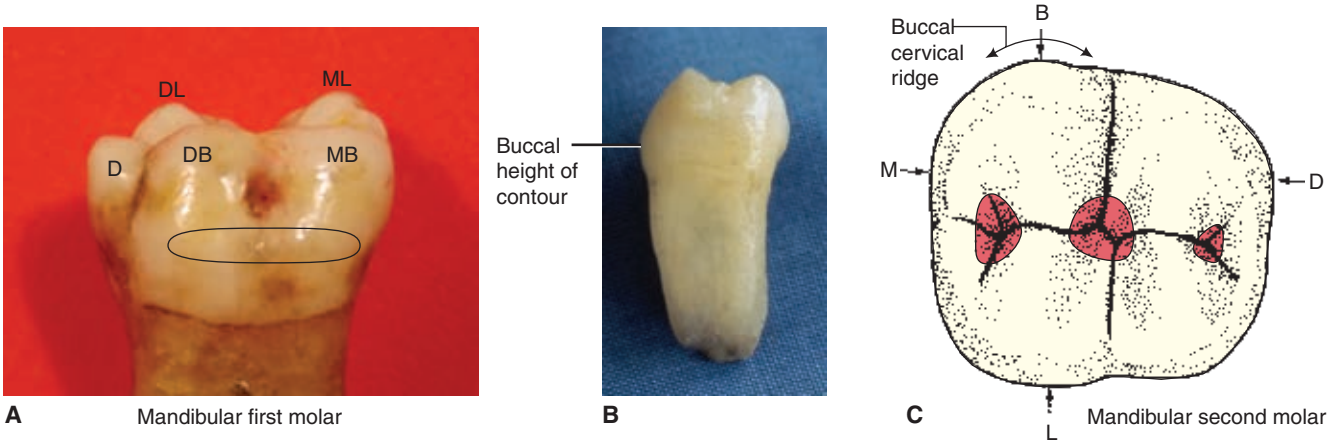


FIGURE 1-33. **A.** On this mandibular first molar from the buccal view, a **buccal cervical ridge** is the rounded prominence located in the cervical third of the crown. **B.** From the proximal view, the **buccal cervical ridge** forms the greatest bulge or crest of curvature in the cervical third of this molar. **C.** From the occlusal view on this four-cusped mandibular second molar, the **buccal cervical ridge** forms a prominent bulge on the mesiobuccal outline.

ongoing abrasion due to eating and even tooth brushing with abrasive toothpastes.

2. Depressions and Grooves of an Anatomic Crown

An occlusal **sulcus** [SUL kuss] (plural sulci [SUL sye]) of a tooth is the broad V-shaped depression or valley on the occlusal surface of each posterior teeth running mesiodistally between the buccal and lingual cusps. The sulcus is formed by the sloping of the buccal and lingual triangular ridges that converge toward the developmental grooves located in the depth of the sulcus on each posterior tooth (*Fig. 1-36*). Although a sulcus is a linear depression, there is much variation to the anatomy within the sulcus of each tooth. For example, there are triangular and marginal ridges (discussed previously) and grooves (channels) within the sulcus, as well as multiple depressions, each called a **fossa** [FAH sah] (plural, fossae [FAH see].

GROOVES: A **groove** is a linear channel often found between cusps in the depth of the sulcus and between ridges. They serve as important escape ways for food morsels when the teeth of the lower jaw move from side to side and forward against the upper teeth during chewing. Partially chewed food squirts out through grooves toward the tongue and cheeks. Each tooth has major *developmental grooves,* which are often consistent in location for teeth of the same type, and other minor, *supplemental grooves,* which can vary greatly from tooth to tooth. **Developmental grooves** separate cusps and other major portions of a tooth formed from the developmental lobes (described later in Section IX of this chapter). On most posterior teeth like the premolar in *Figure 1-37A*, a **central groove** is a developmental groove that separates the buccal from the lingual cusps and is located near the buccolingual center of the tooth sulcus. Other developmental grooves are named according to their location. For example, on *mandibular* molars with two buccal cusps, a **buccal groove** separates the mesiobuccal and distobuccal cusps and is likely to extend onto the buccal surface. On *mandibular* molars with three buccal cusps, there are two grooves separating the three buccal cusps, so they are called a **mesiobuccal groove** that separates the mesiobuccal cusp from the distobuccal cusp, and a **distobuccal groove** that separates the distobuccal cusp from the smallest distal cusp (*Fig. 1-37B*). Both of these grooves are likely to extend onto the buccal surface. Mandibular molars also have a **lingual groove** between the mesiolingual and distolingual cusp, but these grooves are not likely to extend onto the lingual surface. Most *maxillary* molars have a **lingual groove** that often extends onto the lingual surface between the mesiolingual and distolingual cusps, and a **buccal groove** between the mesiobuccal and distobuccal cusps that does not normally extend onto the buccal surface (Fig. 1-37).

FIGURE 1-34. Three distinct unworn **mamelons** are evident on the incisal edge of this mandibular incisor.

Additional occlusal grooves that are not developmental grooves are called **supplemental grooves**. These small irregular (extra) grooves do not occur at the junction of the lobes or major portions of the tooth and do not occur at the same location on teeth of the same type, so these extra grooves are normally not assigned a specific name.

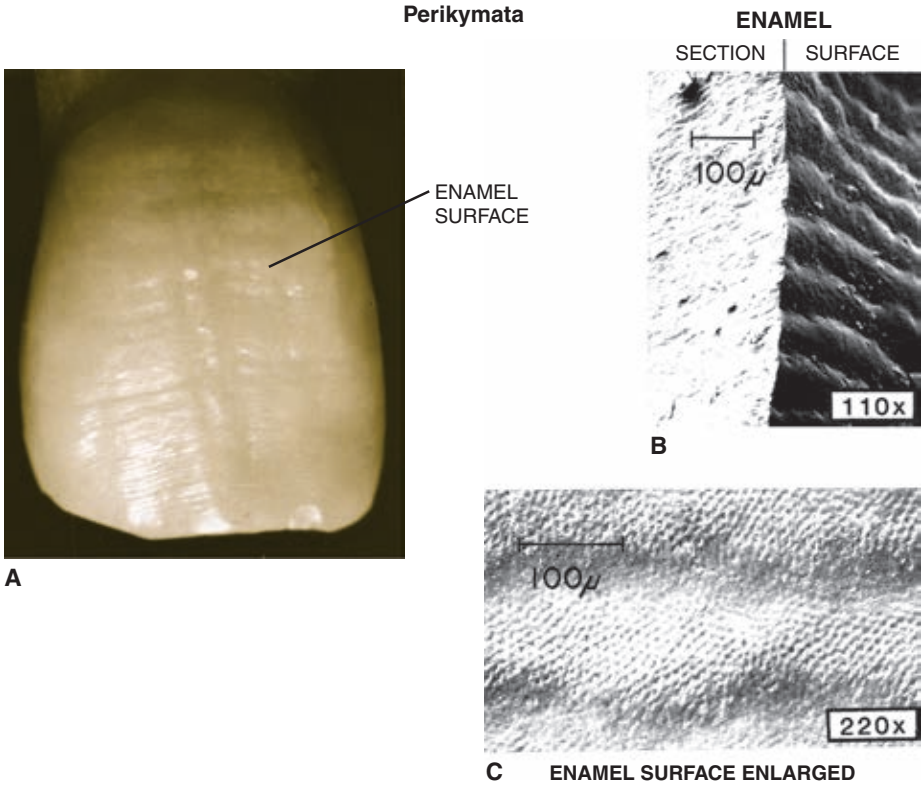


FIGURE 1-35. **A. Perikymata** are the small ridges visible on the labial surface of this incisor. **B.** Magnified cross section of enamel shows perikymata ridges on the tooth surface (on the right half). **C.** Higher magnification (220×) shows the enamel rods that make up enamel ending on the perikymata waves. (These scanning electron micrographs were provided by Dr. Ruth B. Paulson, Associate Professor Emeritus, Division of Oral Biology, the Ohio State University.)

FOSSAE: Located at the mesial and distal ends of the central groove on each posterior tooth within the occlusal table and next to the mesial and distal marginal ridges, there are shallow depressions called a **mesial fossa** and **distal fossa** (sometimes called a **mesial and distal triangular fossa**) (*Fig. 1-38*). **Fossa grooves** (also called *fossa* developmental grooves or triangular *fossa* grooves) may be found within these fossae splitting off of the ends of the central groove directed toward the line angles of the tooth. These grooves can be named for the line angles of the tooth toward which they aim, for example, in Figure 1-38, the **distobuccal developmental groove** (more precisely called the distobuccal triangular or fossa groove) runs toward the distobuccal line angle of the tooth. A **pit** may form at the depth of a fossa where central groove joins the fossa grooves. For example, within the distal fossa on a premolar, there is a distal pit at the junction of the central groove with the distobuccal and distolingual fossa grooves (Fig. 1-38). Most molars and three-cusped premolars have an additional **central fossa** seen in *Figure 1-39*.

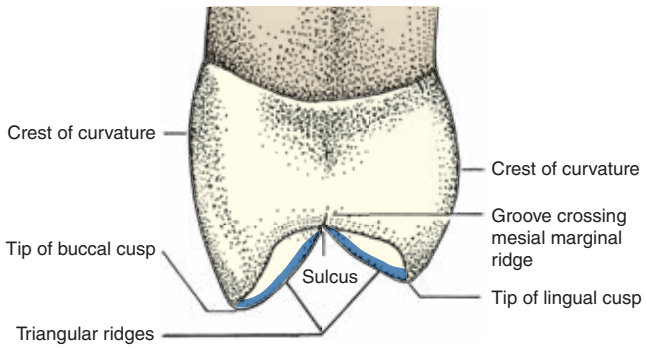


FIGURE 1-36. This two-cusped premolar has a **sulcus** between the buccal and lingual cusps.

Many anterior teeth have a shallow, broad **lingual fossa** that is located on the lingual surface between the mesial and distal marginal ridges and just incisal to the cingulum (particularly on maxillary incisors, *Fig. 1-40*). The lingual ridge of some maxillary canines may divide the lingual surface into two fossae: a mesial fossa bounded by the mesial marginal ridge and the lingual ridge and a distal fossa bounded by the distal marginal ridge and the lingual ridge (*Fig. 1-41*).

Deep, defective **pits and fissures** may be found at the depth of fossae and grooves caused by the incomplete fusion of enamel during tooth development (at the white arrow in *Fig. 1-42*). Because it is very difficult to remove food debris from these inaccessible fissures, tooth decay (also called dental **caries** [CARE eez]) often begins in the deepest part of a fissure or pit (seen spreading out within dentin as the

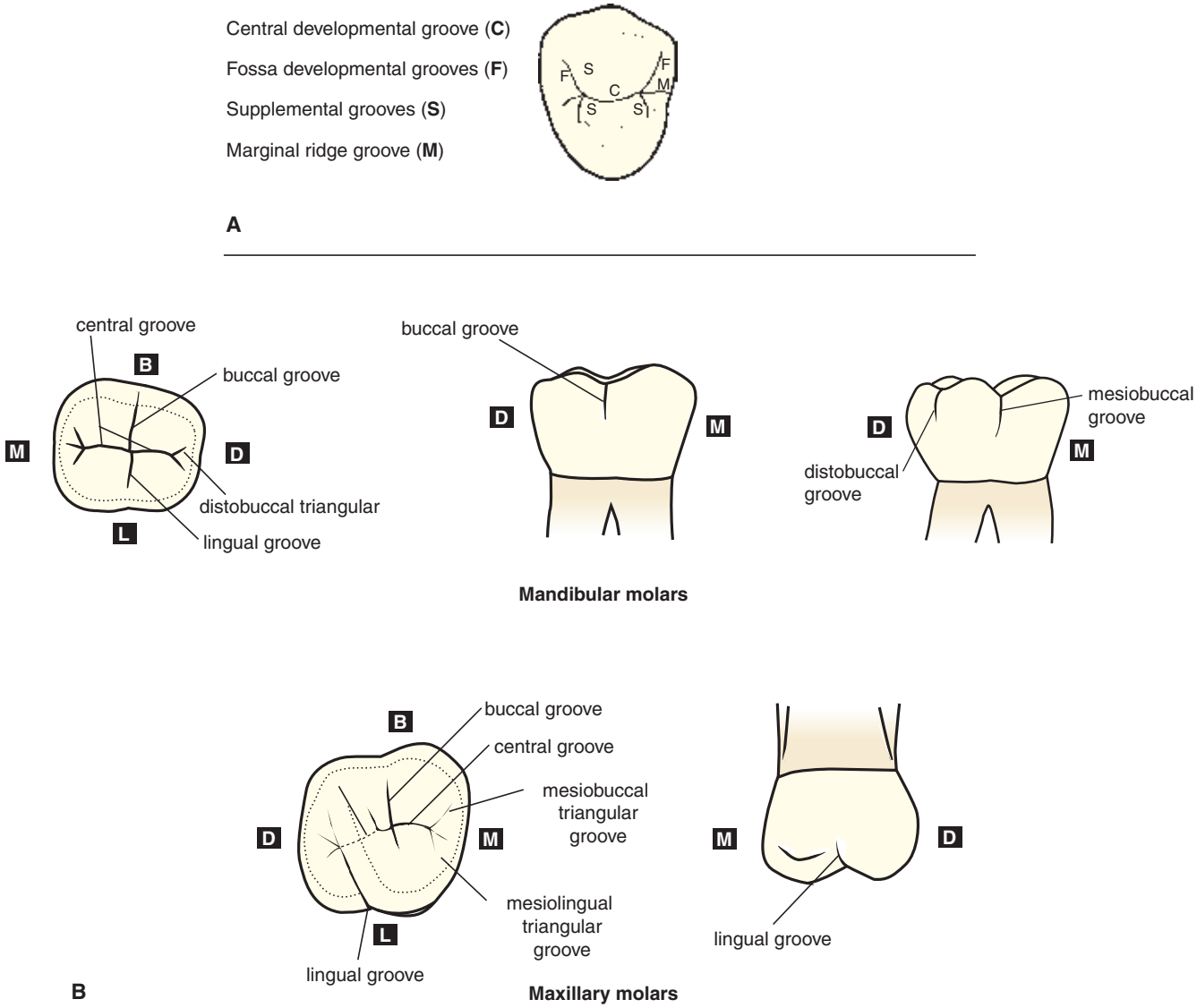


FIGURE 1-37. **A.** This two-cusped premolar has **developmental** (major) and **supplemental** (extra) occlusal **grooves**. (Courtesy of Drs. Richard W. Huffman and Ruth Paulson.) **B.** Grooves are labeled on a mandibular four-cusped molar (upper left and center), a mandibular five-cusped molar (upper right) and a maxillary molar with four major cusps (lower row). The **buccal, lingual, and central grooves** are considered developmental grooves. The **buccal groove** extends between the two buccal cusps onto the buccal surface on *mandibular* molars, and the **lingual groove** extends between the two lingual cusps onto the lingual surface of *maxillary* molars. Five-cusped mandibular first molars have three buccal cusps, so there are two developmental grooves: a **mesiobuccal groove** between the mesiobuccal and distobuccal cusps and a **distobuccal groove** between the distobuccal and distal cusps.

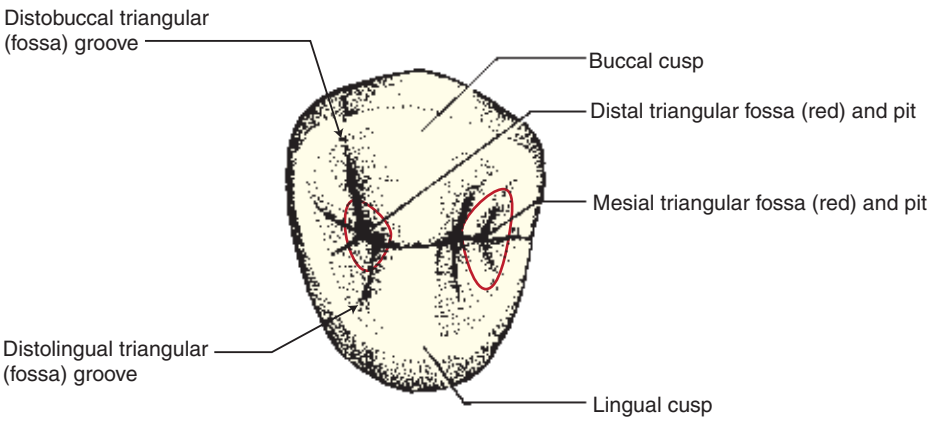


FIGURE 1-38. The **mesial and distal fossae** are outlined in *red* on this maxillary two-cusped premolar.

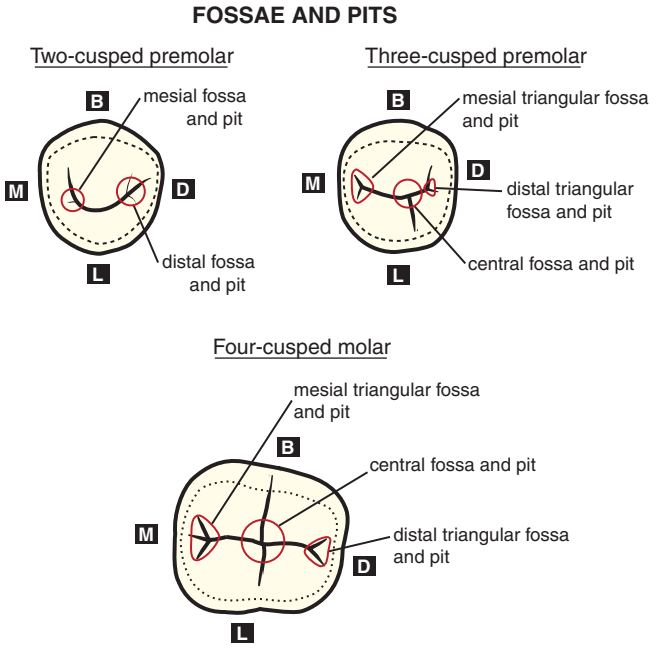


FIGURE 1-39. **Fossae** and pits are labeled on teeth with two, three, and four cusps. Two-cusped teeth have two fossae (a **mesial** and a **distal fossa**), while three- or four-cusped teeth also have a third fossa called a **central fossa**.

dark area between the two black arrows) and described in more detail in Chapter 10. These carious pits and fissures are most likely to be located in four areas: at the depth of deep grooves and pits on the occlusal surface of posterior teeth, in buccal grooves that extend onto the buccal surface of mandibular molars, in lingual grooves that extend onto the lingual surface of maxillary molars, and on the lingual surface of maxillary incisors where the lingual fossa joins the cingulum (*Fig. 1-43*).

In summary, if you compare tooth morphology to a mountain range, the mountain peak would be the cusp tip. Ridges emanating from the mountain peak are like the cusp ridges and triangular ridges. The depression between the mountains is a valley, like the depressions between cusps is a sulcus. The dried river bed at the bottom of the valley is like a groove at the bottom of the sulcus. If the riverbed is cracked

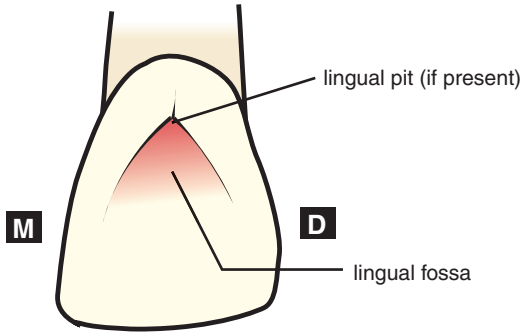


FIGURE 1-40. The lingual surface of this maxillary lateral incisor shows the shallow **lingual fossa** and an adjacent **lingual pit**.

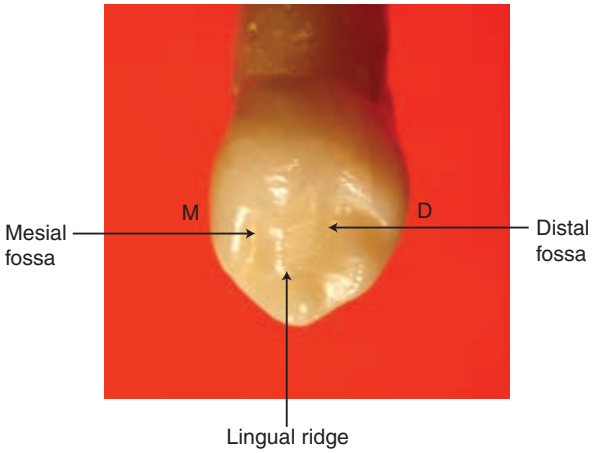


FIGURE 1-41. This maxillary canine has a lingual ridge that divides the lingual surface into a mesial fossa and a distal fossa.

open, it is like a fissured groove. Where two rivers converge (as when grooves or fissures converge), the whirlpools and eddies may have formed a depression, like a fossa, possibly with a pit at its depth. Needless to say, it is difficult to define exactly where a mountain stops and the valley begins, just as it would be difficult to define exactly where a tooth cusp stops and a sulcus or fossa begins. Just realize that these terms are not precise, but that they are helpful when learning how to reproduce tooth form during construction of crowns and placement of fillings or when learning to finish and polish an existing filling.

B. EXTERNAL MORPHOLOGY OF THE ANATOMIC ROOT

Recall that the anatomic root is the part of a tooth that is covered with cementum. The **apex** of the root is the tip or peak at the end of the root, often with visible openings called

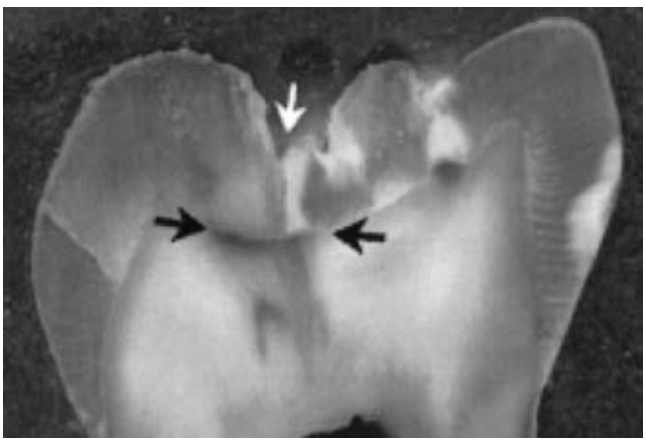


FIGURE 1-42. A cross section of a mandibular molar shows an occlusal groove (*white arrow*), which actually has a **fissure** (crack-like fault) extending through the outer enamel and into the dentin. The *black arrows* show how the **dental decay** spreads out once it reaches softer dentin at the depth of this fissure.

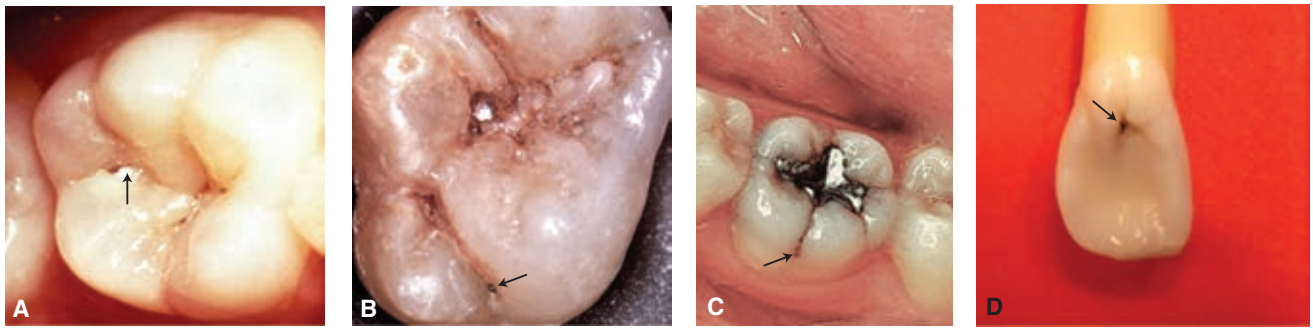


FIGURE 1-43. Caries-prone pits and fissures are located in four places (*arrows*). **A.** The occlusal surfaces of posterior teeth. **B.** The lingual surfaces of maxillary molars. **C.** The buccal surfaces of mandibular molars. **D.** The lingual surfaces of maxillary incisors.

apical foramina, where the nerves and blood vessels enter into the tooth pulp canals. The **cervix** [SUR viks] or neck of the tooth is the slightly constricted region surrounding the junction of the crown and the root (*Fig. 1-44B*).

Some new terms apply to multirooted teeth (*Fig. 1-44B*). The **root trunk** or trunk base is the part of the root of a multirooted molar or two-rooted premolar next to the cementoenamel junction that has not yet split (like a stubby tree trunk before it gives off branches). The **furcation** [fur CAY shun] is the place on multirooted teeth where the root trunk divides into separate roots (called a **bifurcation** on two-rooted teeth and a **trifurcation** on three-rooted teeth). The **furcal region** or interradicular space is the region or space between two or more roots, apical to the furcation where the roots divide from the root trunk.

C. CERVICAL LINE (CEMENTOENAMEL JUNCTION OR CEJ) CURVATURE

When viewed from the mesial or distal aspect, the cervical line of a tooth curves (is convex) toward the incisal or occlusal surface (Fig. 1-44). In general, the amount of curvature is greater on the mesial surface than on the distal surface of

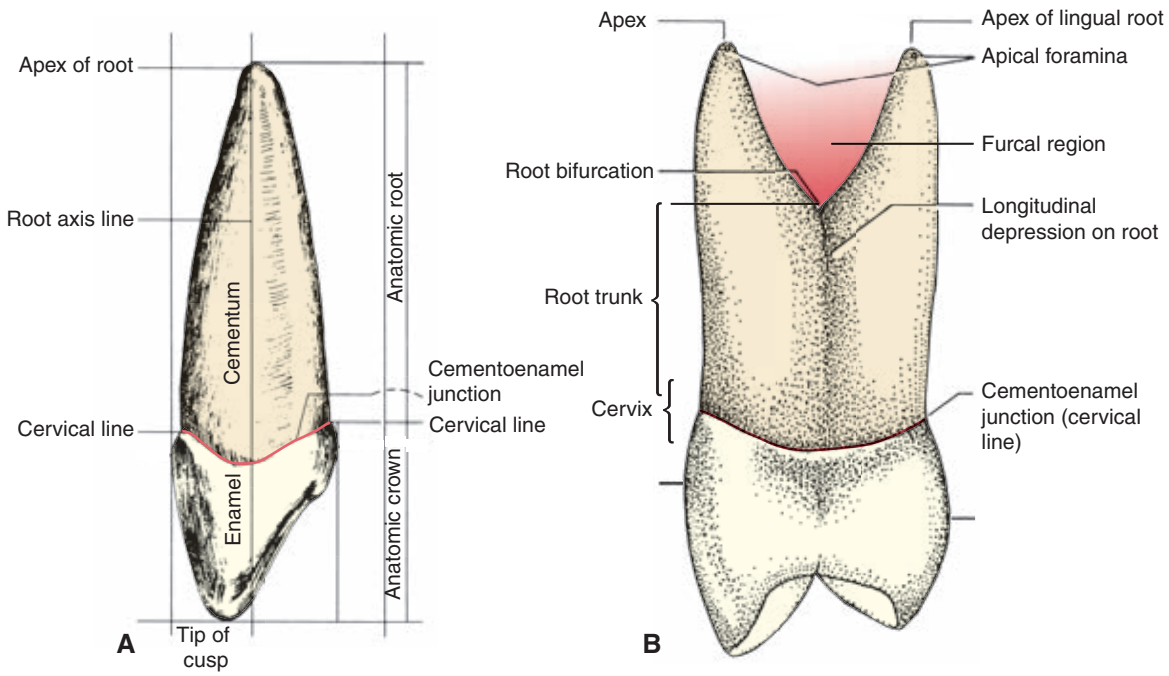


FIGURE 1-44. **A. Root anatomy** on a *single-rooted* canine. **B. Root anatomy** of a *bifurcated* (split) root on a maxillary first premolar.

TABLE 1-2 Summary of Curvatures of the Cementoenamel Junction

CERVICAL LINE (CEMENTOENAMEL JUNCTION) CURVATURES	Proximal surfaces: mesial curvature vs. distal curvature	Generally, teeth have a greater proximal cervical line curvature on the mesial than the distal.
	Proximal surfaces: anterior teeth vs. posterior teeth	Proximal cervical line curvatures are greatest on the mesial surfaces of central incisors and, for most teeth, tend to get smaller when moving from the anterior teeth toward the last molar where there may be no curvature at all.
	Posterior teeth: facial vs. lingual surface	On many posterior teeth, the cervical line is in a more occlusal position on the lingual than on the facial.

the same tooth, and the amount of curvature is greatest for central incisors and diminishes in size for each tooth when moving distally around each quadrant (*Table 1-2*).

D. RELATIVE SIZE

In order to document the relative sizes of tooth crowns and roots, Dr. Woelfel studied a convenient sample of 4572 extracted teeth. His findings are presented in Table 1-7 at the end of this chapter. This table should not be memorized, but it can be useful when comparing the average dimensions of each tooth and in order to appreciate the wide range of dimensions for each tooth. A summary of the most important highlights of that data is presented in *Table 1-3*.

TABLE 1-3 Important Tooth Dimensions to Memorize

Tooth with longest crown	Mandibular canine (Woelfel research: maxillary incisor)
Longest tooth overall	Maxillary canine
Longest root	Maxillary canine
Widest crown mesiodistally	Mandibular first molar
Widest crown buccolingually	Maxillary first molar
Narrowest crown mesiodistally	Mandibular central incisor
Greatest cervical line curve	Mesial of maxillary incisor

SECTION VII TERMINOLOGY RELATED TO THE IDEAL TOOTH ALIGNMENT OF TEETH IN DENTAL ARCHES

When viewed from the occlusal aspect, the alignment of teeth within each dental arch is somewhat U shaped or parabolic like the famous landmark in Missouri, the St. Louis Arch (*Fig. 1-45*). The incisal edges and the buccal cusp tips follow a curved line around the outer edge of the dental arch; the lingual cusp tips of the posterior teeth follow a curved line nearly parallel to the buccal cusp tips. Between the buccal and lingual cusps of posterior teeth is the **sulcular groove (occlusal sulcus)**, a V-shaped depression that extends anteroposteriorly through all of the posterior teeth in each quadrant. This sulcular groove is made up of the occlusal sulcuses of adjacent posterior teeth in each quadrant (Fig. 1-45).

A. MIDROOT AXIS LINE AND TOOTH ALIGNMENT

The **midroot axis line** (or root axis line) is an imaginary line through the center of the tooth root. When viewing the *facial* or *lingual* surface, it can be visualized as a line that divides

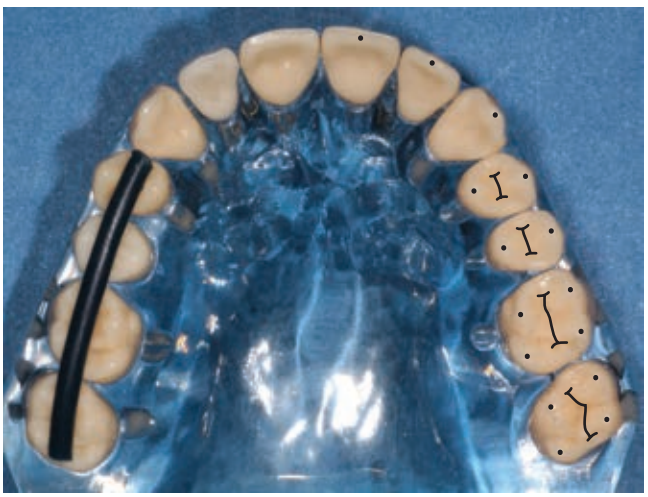


FIGURE 1-45. This model of the maxillary dentition with ideal alignment form an arch shape and the rope of blue wax on the left half falls within the **occlusal sulcus**.

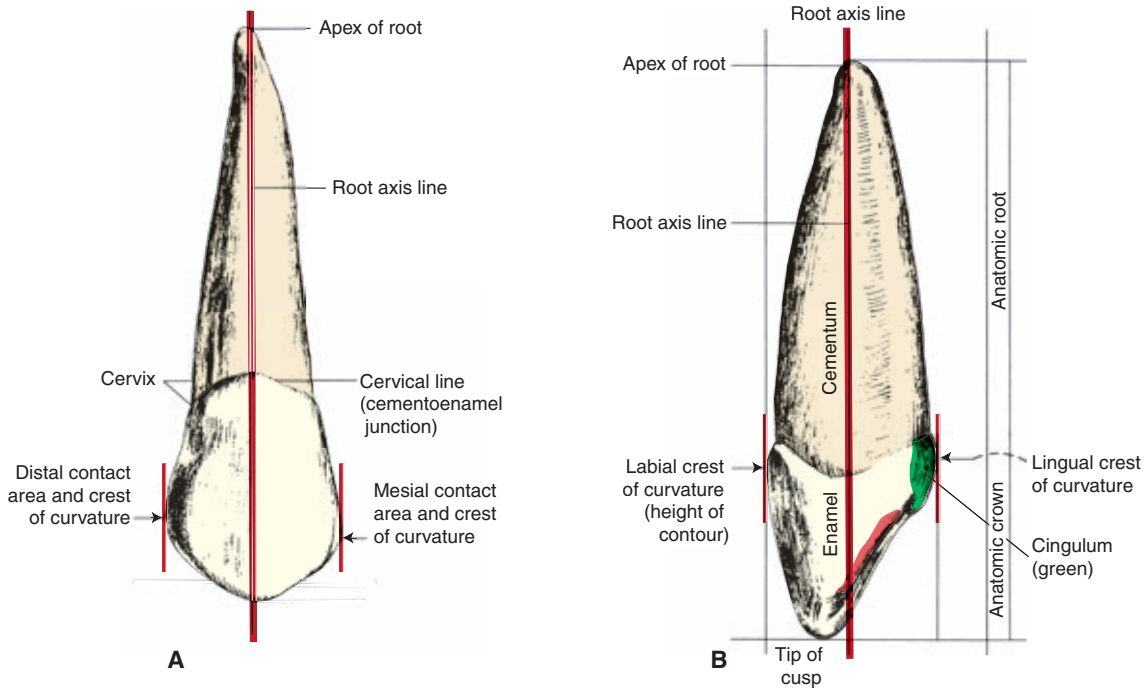


FIGURE 1-46. The **midroot axis line** is drawn on two views of a canine. **A.** When viewed from the facial (or lingual), the greatest bulges on the *mesial* and *distal surfaces (***crests of curvature)** on this canine are the widest points on the crown that touch lines parallel to the midroot axis line. These crests of curvature are essentially the same as the **contact areas** of teeth when they are aligned ideally in the mouth. Notice that these contact areas are positioned more incisally on the mesial surface than on the distal. **B.** When viewed from the proximal, the greatest bulges on the *facial* and *lingual* surfaces (**crests of curvature)** are the points on the facial and lingual crown outline that touch lines that are parallel to the midroot axis line. They are located in the *cervical third* on both the facial surface and on the lingual surface (on the cingulum shaded *green*) for *all anterior* teeth.

the bulk of the root into mesial and distal halves (*Fig. 1-46A*). When viewing the *mesial* or *distal* surface, it divides the bulk of the root into facial and lingual halves (*Fig. 1-46B*). It is an important reference line for describing the location of tooth landmarks. For example, you will learn that the incisal ridge (or cusp tip) of a maxillary canine is more likely to be labial to the midroot axis line (as seen in Fig. 1-46B).

When the posterior teeth in each arch are viewed from the buccal aspect as in *Figure 1-47*, notice that posterior teeth are *not* aligned exactly parallel to one another and all cusp

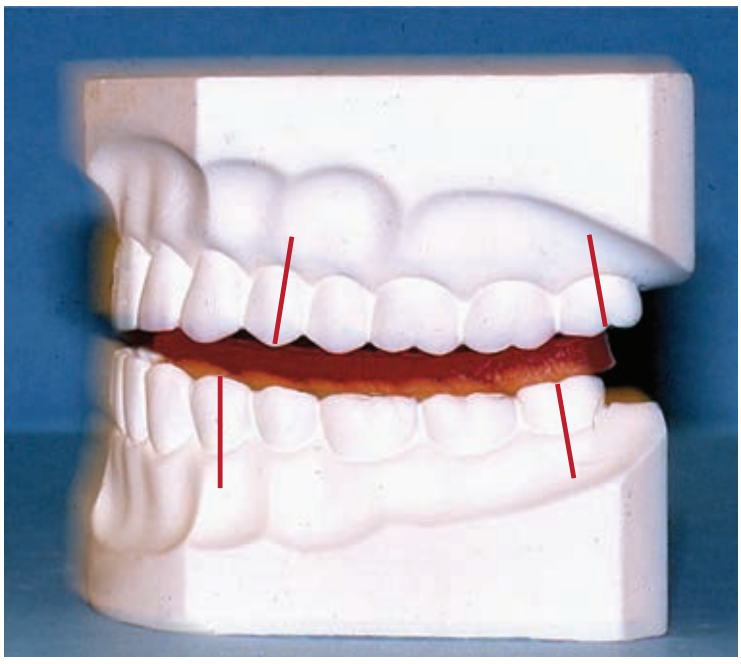


FIGURE 1-47. A wax strip placed between stone models of the maxillary and mandibular teeth demonstrates the **anteroposterior curve** (curve of Spee), which is concave in the mandibular arch but convex in the maxillary arch. Note the difference in the axial alignment of the teeth within each arch demonstrated by the axial lines placed on the third molars and on the first premolars.

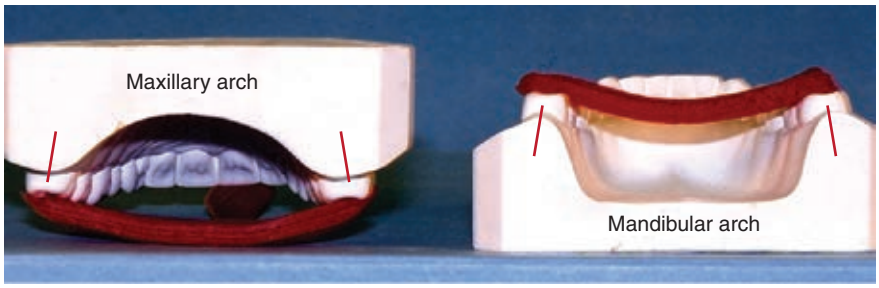


FIGURE 1-48. Dental stone casts viewed from the distal with a wax strip used to demonstrate the **mediolateral curve** (of Wilson). It is convex in the maxillary arch, but concave in the mandibular arch. Note the red lines that denote posterior tooth alignment within each arch: *maxillary* molar crowns tilt toward the *facial*, and *mandibular* molar crowns tilt toward the *lingual*.

tips in a quadrant do *not* normally fall along a ruler-straight line. The axial alignment changes gradually from posterior to anterior teeth, which is evident when you compare the alignment of the mandibular third molar (tipped noticeably more to the mesial) than on the first premolar. Subsequently, if you were to connect the buccal cusp tips with a line, a gradual **anteroposterior curve** (curve of Spee) is evident (see Fig. 1-47). This curve is convex in the maxillary arch, while the curve is concave in the mandibular arch.

When viewed from the distal, maxillary posterior teeth are axially tilted facially within the maxillary arch, whereas mandibular posterior teeth are tilted lingually within the mandibular arch (*Fig. 1-48*). Therefore, *in the mouth*, lingual cusps of *maxillary* posterior teeth appear longer than the buccal cusps, while the lingual cusps of *mandibular* posterior teeth appear shorter than the buccal cusps due to the lingual tilting within the mandible. However, to avoid confusion, you need to realize that later in the book, you will learn that when you hold a mandibular molar in your hand with the midroot axis aligned vertically, the lingual cusps of mandibular molars are actually slightly longer than buccal cusps (*Fig. 1-49*). When a line connects the buccal and lingual cusps of the same type of molars and premolars on opposite sides of the arch, this side-to-side curve is the **mediolateral curve** (of Wilson). The mediolateral curve of the maxillary arch is convex, whereas that of the mandibular arch is concave (Fig. 1-48).

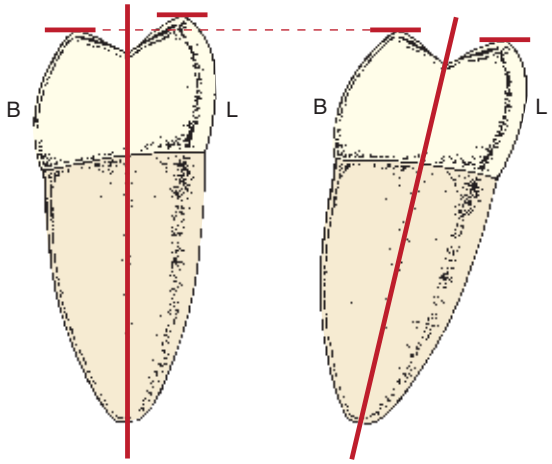


FIGURE 1-49. This mandibular second molar with its mid-root axis aligned vertically (left drawing) has lingual roots that appear longer, whereas the same tooth with the midroot axis tipped lingually, as it would be in the mandible, has lingual cusps that appear shorter.

B. CREST OF CURVATURE (HEIGHT OF CONTOUR) ON THE FACIAL AND LINGUAL SURFACE

The shape and extent of the greatest bulge on the facial and lingual crown surfaces help determine the direction that food particles are deflected as they are crushed between tooth surfaces when chewing. When we chew food, these natural tooth convexities divert food away from the thin free gingiva and gingiva sulcus surrounding the cervix of the tooth and toward the firmer tissues of the mouth, thus minimizing trauma to the gingiva. If teeth were flat facially and lingually, food could more likely damage the gingiva (*Fig. 1-50*). Needless to say, it is best for the dentist, dental hygienist, and/or dental technician to reproduce and maintain these natural convexities when restoring a tooth, when finishing and polishing fillings near the gum line, or when contouring a replacement tooth crown.

The ***facial* or lingual crest of curvature** (**height of contour**) is the point on a crown outline where a line drawn parallel to the midroot axis line touches the greatest bulge on the crown (*Fig. 1-51*). It is usually located in either the cervical third or the middle third, normally not in the occlusal or incisal third. When viewed from the proximal, the location of the crest of curvature on the *facial* surface on both anterior and posterior tooth crowns is normally located in the *cervical third*. The location of the *lingual* crest of curvature depends on whether the tooth is anterior or posterior. The *lingual* crest of curvature on *anterior* teeth is in the *cervical* third, on the cingulum (Fig. 1-46B). The *lingual* crest of curvature on *posterior* teeth is most often located in the *middle* third (Fig. 1-51). Refer to *Table* 1-4 for a summary of the location of the facial and lingual heights of contour for anterior teeth compared to posterior teeth.

C. CONTACT AREAS (OR PROXIMAL CRESTS OF CURVATURE)

When the teeth are in normal, ideal alignment within an arch and viewed directly toward the facial or lingual surfaces, the location of the mesial or distal greatest bulges or crests

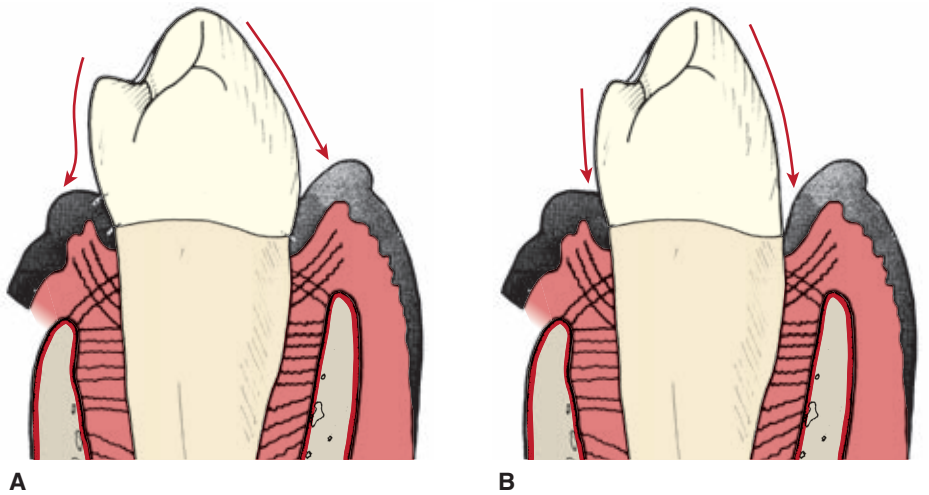


FIGURE 1-50. **A.** Normal *facial* and *lingual* crests of curvature help divert food away from the gingival sulcus. **B.** When crests of curvature are not adequate, food can more readily damage the gingival sulcus.

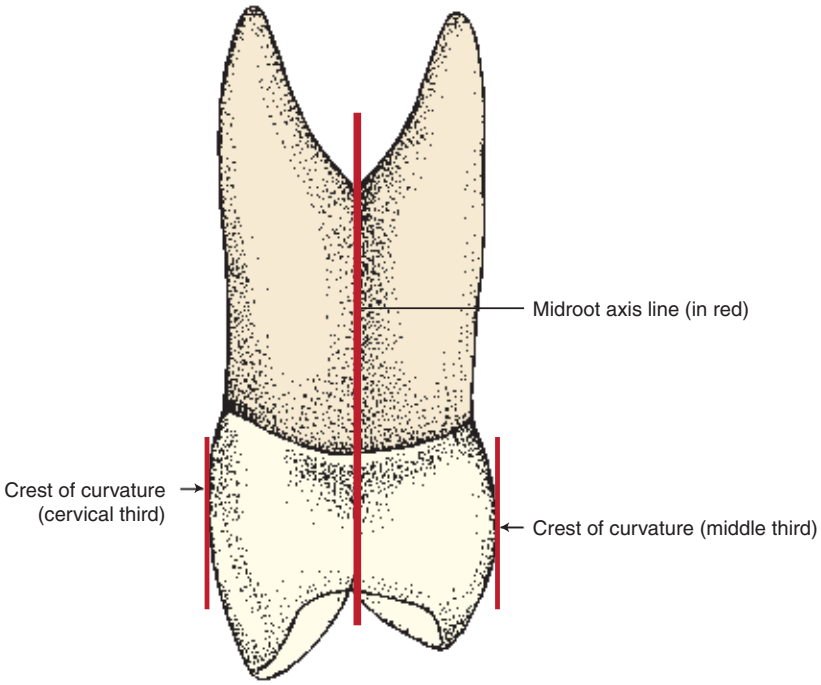


FIGURE 1-51. On the proximal view of this premolar, the *buccal* **crest of curvature** (height of contour) is located in the cervical third, while the *lingual* height of contour is located more occlusally, in the middle third. This is typical of most *posterior* teeth.

TABLE 1-4 Summary of the Location of Facial and Lingual Heights of Contour (Greatest Bulge) of the Crown (Best Seen from the Proximal View)

	FACIAL (HEIGHT OF CONTOUR)	LINGUAL (HEIGHT OF CONTOUR)
Anterior teeth (incisors and canines)	Cervical third	Cervical third (on cingulum)
Posterior teeth (premolars and molars)	Cervical third	In or near middle third

General learning guidelines:
1. **Facial** crest of curvature for all teeth is in **cervical** third.
2. **Lingual** crest of curvature for all **anterior** teeth is in the **cervical** third (on the cingulum).
3. **Lingual** crest of curvature for **posterior** teeth is in the **middle** third (slightly more occlusal in mandibular teeth due to the lingual tilt of the crown).

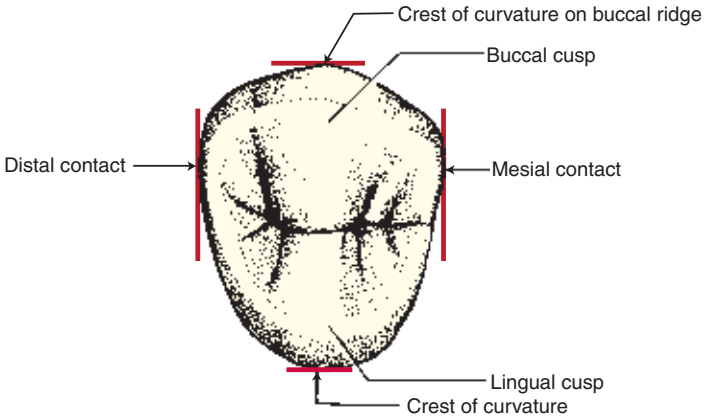


FIGURE 1-52. The mesial and distal **contact areas** seen on the occlusal view of this two-cusped maxillary premolar are located buccal to the center of the tooth buccolingually, which is typical of most posterior teeth.

of curvature is essentially the same location as **contact areas** where two adjacent teeth touch (labeled on a canine from the facial view in Fig. 1-46A and on a premolar from the occlusal view in *Fig. 1-52*).

In a young person, contacts between teeth start off between recently erupted teeth as *contact points*. Then, as the teeth rub together during function, these points become somewhat flattened and truly become **contact areas**. (It has been shown by careful measurements that by age 40 in a healthy mouth with a complete dentition, a total of 10 mm of enamel has been worn off the contact areas of all teeth in an entire arch. This averages 0.38 mm per contact area on each tooth and certainly emphasizes the amount of proximal wear that occurs. Therefore, we would expect contact areas on teeth of older people to be large and somewhat flattened.)

The proximal contact of each tooth with the adjacent teeth has several important functions:

- The positive contact of all teeth within each dental arch stabilizes the position of teeth within each arch.
- When chewing, tooth contacts help prevent food from being forced between the teeth where it could contribute to decay and gum and bone disease (periodontal disease). Further, you must be able to pass floss through each contact area in order to clean the proximal surfaces, which are otherwise inaccessible to the toothbrush.
- Contact protects the thin interdental papillae of the gingiva by diverting food buccally and lingually.

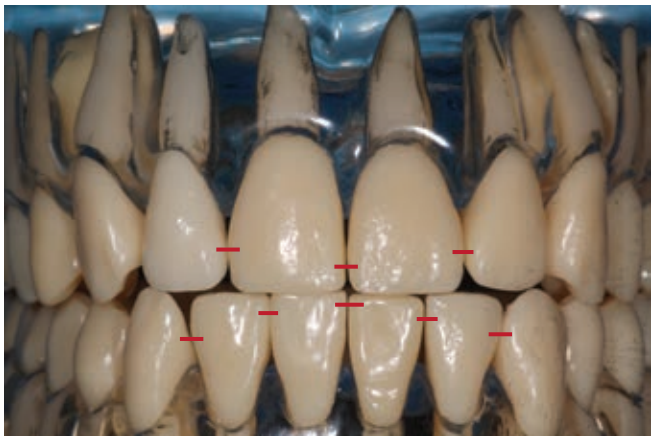
A **diastema** [di ah STEE mah] is a space that exists between two adjacent teeth in the same arch that is not the result of a missing tooth. It is most commonly seen between the maxillary right and left central incisors, but can occur between any teeth (*Fig. 1-53A and B*).

When learning the normal location of the **proximal contacts** for each type of tooth, it will be helpful to learn the following general guidelines that apply to most permanent teeth. Exceptions to these general rules will be presented in later chapters.

A B

FIGURE 1-53. **A.** This stone model has a space between maxillary central incisors called a **diastema**. **B.** On these primary teeth, there is an obvious **diastema** between the maxillary central incisors.

A



B

FIGURE 1-54. **A.** These maxillary teeth are aligned to demonstrate the **location of proximal contacts**: contacts are more incisal (near the incisal edge) on the central incisor, but are located progressively more cervical as you move posteriorly to the third molars. **B.** Proximal contacts between the central incisors are very close to the incisal edge at the midline (most incisal between the mandibular incisors), but more cervical as you move posteriorly.

- When viewing teeth from the facial, contact areas are located in one of three places: in the incisal (or occlusal) third, at the junction of the incisal (or occlusal) and middle thirds, or in the middle third of the crown. Contact areas are not normally located in the cervical third.
- On most teeth, the mesial contact is more incisal or occlusal than its distal contact (*Fig. 1-54A*).
- In general, proximal contacts are closer to the biting/chewing surface on anterior teeth than are posterior teeth. The mesial contact areas on central incisors are positioned near the incisal edge, closest to the biting/chewing surfaces (*Fig. 1-54B*), while contacts on molars are located closer to the middle of the crown, the farthest from the chewing surface.
- When viewing posterior teeth from the occlusal view, contacts are often located slightly to the facial of the tooth midline buccolingually (*Fig. 1-55*).
- When viewing anterior teeth from the incisal view, contacts are nearly centered faciolingually (Fig. 1-55).

D. EMBRASURE SPACES

When adjacent teeth contact, the continuous space that surrounds each contact area can be divided into four somewhat triangular **embrasure spaces**. These spaces are narrowest closest to the contact area where the teeth are in tight contact, but due to the tapered shape and rounded corners of most teeth, these spaces widen facially to form a buccal or labial embrasure space and lingually to form a lingual embrasure space and widen occlusally (or incisally) to form a small occlusal or incisal embrasure space. The fourth space, cervical to the contact area, is properly called the interproximal space.

The **lingual embrasure** is ordinarily larger or longer than the **facial embrasure** because most teeth are narrower (have less bulk) in the lingual half than on the facial half and because their contact points are most often located facial to the faciolingual midline of the crown. See the difference in the embrasure space sizes in *Figure 1-56*.

FIGURE 1-55. These maxillary teeth are aligned to demonstrate the location of proximal contacts when viewed from the occlusal. Between posterior teeth, the contacts are located buccal to the middle of the teeth buccolingually. Between anterior teeth, the contacts are located near the center of the teeth faciolingually.

FIGURE 1-56. When viewed from the occlusal, the **lingual embrasure spaces** of posterior teeth are larger than the **buccal embrasure spaces** due to the taper of the teeth narrower toward the lingual and the location of the proximal contacts buccal to the midline faciolingually.

The **occlusal or incisal embrasure** is usually shallow from the occlusal surface or incisal edge to the contact areas and is narrower faciolingually on anterior teeth but broader on posterior teeth. The occlusal embrasure on posterior teeth is the small area between the marginal ridges of adjacent teeth but occlusal to their contact area. This is the space where we place the dental floss before passing it through the contact area to clean tooth surfaces in the interproximal space.

When viewed from the facial or lingual, the triangular-shaped **interproximal space** is bounded by the proximal surfaces of adjacent teeth, with the apex of the triangle at the contact between two teeth (*Fig. 1-57A and B*). In a mouth with healthy periodontium, this space is completely filled with the **interdental papilla** (*Fig. 1-57C*). Sometimes, this interproximal space is referred to as the **cervical or gingival embrasure**.

Excellent proximal contacts and well-formed crown contours forming the proximal embrasure spaces serve to direct food away from the gingiva. When the embrasures are incorrectly shaped (as with a poorly contoured dental restoration), or when there is a space between the teeth, fibrous food may readily lodge in the interproximal spaces requiring frequent use of dental floss or toothpicks for its removal. This food impaction is not only an annoyance, but it can contribute to the formation of periodontal disease (bone loss) and dental decay.

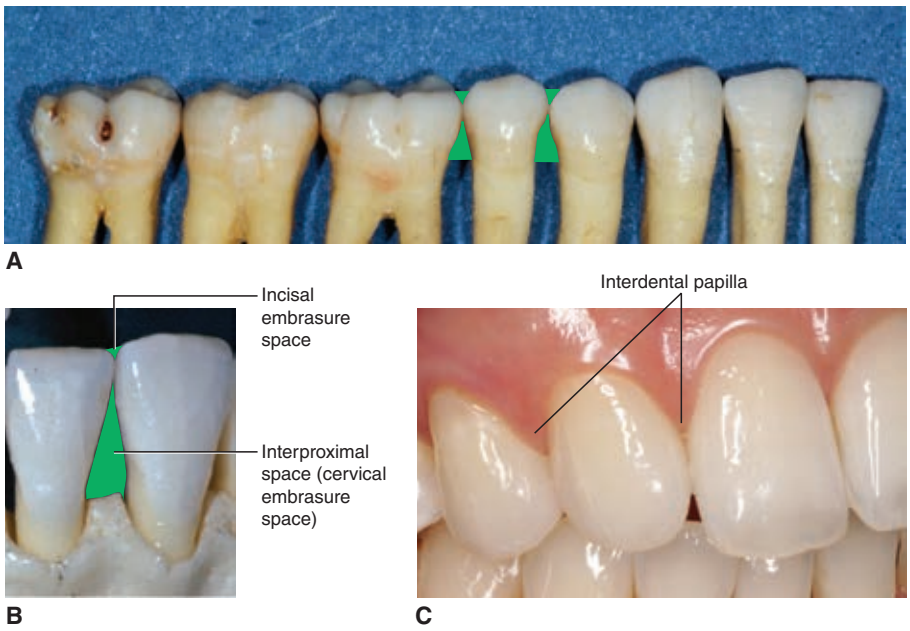


FIGURE 1-57. **A.** The mandibular teeth are aligned to demonstrate the **interproximal spaces** (or cervical embrasure spaces) located between each pair of contacting teeth. **B.** This close-up of mandibular incisors in a skull (without tissue) shows the **interproximal space** cervical to the proximal contact (**gingival embrasure space**). The very small triangular space above the proximal contact is the **incisal embrasure space**. **C.** The interproximal spaces between these maxillary teeth are filled with healthy gingiva called **interdental papillae**.

REVIEW Questions

These questions were designed to help you confirm that you understand the terms and concepts presented in this section. More than one answer may be correct.

1. Which of the following bumps or ridges is NOT likely to be found on a maxillary premolar?
   a. Oblique ridge
   b. Cingulum
   c. Mesial marginal ridge
   d. Transverse ridge
   e. Triangular ridge

2. Which ridges help to surround the perimeter of the occlusal surface (occlusal table) of a two-cusped premolar?
   a. Mesial marginal ridge
   b. Distal marginal ridge
   c. Mesial cusp ridge of the buccal cusp
   d. Distal cusp ridge of the lingual cusp
   e. Transverse ridge

3. On a two-cusped premolar, which ridges meet to form a transverse ridge?
   a. Buccal ridge of the buccal cusp
   b. Triangular ridge of the lingual cusp
   c. Triangular ridge of the mesiolingual cusp
   d. Triangular ridge of the buccal cusp
   e. Cervical ridge of the buccal cusp
4. Which of the following is (are) NOT a cusp found on three-cusped type premolars?
   a. Mesiobuccal
   b. Distobuccal
   c. Buccal
   d. Mesiolingual
   e. Distolingual
5. What is the correct order of anatomic landmarks of a tooth with two roots from the cementoenamel junction to the root tip?
   a. Cervix, trunk, furcation, apex
   b. Trunk, cervix, furcation, apex
   c. Trunk, furcation, cervix, apex
   d. Cervix, trunk, apex, furcation
   e. Furcation, trunk, cervix, apex
6. When viewed from the proximal views, what is the location of the greatest bulge (crest of curvature or height of contour) on the facial surface of all teeth?
   a. Occlusal third
   b. Lingual third
   c. Buccal third
   d. Middle third
   e. Cervical third
7. Which space(s) contain(s) the part of the gingiva known as the interdental papilla?
   a. Buccal embrasure
   b. Occlusal embrasure
   c. Lingual embrasure
   d. Cervical embrasure
   e. Interproximal space

ANSWERS: *1–a, b; 2–a, b, c, d; 3–b, d; 4–a, b; 5–a; 6–e; 7–d, e*

SECTION VIII IDEAL OCCLUSION: INTER (BETWEEN) ARCH RELATIONSHIP OF TEETH

Occlusion [ah KLOO zhun] in dentistry refers to the relationship of the upper and lower teeth when they close together or contact one another during function or rest. Therefore, occlusion involves the contacting of occlusal and incisal surfaces of opposing maxillary and mandibular teeth. The word occlude literally means to close up or shut, as in closing your teeth together.

It is important to learn the relationships of teeth in ideal occlusion in order to identify malocclusions that could contribute to dental problems. The importance of proper occlusion cannot be overestimated. It is essential for both dental health and general health and for a patient's comfort and ability to speak, chew, and enjoy food. Understanding occlusion requires a knowledge not only of the relation of the lower jaw to the upper jaw but also of the jaw joints, their complexities, and the muscles, nerves, ligaments, and soft tissues that affect the position of the mandible. These topics will be covered in much more depth in Chapter 9. The arrangement of teeth within the dental arches (alignment, proximal contacts, and embrasure spaces) has been discussed in the previous section of this chapter, and the ideal relationship of the mandibular teeth to the maxillary teeth will be presented in this section.

Tooth relationships were described and classified as classes I, II, and III in the early 1900s by Edward H. Angle. He classified ideal occlusion as **class I** and defined it based on the relationship between the maxillary and mandibular dental arches. When defining class I occlusion, the teeth should be closed together in their **maximum intercuspal position**, or best fitting together of the teeth, as shown in *Figure 1-58*. This relationship can be achieved on handheld models when the maxillary teeth fit as tightly as possible against the mandibular teeth (i.e., are most stable). The following specific tooth relationships define class I ideal occlusion in the adult dentition:

- **Horizontal overlap of anterior teeth**: The incisal edges of maxillary anterior teeth horizontally overlap the mandibular teeth such that the incisal edges of maxillary teeth are labial to the incisal edges of mandibular teeth (best seen in Fig. 1-58).
- **Vertical overlap of anterior teeth**: The incisal edges of the maxillary anterior teeth extend below (overlap

FIGURE 1-58. Dental stone casts with adult teeth fitting together in the **maximum intercuspal position** (tightest fit). Notice that, from this view, each tooth has the potential for contacting two opposing teeth except the maxillary third molar. The vertical red line marks the relationship of first molars in **class I occlusion**: the mesiobuccal cusp of the maxillary first molar occludes in the mesiobuccal groove of the mandibular first molar. Also, the maxillary canine fits into the facial embrasure between the mandibular canine and first premolar.

vertically) the incisal edges of the mandibular teeth so that, when viewed from the facial, part of the incisal portion of mandibular incisors is hidden from view by the overlapping maxillary incisors (*Fig. 1-59*).

- **Relationship of posterior teeth**: Maxillary posterior teeth are positioned slightly buccal to mandibular posterior teeth (*Fig. 1-60*) so that:
  - The buccal cusp tips and buccal surfaces of the maxillary teeth are buccal to those in the mandibular arch.
  - The lingual cusps of maxillary teeth rest in occlusal sulcuses and fossae of the mandibular teeth.
  - The buccal cusps of the mandibular teeth rest in the occlusal sulcuses and fossae of the maxillary teeth.
  - The lingual cusp tips and lingual surfaces of the mandibular teeth are lingual to those in the maxillary arch.
- **Relative alignment**: The vertical (long) axis midline of each maxillary tooth is slightly distal to the vertical axis of its corresponding mandibular tooth type so that:
  - The tip of the mesiobuccal cusp of the maxillary first molar is aligned directly over the mesiobuccal groove (the mesial of two buccal grooves) on the mandibular first molar (the mesiobuccal cusp of tooth 14 fits into the mesiobuccal groove of tooth 19 in *Fig. 1-61*). This relationship of first molars (the first permanent teeth to erupt) is a **key factor in the definition of class I occlusion**. Further, the maxillary canine fits into the facial embrasure between the mandibular canine and first premolar.
  - Most teeth in an ideal dental arch have the potential for occluding with two teeth in the opposing arch. For example, the distal surface of the maxillary first

FIGURE 1-59. Maxillary and mandibular teeth of the permanent dentition are in the maximum intercuspal position. Observe the **interproximal spaces** filled with the **interdental papillae** between each pair of teeth. Notice how each tooth is in contact with its adjacent teeth, and how the midline between proximal contacts of the maxillary central incisors lines up with the midline between proximal contacts of the mandibular central incisors. Also, note how the incisal edges of maxillary anterior teeth overlap (**vertical overlap**) and hide the incisal edges of the mandibular anterior teeth, and how each of the relatively wide maxillary central incisors overlaps not only the narrow mandibular central incisor but also part of the mandibular lateral incisor (e.g., tooth 9 overlaps tooth 24 and part of 23).

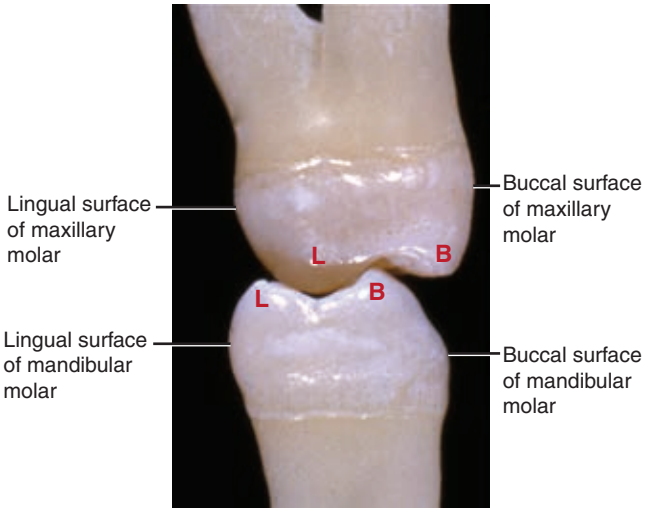


FIGURE 1-60. This proximal view of a maxillary and mandibular molar in normal interarch alignment reveals the alignment and position of buccal and lingual cusps in **ideal occlusion**.

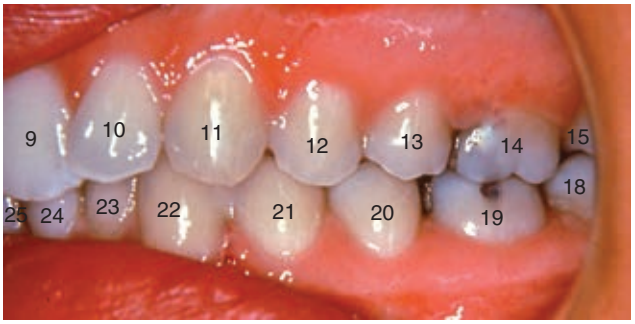


FIGURE 1-61. The left cheek has been drawn back to reveal how each of these maxillary teeth occludes with two opposing mandibular teeth. Tooth 19 has two buccal grooves: mesiobuccal (with a buccal filling) and distobuccal (not visible). Note that the mesiobuccal cusp of the maxillary first molar (tooth 14) occludes with the mesiobuccal groove on the mandibular first molar (19) and that the maxillary canine (11) fits into the facial embrasure between the mandibular canine (22) and the first premolar (21).

premolar (tooth 12 in Fig. 1-61) is posterior to the distal surface of the mandibular first premolar (tooth 21), and therefore, tooth 12 occludes with both the mandibular first and second premolar (teeth 20 and 21). Exceptions to this rule include the mandibular central incisor, which, due to its size and location, only occludes with the maxillary central incisor (as seen in Fig. 1-59), and the maxillary third molar, which only occludes with the mandibular third molar (Fig. 1-58).

To summarize, *ideal* occlusion involves a class I relationship between the maxillary and mandibular first molars in maximum intercuspal position. Also, ideally, there should be no large flattened chewing surfaces (facets) and no tooth grinding (bruxing) habits, bone loss, crooked teeth, loose teeth, or joint pain.[1] Classes II and III of occlusion and malocclusion (literally meaning bad occlusion) will be discussed in detail in Chapter 9.

REVIEW Questions about Occlusion

These questions are to help you confirm that you understand the terms and concepts presented in this section. More than one answer may be correct.

1. Ideal class I occlusion involves an important first permanent molar relationship where the mesiobuccal cusp of the maxillary first molar is located within the
   a. Mesiobuccal groove of the mandibular first molar.
   b. Distobuccal groove of the mandibular first molar.
   c. Buccal groove of the mandibular second molar.
   d. Mesiobuccal groove of the mandibular second molar.
   e. Distobuccal groove of the mandibular second molar.
2. Where do lingual cusps of maxillary teeth occlude in ideal class I occlusion?
   a. In the buccal embrasure space between mandibular teeth
   b. In the lingual embrasure space between mandibular teeth
   c. In occlusal fossae of mandibular teeth

ANSWERS: *1–a; 2–c*

SECTION IX TOOTH DEVELOPMENT FROM LOBES

Tooth crowns develop from lobes or primary growth centers (*Fig. 1-62*). Most normal teeth show evidence of having developed from three to five lobes. As a general rule, the facial portion of **anterior teeth** (incisors and canines) forms from three lobes, and the lingual cingulum area forms from one lobe. Evidence of three facial lobes can sometimes be seen as a labial ridge separated from the rest of the facial surface by two shallow depressions dividing the facial surface into three parts (seen clearly on a maxillary central incisor in *Fig. 1-63A*) or three mamelons on an incisal edge (*Fig. 1-63B*). To summarize, anterior teeth normally develop from four lobes: three facial lobes and one lingual lobe forming the cingulum.

As on anterior teeth, the *facial* portion of the facial cusp of a **premolar** forms from three lobes, often evident by a buccal ridge and a depression on either side dividing the facial surface into three parts. Each *lingual* cusp forms from one lobe. Therefore, a two-cusp-type premolar forms from four lobes: three facial and one lingual, the same as for an anterior tooth. However, a three-cusp-type premolar with two lingual cusps forms from five lobes: three facial and two lingual, one for each lingual cusp.

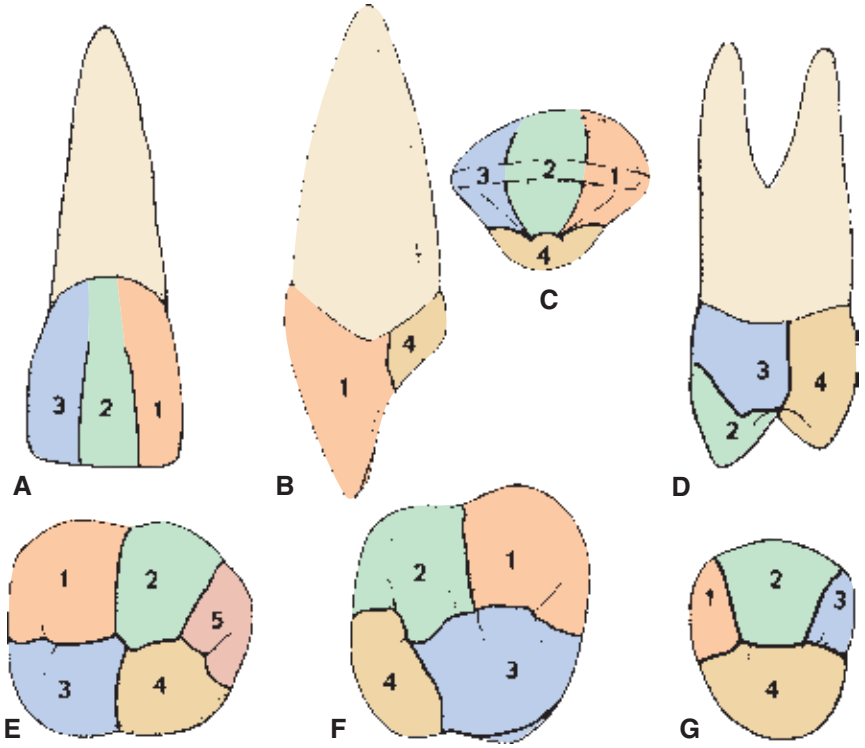


FIGURE 1-62. **Lobes** or primary anatomic divisions on teeth. Drawings **(A)**, **(B)**, and **(C)** show the facial, mesial, and incisal views of a maxillary central incisor that, like all *anterior teeth*, forms from *four* lobes. The lingual cingulum develops from one lobe (labeled 4) seen in views **(B)** and **(C)**. Mamelons may appear on the incisal edge of newly erupted incisors, an indication of the three labial lobes. Drawings **(D)** and **(G)** are the mesial and occlusal view of a *two-cusped premolar* that also forms from *four* lobes. As with anterior teeth, the facial cusp forms from three lobes, and one lingual lobe forms the lingual cusp. The divisions between the facial and lingual lobes are evidenced by the marginal ridge developmental grooves. **Each cusp of a molar is formed by one lobe**. Drawing **(E)** is a mandibular first molar with five lobes, three buccal, and two lingual, which is one lobe per cusp. Drawing **(F)** is a maxillary first molar with three larger lobes and one smaller lobe, or one per cusp. A very small fifth (Carabelli) cusp, when large enough, may have formed from a separate lobe.

As a general rule, each **molar** cusp forms from one lobe. For example, maxillary or mandibular molars with five cusps form from five lobes, and those with four cusps form from four lobes. Some maxillary molars have as few as three cusps and form from three lobes. A small fifth cusp (of Carabelli) may also be present on some maxillary molars, and when it is large, it may have formed from a separate lobe.

Two types of tooth unusual occurrences (called anomalies), peg-shaped maxillary lateral incisors (seen later in Chapter 11) and some extra teeth (also called supernumerary teeth), form from less than three lobes. Guidelines for determining the number of lobes that form each tooth are presented in *Table 1-5*.

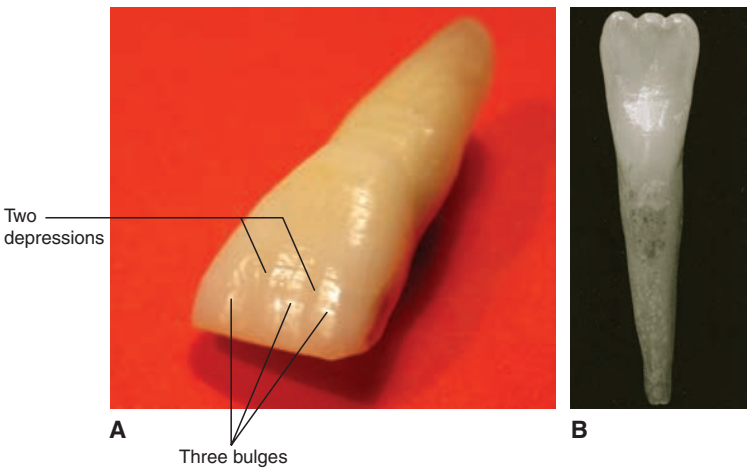


FIGURE 1-63. **A.** The light reflecting off of this maxillary central incisor reveals the *three bulges* reflecting the formation of the facial surface by three facial lobes. The three bulges are separated by two depressions. **B.** This mandibular incisor with *three* mamelons reflects its formation from three facial lobes.

TABLE 1-5 Guidelines for Determining the Number of Lobes Forming Adult Tooth

ANTERIOR TEETH AND PREMOLARS

TOOTH CLASS	NO. LINGUAL CUSPS OR CINGULUM	NO. OF LOBES (FACIAL AND LINGUAL)
All anterior teeth	1 Cingulum	3 + 1 = **4**
Two-cusped premolars	1 lingual	3 + 1 = **4**
Three-cusped premolars	2 lingual	3 + 2 = **5**

Guideline for determining the number of lobes for anterior teeth and premolars:
Number of lobes = 3 facial lobes + 1 lobe per lingual cusp or cingulum

MOLARS

MOLAR BY NUMBER OF CUSPS	NO. TOTAL CUSPS	NO. OF LOBES
Three-cusped molars	3	3
Four-cusped molars	4	4
Five-cusped molars (including large Carabelli cusps)	5	5

Guideline for determining the number of molar lobes:
Number of molar lobes = 1 per cusp (including Carabelli if large)

? REVIEW Questions about Lobes

These questions were designed to help you confirm that you understand the terms and concepts presented in this section. More than one answer may be correct.

1. How many developmental lobes form a premolar with two cusps (one buccal cusp and one lingual cusp)?
   a. 1
   b. 2
   c. 3
   d. 4
   e. 5

2. How many developmental lobes form a maxillary molar with three cusps (two buccal cusps and one lingual cusp)?
   a. 1
   b. 2
   c. 3
   d. 4
   e. 5

3. How many developmental lobes form a three-cusped premolar with one buccal cusp and two lingual cusps?
   a. 1
   b. 2
   c. 3
   d. 4
   e. 5

4. How many developmental lobes form a mandibular lateral incisor?
   a. 1
   b. 2
   c. 3
   d. 4
   e. 5

5. What separates the portions of tooth formed by different lobes?
   a. Supplemental grooves
   b. Mamelons
   c. Cusp ridges
   d. Transverse ridges
   e. Developmental grooves

ANSWERS: *1–d; 2–c; 3–c; 4–d; 5–e*

SECTION X INTERESTING VARIATIONS IN ANIMAL TEETH COMPARED TO HUMAN TEETH USING DENTAL FORMULAE

A *dental formula* for the human primary dentition can be represented by placing the abbreviation for incisors (I) followed by an upper number representing the number of incisors in an upper quadrant over a bottom number representing the number of incisors in a lower quadrant (I 2/2), then the number of canines (C) in an upper and lower quadrant (C1/1), and then the number of molars (M) in an upper and lower quadrant (M2/2). The formula used to represent teeth in the human primary dentition is as follows:

$$I\frac{2}{2}C\frac{1}{1}M\frac{2}{2} = 5 \text{ upper and } 5 \text{ lower teeth in each quadrant; } 20 \text{ teeth in all four quadrants}$$

The dental formula for the human permanent dentition, adding the new abbreviation for premolars (PM), is as follows:

$$I\frac{2}{2}C\frac{1}{1}PM\frac{2}{2}M\frac{3}{3} = 8 \text{ upper and } 8 \text{ lower teeth in each quadrant, } 32 \text{ teeth in all four quadrants}$$

It is interesting to note that the dentition of animals can be represented by the same type of formula as described above. Look at the formulas for animals in *Table* 1-6, and note that cows have no upper incisors or upper canines. They have three upper and three lower premolars on each side. Did you know that dogs have twice as many premolars as humans if you include uppers and lowers, as well as the right and left sides? Did you know that the tusks on an elephant are maxillary central incisors? Elephants have the largest diastema in the world, large enough for the massive trunk between their central incisors.

TABLE 1-6 Some Dental Formulae (Order of Teeth per Quadrant) and Interesting Facts about Teeth in Animals[2–4]

Humans, Old World monkeys, and apes	$I\frac{2}{2}C\frac{1}{1}P\frac{2}{2}$	$M\frac{3}{3}$	Porcupines and beavers	$I\frac{1}{1}C\frac{0}{0}P\frac{1}{1}$	$M\frac{3}{3}$
New World monkeys	$I\frac{2}{2}C\frac{1}{1}P\frac{3}{3}$	$M\frac{3}{3}$	Bears and pandas	$I\frac{3}{3}C\frac{1}{1}P\frac{4}{4}$	$M\frac{2}{3}$
Dogs, wolves, and foxes	$I\frac{3}{3}C\frac{1}{1}P\frac{4}{4}$	$M\frac{2}{3}$	Squirrels	$I\frac{1}{1}C\frac{0}{0}P\frac{2}{1}$	$M\frac{3}{3}$
Cats	$I\frac{3}{3}C\frac{1}{1}P\frac{3}{2}$	$M\frac{1}{1}$	Rabbit‡	$I\frac{2}{1}C\frac{0}{0}P\frac{3}{2}$	$M\frac{3}{3}$
Cows	$I\frac{0}{3}C\frac{0}{1}P\frac{3}{3}$	$M\frac{3}{3}$	Mice and rats	$I\frac{1}{1}C\frac{0}{0}P\frac{0}{0}$	$M\frac{3}{3}$
Horses and zebra*	$I\frac{3}{3}C\frac{1}{1}P\frac{4}{4}$	$M\frac{3}{3}$	Moles	$I\frac{3}{3}C\frac{1}{1}P\frac{4}{4}$	$M\frac{3}{3}$
Walruses	$I\frac{1}{0}C\frac{1}{1}P\frac{3}{3}$	$M\frac{0}{0}$	Vampire bats	$I\frac{1}{2}C\frac{1}{1}P\frac{2}{3}$	$M\frac{0}{0}$
Elephants†	$I\frac{1}{0}C\frac{0}{0}Dm^{\dagger}\frac{3}{3}$	$M\frac{3}{3}$	Shrews	$I\frac{3}{1}C\frac{1}{1}P\frac{3}{1}$	$M\frac{3}{3}$

*Pigs and hippopotami have the same formula, except that they have two or three upper and two or three lower incisors.

†Elephants have deciduous molars (Dm) but no premolars. An elephant's skull is not larger than necessary to house its brain. The size is needed to provide mechanical support for the tusks (one third of their length is embedded in the skull) and the enormous molars. Each molar weighs about 9 pounds and is nearly a foot long mesiodistally on the occlusal surface. Tusks (the central incisors) can be as long as 1½ feet and weigh 440 pounds.[5]

‡Guinea pigs have the same formula, except that they have only one maxillary incisor.

The beaver has four strong curved incisors. They have very hard, bright orange enamel on the labial surface and much softer exposed dentin on the lingual surface. As the dentin wears off, this leaves very sharp cutting edges of enamel. The incisors continue to grow throughout life. The posterior teeth have flat, rough edges on the occlusal surface, and they stop growing at 2 years of age. There is a large diastema immediately posterior to the incisors, and flaps of skin fold inward and meet behind the incisors to seal off the back part of the mouth during gnawing.

Therefore, splinters are kept out. The flaps of skin relax for eating and drinking.

The shrew has two hooked cusps on the upper first incisor. Its primary dentition is shed in utero. The shrew's 1- to 1½-year life span is limited by the wear on their molars. Death occurs by starvation once the molars wear out. Also, their small body can store only enough food for 1 to 2 h, so they must feed almost continually. Their diet consists of small invertebrates, woodlice, and fruit.

The vampire bat has large canines, but its highly specialized upper incisors, which are V shaped and razor edged, are what remove a piece of the victim's skin. The bat's saliva contains an anticoagulant, and its tongue rolls up in a tube to suck or lap the exuding blood.

Some vertebrates do not have any teeth (complete anodontia) but have descended from ancestors that possessed teeth. Birds have beaks but depend on a gizzard to do the grinding that molars would usually perform. Turtles have heavy jaw coverings, which are thin edged in the incisor region and wide posteriorly for crushing. The duck-billed platypus has its early-life teeth replaced by keratinous plates, which it uses to crush aquatic insects, crustaceans, and mollusks. The whalebone whale and anteaters also have no teeth, but their diets do not require chewing.

LEARNING EXERCISE 1

Sketch a tooth and adjacent gingiva in cross section, and label the following structures: enamel, dentin, cementum, root canal, pulp chamber, apical foramen location, dentinoenamel junction, cementoenamel junction, dentinocemental junction, periodontal ligament space, alveolar bone, gingiva, gingival sulcus, anatomic crown, and anatomic root. Use Figures 1-10 and 1-12 as a guide.

LEARNING EXERCISE 2

Identify the teeth visible in *Figure 1-64* using the Universal Numbering System. Remember that as you are viewing this mouth, the left side of the photograph is the right side of the mouth. Begin with the second molar in the maxillary arch and continue to the central incisor. Then drop to the mandibular central incisor and continue numbering back to the mandibular second molar. Compare your responses to the answers that follow. Then identify the same teeth using the International System and finally the Palmer System.

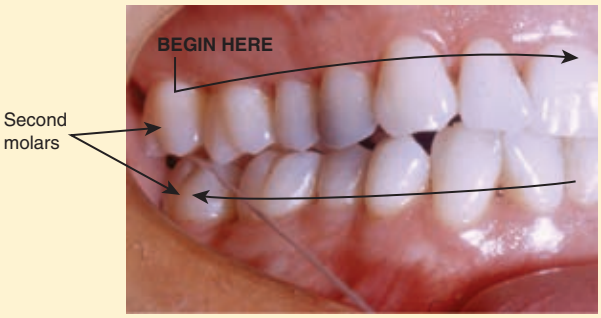


FIGURE 1-64. As per the directions for this learning exercise, identify all visible teeth using the Universal number. Then identify the same teeth using the International System, then the Palmer System.

Answers.

Universal tooth numbers for teeth in order:

2, 3, 4, 5, 6, 7, 8; 25 for central incisor, 26, 27, 28, 29, 30, 31. The correct numbers using the International System are 17, 16, 15, 14, 13, 12, 11; 41 for central incisor, 42, 43, 44, 45, 46, 47. Then, use Table 1-1 to confirm the correct method for identifying each of these teeth using the Palmer System.

LEARNING EXERCISE 3

Identify the teeth visible in *Figure 1-65* using the Universal Numbering System, beginning with the maxillary first molar on the left side of the photograph, and continue numbering through the maxillary first molar on the right side. Then drop down to the mandibular first molar and continue numbering through the first molar on the other side (*Fig. 1-66*).

LEARNING EXERCISE 3 *(continued)*

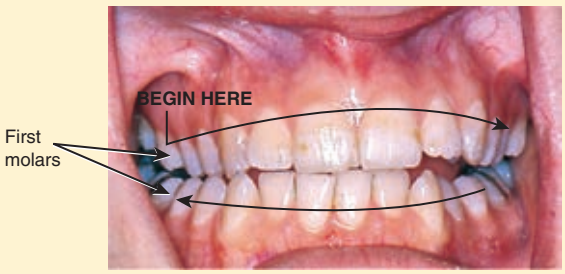


FIGURE 1-65. As per the directions for this learning exercise, name each structure. Then identify the same teeth using the International System, then the Palmer System.

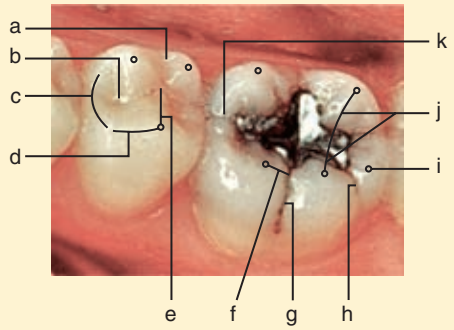


FIGURE 1-66. As per the directions for this learning exercise, name each structure on this mandibular left second premolar with three cusps (cusp tips denoted by three small circles) and this mandibular left first molar with five cusps (cusp tips denoted by five small circles).

Answers:

Universal tooth numbers for teeth in order:

3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14; then 19 for mandibular first molar, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30. The correct numbers using the International System are as follows: 16, 15, 14, 13, 12, 11, 21, 22, 23, 24, 25, 26; then 36 for mandibular left first molar, 35, 34, 33, 32, 31, 41, 42, 43, 44, 45, 46. Then use Table 1-1 to confirm the correct method for identifying each of these teeth using the Palmer System.

LEARNING EXERCISE 4

One tooth in Figure 1-66 is a mandibular left second premolar with three cusps (cusp tips are indicated by the three small circles), and the other tooth is a mandibular left first molar with five cusps (cusp tips indicated by five small circles). Based on this information, you should be able to identify each of the structures (except maybe i) indicated in Figure 1-66. Confirm your answers below.

Answers: (a) Lingual groove; (b) mesial pit; (c) mesial marginal ridge; (d) mesial cusp ridge of the buccal cusp; (e) triangular ridge of the buccal cusp; (f) distal cusp ridge of the mesiobuccal cusp; (g) mesiobuccal groove; (h) distobuccal groove; (i) distal cusp tip; (j) transverse ridge made up of the triangular ridges of the distobuccal cusp and the distolingual cusp; (k) mesial marginal ridge groove.

CRITICAL Thinking

1. A. Using good light source (like a small flashlight), a large mirror (magnifying if possible), and a small, clean disposable dental mirror (which can be purchased from most drug stores), evaluate the facial and lingual surfaces of a **maxillary right lateral incisor** in your own mouth. Describe the tooth in as much detail as possible trying to use as many of the terms presented in this chapter as possible. Underline each term you use. For example, "There is a pit on the lingual or palatal surface in the cervical or gingival third in the lingual fossa adjacent to the cingulum that is deeply stained."

   B. Repeat this exercise for the maxillary left lateral incisor, then the maxillary right central incisor, and finally the maxillary left central incisor.

2. This exercise is designed to assure student mastery of the three common systems used to identify teeth.

   A. In the chart that follows, record the **Universal tooth number** to identify each of the four permanent first molars. Next, identify each of these teeth using the **International System**. Finally, use the **Palmer System**.

	Maxillary Right First Molar	Maxillary Left First Molar	Mandibular Left First Molar	Mandibular Right First Molar
Universal				
International				
Palmer				

   B. In this chart, record the correct answers for each of the four permanent central incisors.

	Maxillary Right Central Incisor	Maxillary Left Central Incisor	Mandibular Left Central Incisor	Mandibular Right Central Incisor
Universal				
International				
Palmer				

3. Obtain a model of someone's complete adult dentition from your dentist or orthodontist. Evaluate the shape of each tooth to confirm which teeth are present. On this model, answer each of the following questions: Do all incisors have marginal ridges and lingual fossa? Do the maxillary canines have distinct facial ridges? Do they have a distinct lingual ridge? Do mandibular canines have distinct marginal ridges and lingual fossae? Do any of the premolars have three cusps? If so, are they mandibular second premolars? Do any premolars have a lingual cusp that is so short it is almost nonexistent? If so, are they mandibular first premolars? Do all first molars have five cusps? What are their Universal numbers?

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1. Advanced Topics about the Embryology and Mineral Content of Tooth Tissues

When you study tooth embryology, you will learn that there are three cell layers in the forming embryo: the outer **ectoderm**, the middle **mesoderm**, and the inner **endoderm**. Some outer ectodermal cells form an enamel organ. Enamel develops from the enamel organ (ectoderm) and is a product of specialized epithelial cells called **ameloblasts** [ah MEL o blasts]. Some mesodermal cells form a *dental sac* with specialized cells called **cementoblasts** [se MEN toe blasts] that produce cementum. Other mesodermal cells form a *dental papilla* with specialized cells called **odontoblasts** [o DON tow blasts] that produce dentin. **Odontoblasts**, dentin-building cells, are located at the junction between the pulp and dentin. Odontoblasts can continue to form new dentin over a lifetime (called **secondary dentin**), and when a tooth is traumatized (as from decay), the odontoblasts can form a type of dentin called **reparative dentin**.

The three tooth tissues differ in their hardness since each contains a different amount of mineral content, primarily hydroxyapetite. Enamel, the hardest tissue, is 95% calcium hydroxyapetite (mineralized and calcified) and only 5% water and enamel matrix. Mature dentin is composed of about 70% calcium hydroxyapetite, 18% organic matter (collagen fibers), and 12% water. Cementum is composed of 65% calcium hydroxyapetite, 35% organic matter (collagen fibers), and 12% water. (Another author, Melfi, states that the mineral content of cementum is only about 50%.)

Dr. Woelfel's Original Research Data

Data obtained from Dr. Woelfel's original research on tooth dimensions were used to draw conclusions throughout this book. Average measurements obtained on a sample of 4572 extracted teeth obtained from dentists in Ohio from 1974 through 1979 are presented here in *Table 1-7*. Root lengths were measured from the cervical line to the apex of the root. On maxillary molars with two buccal and one lingual root, the measurements were taken to the tip of the longest buccal root, usually the mesiobuccal. On mandibular molars with two roots, a mesial and distal, the measurement was taken to the apex of the longest root, usually the mesial root. On two-rooted premolars, measurements were taken to the apex of the buccal root.

TABLE 1-7 Average Measurements on 4572 Extracted Teeth Obtained From Ohio Dentists during a Study by Dr. Woelfel and his First-Year Dental Hygiene Students of the Ohio State University College of Dentistry, 1974–1979

	CROWN LENGTH (MM)	ROOT LENGTH (MM)	ROOT-TO-CROWN RATIO	OVERALL LENGTH (MM)	CROWN WIDTH MD (MM)	CERVIX WIDTH MD (MM)	CROWN WIDTH FL (MM)	CERVIX WIDTH FL (MM)	MESIAL CERVICAL CURVE (MM)	DISTAL CERVICAL CURVE (MM)
MAXILLARY TEETH										
Central incisor (398)	**11.2**[A]	13.0	1.16	23.6	8.6	6.4	7.1	6.3	**2.8**[H]	2.3
Lateral incisor (295)	9.8	13.4	1.37	22.5	6.6	4.7	6.2	5.8	2.5	1.9
Canine (321)	10.6	**16.5**[C]	1.56	**26.3**[D]	7.6	5.6	8.1	7.6	2.1	1.4
First premolar (234)	8.6	13.4	1.56	21.5	7.1	4.8	9.2	8.2	1.1	0.7
Second premolar (224)	7.7	14.0	1.82	21.2	6.6	4.7	9.0	8.1	0.9	0.6
First molar (308)	7.5	12.9 MB root 12.2 DB 13.7 L	1.72	20.1	10.4	7.9	**11.5**[G]	10.7	0.7	0.3
Second molar (309)	7.6	12.9 MB root 12.1 DB 13.5 L	1.70	20.0	9.8	7.6	11.4	10.7	0.6	0.2
Third molar (305)	7.2	10.8 MB root 10.1 DB 11.2 L	1.49	17.5	9.2	7.2	11.1	10.4	0.5	0.2
Avg. for 2392 upper teeth	8.77	13.36	1.55	21.59	8.23	6.11	9.20	8.48	1.40	0.97
MANDIBULAR TEETH										
Central incisor (226)	8.8	12.6	1.43	20.8	**5.3**[E]	3.5	5.7	5.4	2.0	1.6
Lateral incisor (234)	9.4	13.5	1.43	22.1	5.7	3.8	6.1	5.8	2.1	1.5
Canine (316)	**11.0**[B]	15.9	1.45	25.9	6.8	5.2	7.7	7.5	2.4	1.6
First premolar (238)	8.8	14.4	1.64	22.4	7.0	4.8	7.7	7.0	0.9	0.6
Second premolar (227)	8.2	14.7	1.80	22.1	7.1	5.0	8.2	7.3	0.8	0.5
First molar (281)	7.7	14.0 M root 13.0 D	1.83	20.9	**11.4**[F]	9.2	10.2	9.0	0.5	0.2
Second molar (296)	7.7	13.9 M root 13.0 D	1.82	20.6	10.8	9.1	9.9	8.8	0.5	0.2
Third molar (262)	7.5	11.8 M root 10.8 D	1.57	18.2	11.3	9.2	10.1	8.9	0.4	0.2
Avg. for 2180 lower teeth	8.62	13.85	1.62	21.61	8.17	6.24	8.22	7.44	1.20	0.80

Size ranges are shown in tables in each chapter.
Key for Tooth Surface Abbreviations: D, distal; DB, distobuccal; FL, faciolingually; L, lingual; M, mesial; MB, mesiobuccal; MD, mesiodistal.
A, longest crown by Woelfel; B, longest crown by Kraus; C, longest root: D, longest tooth overall; E, narrowest crown mesiodistally; F, widest crown mesiodistally; G, widest crown faciolingually; H, greatest cervical line curve.