Chapter 7: Anatomy and Physiology

A thorough understanding of dental and oral anatomy and physiology is essential for all members of the veterinary dental team. You must know what is normal and be able to quickly recognize the abnormal. Often, an unsedated animal will allow you only a brief look in the mouth and so you must be able to take a mental snap-shot and notice subtle indicators of disease. Much of this ability will come with practice, but it starts here, by studying comparative dental anatomy and becoming familiar with the language of dentistry. This is but a brief introduction.

I had wanted to write this as two separate chapters, but the two subjects are so intimately intertwined that I could not discuss one without discussing the other.

Terminology

In dentistry, attention to detail is essential. Nowhere more so than in charting. We must all keep accurate records of findings and treatments if we are to communicate with other staff members and the owners and to assess the progress of any condition. To make this task easier, there are a number of terms to describe parts of the mouth and teeth as well as to describe which tooth is being discussed.

Each tooth has a *crown* and a *root*. The tip of the root is the *apex* so moving toward the tip of the root is to move *apically*. Around the apex is the *peri-apical* region. Where the root and the crown meet is the *neck* or *cervical region* of the tooth. It is in this area that the enamel covering of the crown ends at the *cemento-enamel junction*. The crown of the tooth is that portion covered by enamel. As you travel from the neck to the tip or *cusp* of the crown, you are traveling *coronally*.

The face of the tooth towards the lips or cheek is the *labial* or *buccal* aspect. 'Labial' is usually reserved for incisors and canines and 'buccal' is used for the 'cheek teeth'. The surfaces facing the tongue and palate are the *lingual* and *palatal* aspects respectively.

The surface of the tooth closest to the tooth behind it is the *distal* aspect and the surface closest to the tooth in front is the *mesial* aspect. With the incisors, being arranged more medio-lateral than rostro-distal, call the surface closest to the facial mid-line mesial and the surface furthest from the mid-line distal.

In multi-rooted teeth there is a place where the roots come together to join the rest of the tooth. This crotch-like area is called the *furcation*.

Each tooth has its own name, and there are several systems that have been used. The American Veterinary Dental College, American Veterinary Dental Society and Academy of Veterinary Dentistry have all agreed to recognize two systems.

In the *Anatomical System*, I, C, P and M denote permanent incisor, canine, premolar and molar respectively. Primary teeth are denoted by lower case letters (i, c, p, and m). The specific tooth is indicated by an Arabic numeral and the quadrant by the location of the numeral with respect to the letter. Therefore, the right upper third permanent premolar is referred to as P^3; P for permanent premolar, 3 for third and placed superscript to the right of the letter to indicate the right maxillary quadrant. Supernumerary teeth are identified by an S or s preceding the appropriate upper or lower case letter. So, s_2i would be a supernumerary left mandibular second primary incisor.

The anatomic system works well visually but is a bit clumsy for verbal communication and does not lend itself easily to computerized records. In these instances, the *Modified Triadan System* is

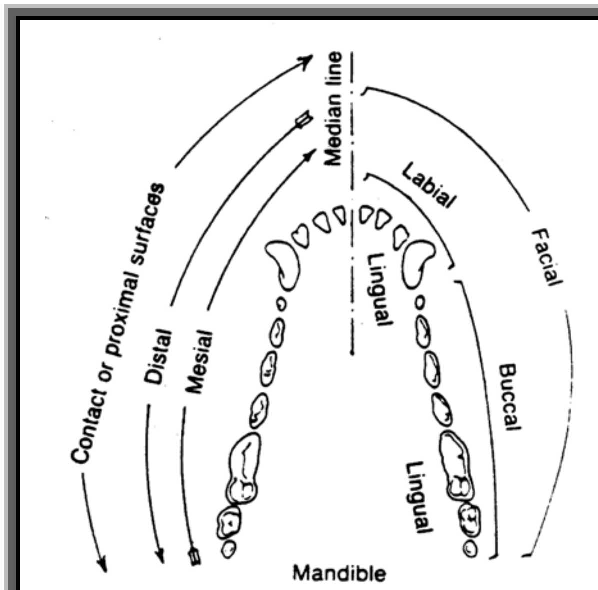

Figure #7.1. The names of the faces of the teeth.

useful. It refers to each tooth by a three-digit number. The first numeral indicates the quadrant and the next two tell which tooth in the quadrant as counted from the midline to distal.

The number sequence of the quadrants is; permanent upper right = 1, permanent upper left = 2, permanent lower left = 3, permanent lower right = 4, primary upper right = 5, primary upper left = 6, primary lower left = 7, and primary lower right = 8. In each quadrant the first incisor is always 01, the second is 02 and so on. So the right upper fourth permanent premolar is 108, the left mandibular third primary premolar is 707 and the right lower permanent third molar is 411.

Upper Right Permanent=1 Upper Right Primary=5	Upper left permanent=2 Upper left primary=6
Lower Right Permanent=4 Lower Right Primary=8	Lower Left Permanent=3 Lower Left Primary=7

When it comes to the cat, things are not as straight forward. The cat is missing the upper first and the lower first and second premolar teeth and so have second, third and fourth upper and third and fourth lower premolars only. Each quadrant has only one molar. When counting the teeth in the right upper quadrant, with tooth 105 absent, the sequence would go 101, 102, 103, 104, 106, 107, 108, 109. For the lower left quadrant, with the first and second premolar missing, the sequence goes 301, 302, 303, 304, 307, 308, 309. The sample dental in Appendix D show the full adult dentition of the dog and cat and the primary dentition for the dog, with each tooth numbered for reference. Interestingly, most felines, from domestic cats up to lions and tigers have the same dental formula.

The Rule of 4 and 9 states that every tooth ending in 04 is a canine tooth and every tooth ending in 09 is the first molar. The rule of 9 and 4 makes it easy to remember the numbers of each tooth without having to go back to the first incisor and count around to the tooth in question. For example, tooth 107 has to be a premolar because it is greater than 104 (the canine) and less than 109 (the first molar). When identifying a tooth, you can start to count from the midline (at 01), at the canine (at 04) or at the first molar (at 09), so you have three known landmarks for orientation. This rule and the modified Triadan system work perfectly for every quadruped mammal, so long as teeth that are absent get left out of the counting sequence.

The Tooth

The tooth is the basic unit of concern in dentistry. Therefore, any study of dentistry must start with an understanding of the anatomy and physiology of the tooth. In veterinary dentistry, there is a wide range of tooth types and morphologies, but this discussion will focus on a simple, single rooted tooth as might be found in humans, dogs and cats.

Each tooth has a *crown* (the portion above the normal gingival margin) and a *root* (the portion below the normal gingival margin). The bulk of a mature tooth is composed of *dentin*. The dentin of the crown is covered by *enamel* and the dentin of the root is covered by *cementum*. The cementoenamel junction marks the transition from root to crown and is known as the *neck*, *cervix* or *cervical region* of the tooth. Inside the dentin of the root and the crown is a hollow chamber filled with the soft tissue known as *pulp*. This chamber is referred to as the *pulp chamber* in the crown and the *root canal* within the root of the tooth.

In a multi-rooted tooth, the crotch-like area where the roots diverge from the crown is known as the *furcation*. This is a very important landmark with respect to periodontal disease. Once gingival recession, bone loss or pocket formation expose the furcation, getting and keeping the tooth thoroughly clean becomes much more challenging.

The roots of the teeth reside in depressions in the maxillary, incisive and mandibular bones, known as the *alveoli*. The walls of the alveolus are composed of dense, cortical bone known as the *lamina dura* or *alveolar bone proper*. Between the cementum of the root and the lamina dura is the *periodontal ligament space*, occupies by the *periodontal ligament*. This ligament holds the tooth in place while affording some movement, thus acting as a shock absorber.

Enamel

Enamel is the hardest tissue in the mammalian body. It is composed of crystals of hydroxyapatite arranged in prisms roughly perpendicular to the junction with the underlying dentin. The closely packed crystals occupy 88% of the volume of the enamel, the remaining 12% being water and organic material. By weight, enamel is 96% mineral. It is acellular and considered non-living.

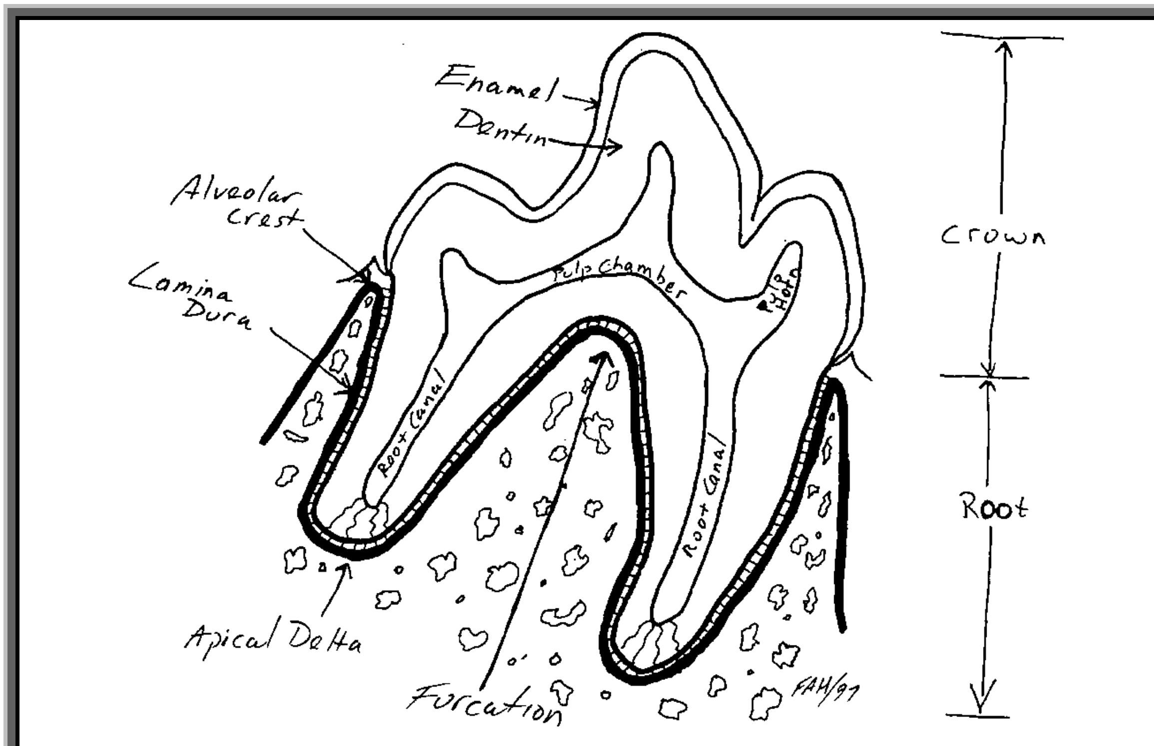

Figure #7.2. Line drawing of the right mandibular first molar (tooth 409) in a dog. Note how the shape of the pulp chamber mimics the shape of the crown, such that an innocent looking chip fracture of a cusp may still cause a pulp exposure or a near exposure.

Figure #7.3. This radiograph of the maxillary incisors of a young dog shows abnormal root development. Clinically, the dog had enamel hypocalcification and the teeth were loose.

Enamel is formed by *ameloblasts* during tooth development. Amelogenesis (enamel production) stops prior to tooth eruption and no more enamel is produced. Once the tooth has erupted into the oral cavity, enamel is lost gradually (or rapidly if the animal has a chewing vice) to chemical and mechanical forces.

Anything that disrupts the delicate ameloblasts during enamel production will result in defective enamel, which may be very weak and brittle. This defective enamel may be present at eruption but will soon be lost to abrasive forces. This leaves an area of exposed dentin and rough margins to the surrounding enamel. This *enamel hypocalcification* may affect a spot on a single tooth if the insult is localized (e.g., infection from a fractured deciduous tooth, iatrogenic from careless deciduous tooth extraction, bruising from local facial trauma). Many systemic conditions, such as hypoproteinemia, pyrexia, epitheliotrophic virus infection can cause widespread enamel hypocalcification on the areas of the teeth that are undergoing amelogenesis during the time of the illness. This often appears as a band of abnormal enamel encircling the teeth with the enamel produced before the illness and that produced after the illness looking perfectly normal.

Serious systemic illnesses may also cause hypoplasia of the root structure of the permanent teeth and so affected animals require radiographic assessment. Genetic abnormalities such as dentinogenesis imperfecta also result in abnormal root structure development.

Enamel hypoplasia is a different condition in which the enamel produced is properly mineralized and is shiny and hard like normal enamel, but it is thinner. Often, there is a terracing effect as one proceeds from the normal enamel, down the stairs to the bottom of the lesion and then back up the stairs to the normal enamel on the other side.

Dogs and cats have a relatively thin layer of enamel compared to humans. A study (Crossely DA. Tooth enamel thickness in the mature dentition of domestic dogs and cats - preliminary study. J Vet Dent. 12(3): 111 - 113, 1995) found that the enamel of most cat teeth ranges from <0.1 to 0.3 mm. In dogs, the range for most teeth was <0.1 to 0.6 mm whereas in humans, the enamel on occlusal tables is usually 1 to 2 mm thick.

Enamel is *relatively* non-porous, impervious and smooth and therefore relatively easy to clean and slow to stain. It acts as an effective barrier to prevent bacteria in the oral cavity from reaching the pulp tissues. Enamel has no sensory capacity and so it protects the underlying tissues from mechanical and chemical irritation.

Enamel, though hard, is brittle, tending to shear along the planes of the prisms. A tooth composed entirely of enamel would fracture easily as it has no elasticity or flexibility. It is common to see fine dark brown lines along the distal surfaces of the canine teeth of large dogs. These represent superficial cracks in the enamel indicating that the tooth has been bent or distorted enough to cause cracks in the enamel but not enough to fracture the more flexible underlying dentin. These lines, though unsightly are of no clinical significance. They do, however, indicate that the patient is putting his/her teeth under some strain and may have habits that put the tooth at risk of crown fracture. A discussion with the owner would be in order to identify and remove the causes of the stress. Common causes include playing tug-of-war and other activities that see the dog grab firmly with the canine teeth and pull back such as Shutzhund training.

Dentin

Dentin, which makes up the bulk of canine, feline and human teeth is about as hard as bone but much softer than enamel. It is pale yellow in colour, compared to the stark white of normal enamel. Dentin is roughly 72% mineral, 18% organic matter (mostly collagen) and 10% water by weight.

Dentin is arranged as a collection of tubules running from the pulp towards the enamel. The tubules are roughly 4µm in diameter near the pulp and narrow to 1µm near the enamel.

Lining the inner aspect of the dentin wall is a layer of cells known as *odontoblasts*. These cells have cytoplasmic extensions going into the lumens of the tubules running all the way to the enamel of the crown and the cementum of the root. Therefore, dentin is considered a living tissue. In some of the tubules, unmyelinated

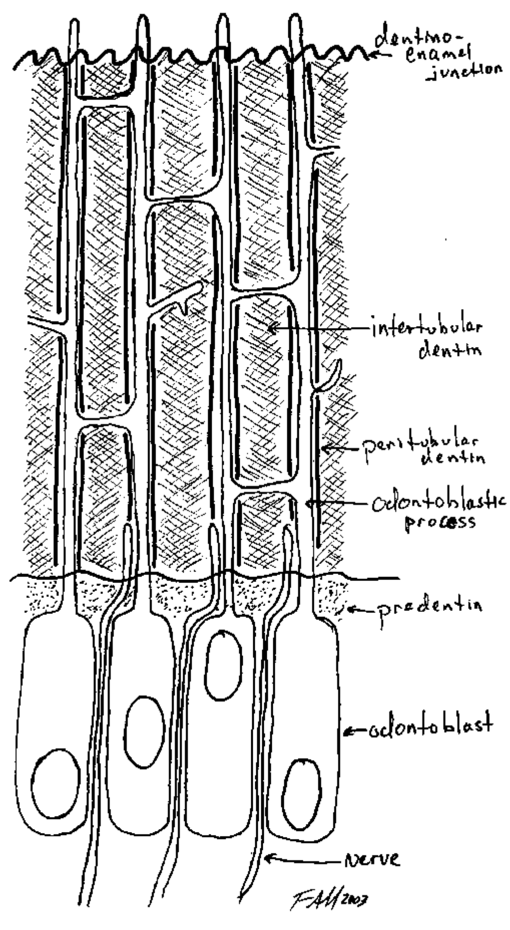

Figure #7.4. Odontoblasts with odontoblastic processes extending into the dentin tubules to reach the dentinoenamel junction. Note also the nerve fibers extending into the tubules. Any fracture that involves dentin will involve damage to the odontoblasts. Tooth survivability depends on many factors.

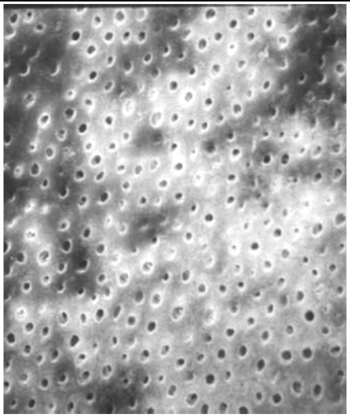

Figure #7.5. Electronphotomicrograph of a freshly cut dentin surface showing the exposed lumens of the dentin tubules. In a healthy tooth, each of these pores would contain an odontoblastic process and so any dentin exposure constitutes pulp exposure at the microscopic level. In some cases, the pulp can deal with this, in others, it cannot.

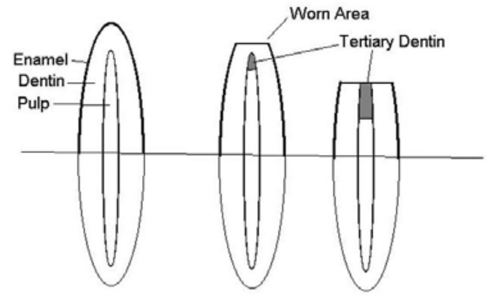

Figure #7.6. Development of darker tertiary dentin within a tooth undergoing gradual wear. As long as the rate of wear is slower than the rate of tertiary dentin production, the tooth may survive. If the rate of wear exceeds the rate of tertiary dentin production, the pulp will die, necessitating extraction or root canal treatment.

nerve fibers lie alongside the *odontoblastic processes* and so dentin is a sensitive tissue that can detect heat, cold, touch and variations in osmotic pressure (this is what causes teeth with exposed dentin to be sensitive to sweets). All stimuli detected by these nerve endings are registered as pain.

Dentin is produced by cells known as *odontoblasts* on the inside of the tooth throughout the life of the tooth. *Primary dentin* is that dentin which is formed prior to and during tooth eruption. Normal *secondary dentin* is formed continuously thereafter, causing a gradual reduction in the size of the pulp chamber and is structurally similar to primary dentin. The rate of secondary dentin production is fastest just after eruption of the tooth and declines as the animal ages. Therefore, the difference in pulp chamber size between one and two years of age is very dramatic whereas the change between nine and ten years of age may be imperceptible radiographically.

Irregular secondary, *reparative* or *tertiary dentin* is formed in areas exposed to injury or irritation. It has a distorted collagen pattern, fewer tubules, no nerve fibers and a darker colour than normal dentin.

The collagen component gives dentin some flexibility and allows teeth to withstand considerable forces without fracturing. The overlying enamel may crack and craze, but the dentin can be distorted and return to its normal shape.

A fresh chip-fracture of the crown of a tooth will expose dentin with open tubules and may tear or expose odontoblastic processes and nerve fibers. Therefore, the exposed dentin is sensitive to heat, cold, touch and chemical irritation. The open tubules will quickly become colonized with oral bacteria, which may propagate through the tubules to infect and kill the pulp. If there is 2 or more millimeters of dentin between the pulp and the fracture site, the odontoblasts under the fracture may have time to produce sufficient tertiary dentin to protect the pulp and prevent an irreversible pulpitis. If there is less than 2 millimeters of dentin covering the pulp, an irreversible pulpitis with pulp necrosis is likely. If you can see a pink hue (known as a *pulpal blush*) through the exposed dentin of a recently fractured tooth, the tooth requires treatment to either protect or remove the pulp.

If a tooth wears gradually, due to a chewing habit for example, as the level of wear breeches the enamel and starts to approach the pulp chamber, tertiary dentin is produced as the pulp retreats from potential exposure. If the wear is gradual enough the teeth can be worn down to the gum line without ever exposing the pulp (see figure #7.6). On the other hand, if the rate of wear exceeds the rate of tertiary dentin production, the pulp will die and further wear will expose the pulp chamber. The exposed tertiary dentin of worn teeth is often brown in

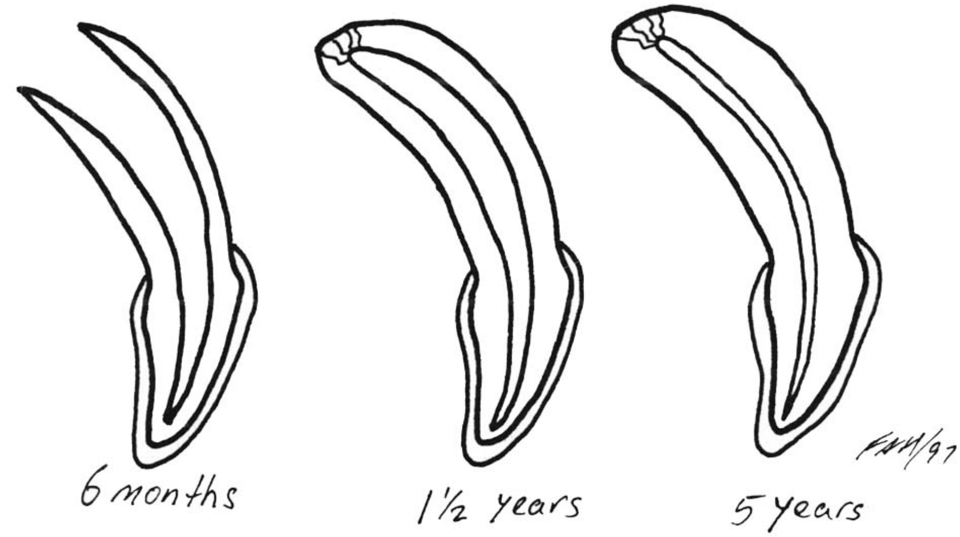

Figure #7.7. The developing tooth at various stages. The tooth on the left is immature (still erupting) with a wide-open apex, very thin hard-tissue wall and a massive pulp chamber. The tooth at centre might be found in a one and a half-year-old dog. The apex has formed and the apical delta is present. The tooth wall is still relatively thin with a large pulp chamber. The tooth at right might be found in a five-year-old dog. The pulp chamber and root canal are quite narrow but the pulp extends almost as far coronally as in the immature tooth.

colour but is smooth and shiny (wet or dry) and hard. Debris packed in an open pulp chamber is usually dark brown to black, dull when dry and will yield under probing with a dental explorer.

During mechanical abrasion, organic debris becomes impacted into the dentinal tubules, effectively sealing them from the outside world. Therefore, dentin exposed due to mechanical wear will not be as sensitive as dentin exposed by an acute fracture.

The Endodontic System

The endodontic system of the tooth consists of the *pulp chamber* (in the crown) and one or more *root canals* (within the roots). The pulp chamber has *pulp horns*, which correspond to the shape of the overlying tooth cusp (see figure #7.2). With time, the pulp chamber and canals become smaller as secondary dentin is produced (see 7. #7). The endodontic system contains the *pulp*, which is composed of odontoblasts, fibroblasts, various other cells, blood vessels, lymphatics, nerve fibers and ground substance. In the mature dog or cat tooth, the pulp enters the tooth through many tiny openings in the root apex known collectively as the *apical delta*. There may also be accessory lateral canals further up the root.

The pulp contains unmyelinated fibers, which control vasoconstriction in the pulp, and myelinated fibers, which register pain via the trigeminal nerve.

If pulp is exposed through fracture, abrasion or decay, it quickly becomes contaminated, inflamed and then necrotic. To salvage the tooth, root canal treatment is indicated. Pulps may also be damaged by blunt trauma with no crown fracture. As the bruised pulp dies, blood leaks from the vessels and seeps into the dentinal tubules, causing a discolouration of the crown. Pink, purple or gray discolouration of a crown is another indication for root canal treatment.

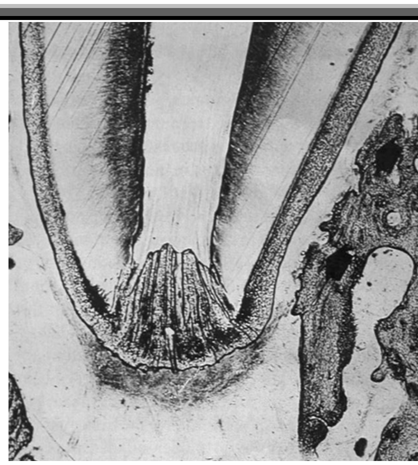

Figure #7.8. A photomicrograph of the apical delta of the canine tooth of a dog. There is periapical inflammation evident.

Any tooth with irreversible pulp disease (pulp necrosis), regardless of the cause, is a candidate for treatment. Very simply, the tooth needs to be extracted or it requires root canal therapy. Which treatment is chosen depends on several factors beyond the scope of this chapter (see Chapter 15: Endodontics). Leaving an endodontically diseased tooth in place may never cause any externally visible signs, but you can be assured that such teeth are sources of chronic pain and infection and need to be dealt with. When extracting these teeth, it is vital that they be completely removed. I have seen numerous cases of recurrent infra-orbital swelling in which the offending tooth has been previously extracted. On radiographic examination, the cause of recurrence is invariably a retained root tip acting as a contaminated foreign body.

Cementum

Cementum covers the outer surface of the root. It is in many ways similar to bone and acts functionally as the periosteum for the root. Though physically part of the tooth, it is considered to be part of the periodontal support apparatus.

The cementum at the root apex is cellular (*cementoblasts*) and has some capacity for repair but the cementum near the crown is acellular with the reparative capacity provided by cementoblasts within the periodontal ligament. Chronic irritation of the apical periodontal structures can lead to a thickening of the cellular cementum (*hypercementosis*) seen radiographically as a bulging apex. This can arise from traumatic occlusal forces (due to malocclusion or a chewing vice) or from irritation of endodontic (pulp) origin. The bulging root tip can act to lock the root in the socket, making extraction challenging.

Cementum is the tissue to which the periodontal ligament fibers and gingiva attach. These tissues will not attach to enamel, dentin or restorative materials. Therefore, loss of cementum, either by subgingival slab fractures or over-zealous root planing, will prevent gingival and ligament reattachment to the root surface. The result will be a permanently deep periodontal pocket with no hope for reattachment. Periodontal flap surgery (apically repositioned flaps) can sometimes eradicate the pocket to salvage the tooth.

More detail on cementum can be found in the section on Periodontal Morphology and Physiology.

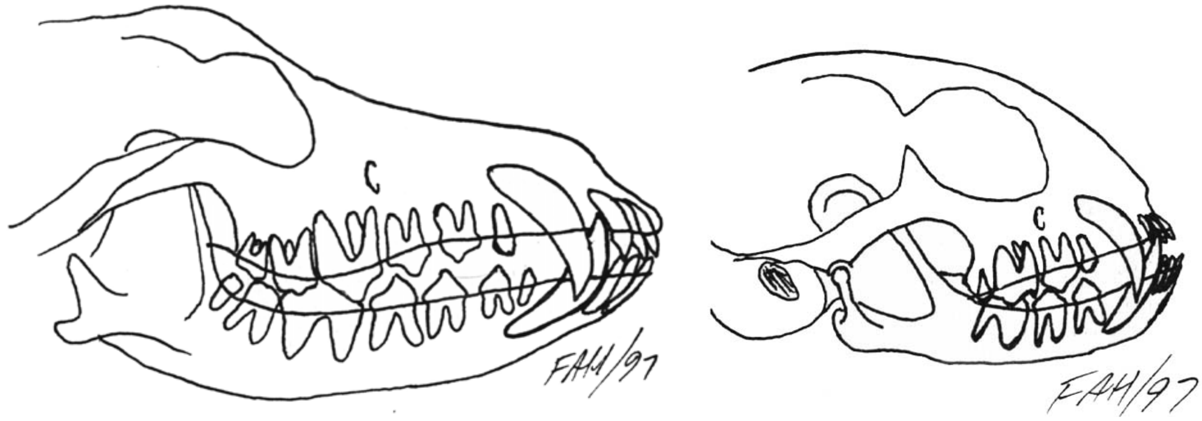

Figure #7.9. Right side of dog and cat skulls showing the crowns and roots of the teeth in a normal animal with full adult dentition. Note the number, size and shape of the roots for each tooth.

Dental Formulae

Kittens have a deciduous dental formula that looks like this:

2(i3/3 c1/1 p3/2) = 26.

What that means is that on each side of the head, they have 3 upper and lower incisors, 1 upper and lower canine and 3 upper and 2 lower premolars. The lower case letters are used to signify that we are talking about deciduous teeth.

The permanent dental formula in cats is as follows:

2(I3/3 C1/1 P3/2 M1/1) = 30.

Each side of the head has 3 upper and lower incisors, 1 upper and lower canine, 3 upper and 2 lower premolars and 1 upper and lower molar. The capital letters indicate permanent dentition.

The dental formulas for dogs are:

2(i3/3 c1/1 p3/3) = 28

and

2(I3/3 C1/1 P4/4 M2/3) = 42.

The table shows the approximate age (in weeks) of eruption for deciduous and permanent dentition in dogs and cats.

It is important to note that there are no deciduous first premolars or deciduous molars. Though the deciduous mandibular and maxillary fourth premolars in the dog and the cat look very much like the permanent first molars and function just like them, they give rise to the permanent fourth premolars.

Approximate eruption times of teeth in weeks

	Deciduous		PERMANENT	
	Puppy	KITTEN	DOG	CAT
Incisors	4-6	3-4	12-16	11-16
Canines	3-5	3-4	12-16	12-20
Premolars	5-6	5-6	16-20	16-20
Molars			16-24	20-24

Figure #7.10. A radiograph of a 12-week-old GSHP. The permanent first premolar, which has no deciduous predecessor, is just about to erupt. The second, third and fourth premolars are seen forming between the roots of their deciduous counterparts. The first and second molars are also seen forming with no deciduous predecessors. Note how the deciduous fourth premolar looks and acts like the permanent first molar but is obviously giving rise to the permanent fourth premolar.

Dental Morphology

The teeth of all mammals are categorized as *incisors*, *canines*, *premolars* and *molars*, according to morphology and function. Dogs and cats use their teeth in much the same way and have similar morphology.

Incisors are the most rostral teeth, there being three in each quadrant. In dogs, these single rooted teeth have one, large central cusp and a much lower cusp at either side. They are flat labio-lingually and have a sharp incisal edge. Incisors increase in size from the first to third tooth. The roots are narrower but longer than the crowns. The maxillary incisors have a ridge on the palatal side just above the free gingival margin known as the *cingulum*. In domestic cats, the incisors are very small with three small ridges along the incisal edge. In the wild, incisors are used to grasp the hide to pull it from the carcass when eating and for grooming of the fur coat.

Distal to the incisors are the single canine or cuspid teeth. These long, single rooted teeth have a simple, conical crown, which tapers to a sharp point. In dogs, the crown curves distally to prevent prey from escaping. In cats the labial face of the tooth will have one or more longitudinal grooves in the enamel. Canine teeth are used for apprehending, holding and killing prey as well as for defense and display.

Distal to the canines are the premolars. In dogs, the first premolar has one simple root and a short, pyramidal crown. The second and third maxillary and second to fourth mandibular premolars all have two roots and a triangular crown with a prominent central cusp and smaller mesial and distal cusps. The premolars are helpful in holding small prey in the mouth and for shearing large chunks of meat from larger prey. These premolars are never supposed to come into contact with the teeth from the opposing jaw.

In cats, the first maxillary premolar is missing and the second may have one root or two fused roots with a single, simple crown. Cats are also missing the mandibular first and second premolars. The maxillary third premolar and the mandibular third and fourth premolars are very similar to those of dogs.

The maxillary fourth premolar of dogs and cats is a three-rooted tooth with a complex crown. There is a long, narrow mesiobuccal root, a shorter mesiopalatal root and a long, wide distal root. The crown has a large mesial cusp and a lower, broader distal cusp with a deep *developmental groove* between them. There is also a cusp above the palatal root. The maxillary fourth premolar is the upper carnassial tooth (meat cutter) which, along with the mandibular first molar (the lower carnassial) acts as a pair of scissors to cut meat from prey.

Molars are teeth which have flattened occlusal tables and contact each other in order to grind food. The maxillary molars of the dog have three roots each. There is a narrow mesiobuccal root, a narrow distobuccal root and a shorter triangular palatal root. Over the two buccal roots are short, triangular cusps. Over the palatal cusp is the occlusal table, which acts a grinding surface with the lower molars. In the centre of the crown of the maxillary first molar there is often a pit in the occlusal surface, which is prone to the development of caries (tooth decay).

The first mandibular molar in dogs acts as both a premolar and a molar. There are two large roots with the mesial larger than the distal. The large mesial cusp acts as one blade of the scissors in conjunction with the maxillary fourth premolar. The distal cusp is lower and has a ridged occlusal surface, which contacts the mesial portion of the occlusal table of the maxillary first molar. The second mandibular molar has two roots and a ridged occlusal surface, which contacts the distal portion of the first maxillary molar and the mesial portion of the second maxillary molar. The third mandibular molar has one simple root and a short crown, which contacts the distal portion of the occlusal table of the maxillary second molar.

Cats are true carnivores and have little need to grind their food. The maxillary molar may have one root or two fused roots, which are short and

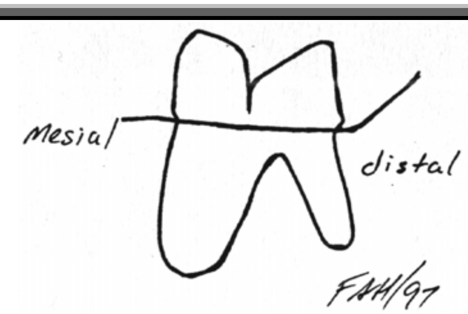

Figure #7.11. The lower left molar of a cat (tooth 309) showing large mesial root and small distal root.

stocky. The crown is oblong and has a low, ridged profile but may never contact the lower molar. The mandibular molar is the lower carnassial as in dogs, but both mesial and distal cusps act as meat cutters. The two cusps are relatively equal in size with a deep developmental groove between them. There are two roots, of which, the mesial is by far the larger. The distal root is quite narrow and supports the distal half of the distal cusp.

Morphology And Physiology Of The Periodontium

The periodontium consists of the tissues investing and supporting the teeth, including the cementum, periodontal ligament, alveolar bone and gingiva. This section will discuss each of these components separately and their intimate relationship.

The Gingiva

The gingiva is that portion of the oral soft tissue covering the alveolar processes of the jawbones and surrounding the necks of the teeth. It is the first line of defense against mechanical insult from mastication and from bacterial invasion of the deeper structures of the periodontium. Anatomically, it is divided into three regions; *marginal or free gingiva*, *attached gingiva* and *interdental gingiva*.

Marginal gingiva is the most coronal portion of the gingiva and in normal, healthy patients, it is that portion which is not attached to the tooth, but rather lies passively against it. As it is not attached, there is a potential space between the tooth and the marginal gingiva known as the *gingival sulcus*. The marginal gingiva, therefore, forms the outer wall of the gingival sulcus.

The coronal edge of the marginal gingiva is termed the *free gingival margin*. On the outer surface of the marginal gingiva, in about 50% of human subjects, there is a shallow linear depression known as the *marginal groove* or *free gingival groove* which demarcates the apical extent of the marginal gingiva and its border with the attached gingiva.

In germ free animals, the depth of the gingival

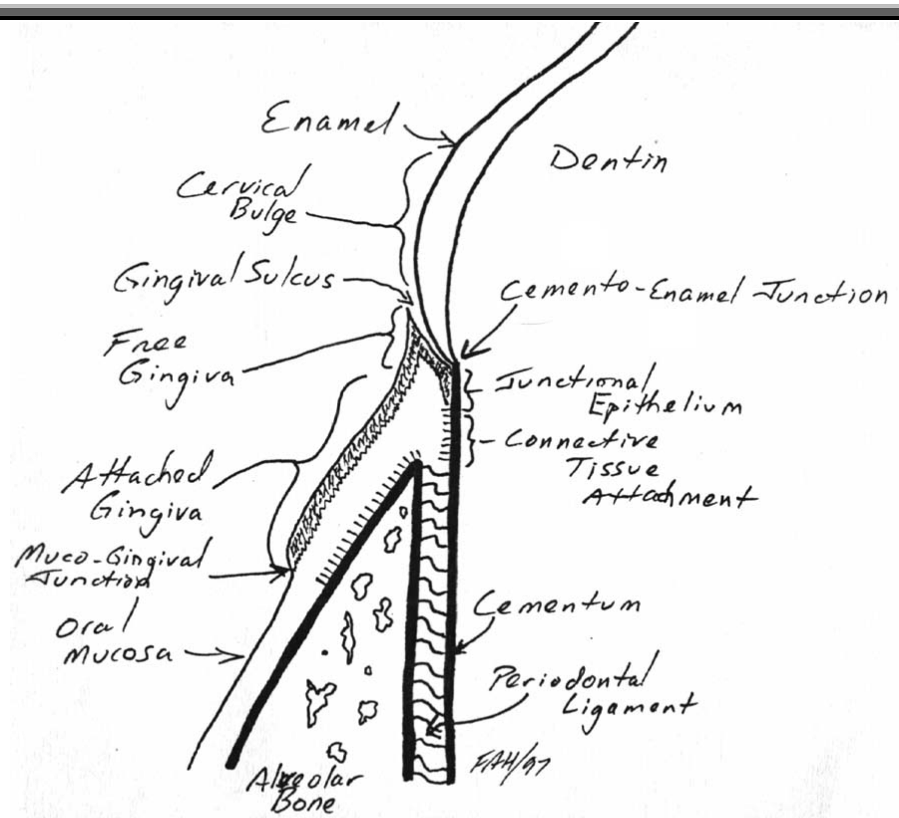

Figure #7.12. Relationship of the periodontal structures to the tooth. Note how the gingiva is not attached to the enamel but is firmly bound to the cementum of the portion of the root that extends above the crest of the alveolar bone. A tight collar of gingival attachment to this cementum is the primary barrier to periodontal disease.

sulcus is 0 millimeter or very near to it. In all others, even with clinically healthy gingiva, there is a sulcus, the depth of which can be measured by use of a periodontal probe. The normal sulcar depth varies between individuals of the same species, between different species and even between different regions in the mouth of an individual. In the cat, normal depths are between 0.5 millimeter and 1.0 millimeter, with the deeper sulci found in areas where there is the most gingiva such as around the canine teeth. In dogs, normal sulci are from 1.0 to 3.0 millimeters. In humans, normal depths are reported as 2.0 to 3.0 millimeters.

The *attached gingiva* is that portion apical to the marginal gingiva and which is tightly bound to the cementum of the root coronal to the alveolar crest and to the periosteum of the alveolar bone. The facial aspect of the attached gingiva ends apically at a border with the relatively loose and movable *oral mucosa*. This is seen on the outer surface as the *mucogingival junction*. The mucogingival junction remains stationary throughout life and so as the free gingival margin recedes in periodontal disease, the width of the gingival band decreases. The width of the gingiva differs in different regions of the mouth. In dogs and cats, it is widest over the canines and narrowest around the last molar. On the lingual aspect of the mandible, the attached gingiva ends at the junction with the lingual alveolar mucosa. The palatal surface of the maxillary attached gingiva blends with the equally firm and immobile palatal mucosa.

The *interdental gingiva* occupies the space between the teeth. The architecture of the interdental gingiva is dependent on how close the teeth are to each other. In different regions of the mouth, teeth may be in close contact, loose contact or no contact at all. In areas of interproximal contact, the area below the contact is called the *gingiva embrasure*. If teeth are in close contact at the free gingival margin, there will be a triangular *gingival papilla* on the facial and lingual/palatal aspect with a valley-like depression known as the *gingival col* in between. If the teeth are in loose contact, there may be a single pyramidal papilla occupying the interproximal space. If teeth are not in contact, the space between them is known as a *diastema*. The diastema will be occupied by gingiva bound to the interdental bone and having a smooth, round contour without a papilla.

In the incisor area, the roots taper apically. Therefore, as gingival recession progresses, the interproximal contact might change from close to loose to none and the interdental gingival architecture will change to reflect this. First, the col will be lost as the two papilla merge into one and then the papilla height will decline until it has the smooth, round shape of diastemal gingiva. This evolution may be seen in other regions of the mouth as well.

Histologically, the gingiva is divided into a connective tissue core covered by stratified squamous epithelium. The epithelium is of three types; *oral epithelium*, *sulcar epithelium* and *junctional epithelium*.

Oral epithelium runs from the crest of the marginal gingiva to the mucogingival junction. It consists of keratinized or parakeratinized stratified squamous epithelium with prominent rete pegs. The keratinocytes are connected to one another by desmosomes and tight junctions. There is evidence that tight junctions allow passage of ions and small molecules from cell to cell. The epithelium is connected to the underlying connective tissue by a basal lamina, which is produced by the cells of the stratum basale. The basal lamina is permeable to fluids but acts as a barrier to particulate matter.

Sulcar epithelium is the thin, non-keratinized stratified squamous epithelial lining of the gingival sulcus. This epithelium has the potential to keratinize if it is exposed to the oral cavity or if the bacterial flora in the sulcus is totally eliminated. This suggests that local bacterial irritation prevents keratinization. As a semipermeable membrane, sulcar epithelium is a very important part of the gingival defense mechanism.

Sulcular fluid, produced in the gingival connective tissue, passes through the sulcar epithelium as part of the defense mechanism of the gingiva. Studies have shown that, following intramuscular injection or oral administration of a number of substances, these same substances can be recovered from sulcar fluid. This has been demonstrated using fluorescein, India ink, saccharated iron oxide, albumin, endotoxin, thymidine, histamine, phenytoin, horseradish peroxidase, tetracyclines, metronidazole, and spiramycin. This list includes substances with a molecular weight of up to one million. It has been suggested that the molecules and ions travel through intercellular spaces without the need to cross cell membranes.

Sulcar fluid is considered an inflammatory exudate in that very little or no sulcar fluid can be collected from strictly normal gingiva and the small amount collected is considered artifact due to inflammation induced by the collection process. The amount of sulcar fluid produced increases as the degree of inflammation increases.

Sulcar fluid contains a number of cellular elements including bacteria, desquamated epithelial cells, neutrophils, lymphocytes and monocytes as well as electrolytes, organic components, including a wide array of carbohydrates and proteins, a number of enzymes and bacterial components including lactic acid, urea, hydroxyproline, endotoxins, cytotoxic substances and hydrogen sulfide.

Sulcar fluid is believed to have a cleansing action as it flushes the sulcus of bacteria and particulate matter. Some of the plasma proteins are credited with enhancing adhesion between the epithelium and tooth, thereby slowing the apical migration or impaction of bacteria and foreign matter between tooth and periodontium. The presence of viable leukocytes, immunoglubulins and compliment factors all add to the protective properties of the sulcar fluid.

Junctional epithelium is a band of non-keratinized stratified squamous epithelium, which forms the *epithelial attachment* to the tooth. The junctional epithelium attaches to the root cementum immediately apical to the cementoenamel junction. The attachment of the junctional epithelium to the tooth is supported by the gingival fibers, which brace the marginal gingiva against the tooth. Therefore, the junctional epithelium and the gingival fibers are considered a functional unit known as the *dentogingival unit*. The epithelial turnover time in 'experimental animals' for junctional epithelium is reported as 1 to 6 days. For the remainder of the gingival epithelia (sulcar and outer), turnover is reported to be between 10 and 12 days. Though an important part of the gingival attachment apparatus, the junctional epithelium forms a relatively loose bond to the tooth and this breaks down in the early stages of periodontal disease.

Apical to the junctional epithelium is the much firmer and more resilient *connective tissue attachment*. When treating periodontal pockets, the hope is to re-establish a good band of connective tissue attachment in favour of having the development of a long junctional epithelium.

Internal to the gingival epithelium is the gingival connective tissue known as the *lamina propria*, composed of a *papillary layer* below the epithelium and a *reticular layer* next to the alveolar periosteum. The lamina propria is densely collagenous with a system of collagen fiber bundles called the *gingival fibers*. These fibers brace the marginal gingiva against the tooth, provide the rigidity necessary to withstand the mechanical insults of mastication and unite the free marginal gingiva with the cementum of the root.

The main cellular component of the gingival connective tissue is the fibroblast. They are responsible for the synthesis and secretion of collagen as well as other proteins (elastin, glycoproteins, glycosamineglycans). Therefore, fibroblasts are responsible for healing of gingiva following surgery or disease processes. Other cells in the gingiva include mast cells and small foci of inflammatory cells. Though the presence of inflammatory cells is almost universal, they are not considered a normal component of perfectly healthy gingiva, but are present as a result of antigenic stimulation.

As well as collagen, the gingiva contains other, non-collagenous, proteins such as glycoproteins, which mediate attachment of cells to their substrate.

Supraperiosteal arterioles run along the facial and lingual surfaces of the alveolar bone and give rise to capillaries, which extend along the sulcar epithelium and between rete pegs of the outer gingival epithelium. These arterioles occasionally pass through the alveolar bone to the periodontal ligament. The *vessels of the periodontal ligament* extend into the gingiva and anastomose with sulcar capillaries. Arterioles emerging from the crest of the interdental septa run parallel to the crest of the bone and anastomose with the vessels of the periodontal ligament, capillaries in the crevicular areas and the vessels that run over the alveolar crest.

Under the outer gingival epithelium, capillaries extend into the papillary connective tissue between the rete pegs and end as hairpin loops, which sometimes are linked by cross communications. There are also flattened capillaries, which act as reserve vessels to be filled in response to irritation. Along the sulcar epithelium, there is a flattened plexus of capillaries from the base of the sulcus to the free gingival margin.

The lymphatic drainage of the gingiva starts in the papillary connective tissue runs external to the alveolar periosteum and on to the regional lymph nodes, particularly the sub-mandibular group.

The gingiva is innervated by fibers arising from the periodontal ligament and from the labial, buccal and palatal nerves. The nerves end as Meissner-type tactile corpuscles, temperature sensitive Krause-type end bulbs and encapsulated spindles.

Cementum

Cementum is a bone-like tissue covering the root of the tooth. It is composed of collagen fibrils and a calcified interfibrillar matrix. Cementum has an inorganic content (45 to 50 %) of hydroxyapatite, which is lower than that of bone (65 %), dentin (70%) and enamel (90%). Primary or acellular cementum covers the cervical two thirds of the root and is formed before the tooth comes into occlusal contact. Secondary or cellular cementum forms around the apical third of the root after the tooth comes into occlusion. It is less regular in architecture and contains individual cells in lacunae that communicate with each other through canaliculi. Both forms of cementum are arranged in lamellae separated by incremental lines parallel to the long axis of the tooth. These more mineralized lines represent periods of rest in cemental formation.

The organic component of cementum is mainly collagen in the form of two types of fibers. One type is the collagen fibers of the cemental matrix produced by cementoblasts, which also produce the interfibrillar ground substance. The other type is the Sharpey's fibers, which are the terminal portions of the principle fibers of the periodontal ligament. Sharpey's fibers are produced by fibroblasts.

Sharpey's fibers make up the bulk of acellular cementum. Most fibers enter at right angles to the long axis of the root and penetrate deep into the cementum but others insert at a variety of angles. The size, number and distribution of Sharpey's fibers increase with function (the more stress on the periodontal ligament, the more Sharpey's fibers). In cellular cementum, Sharpey's fibers make up less of the tissue.

In humans, cemental thickness varies from 16 to 60 microns cervically to 150 to 200 microns apically and in furcations. Cementum deposition continues throughout life so the thickness increases with age. Cementum formation is usually much slower than the formation of bone or dentin.

Excessive cementum deposition is termed *hypercementosis*. It may be restricted to one tooth or be generalized. It occurs as generalized thickening of the cementum with nodular enlargements in the apical third. The causes are varied and poorly understood. Many of the same factors associated with root resorption are also linked to hypercementosis. These include excessive occlusal or orthodontic forces and chronic periapical irritation.

Cementum is constantly undergoing resorption and repair. As long as the two are in balance, there is no problem. Excessive resorption can be seen as a result of excessive occlusal or orthodontic forces or due to pressure from malaligned erupting teeth, cysts and tumors, embedded teeth, replanted teeth, periapical or periodontal disease. Resorption can also be linked to systemic diseases such as deficiencies of calcium, vitamin D and A and hypothyroidism.

Following a period of resorption, cementum may undergo repair. Repair is often by cellular cementum, separated from the underlying cementum by a darkly staining reversal line. The new cementum re-establishes a functional relationship with the Sharpey's fibers. Cemental repair requires vital connective tissue, so if epithelium proliferates into an area of resorption, repair will not occur.

Ankylosis is fusion of cementum and alveolar bone and obliteration of the periodontal ligament. It can occur as a result of excessive occlusal trauma, chronic periapical irritation and after tooth reimplantation. Ankylosis results in root resorption and healing of the defect with bone. Therefore, ankylosed reimplanted teeth will often lose their root and exfoliate after 4 to 5 years.

The reparative capacity of cementum is not limited to filling areas of resorption. Complete horizontal or oblique root fractures can heal, if circumstances are favorable. If the fracture is exposed to the oral cavity and infection, repair will be less likely. Even in unexposed fractures, the deposition of calcified tissue is inversely related to proximity to the oral cavity. The degree of healing is also inversely related to the distance between the fracture fragments.

As well as complete root fracture, fragments of cementum may be pulled away from the root as cemental tears. The tear may be complete or incomplete with the fragment partially attached to the root. Torn cementum may be reabsorbed, be reunited with the root by reparative cementum or remain free in the periodontal ligament. In this last instance, new cementum will be deposited around the fragment and periodontal ligament fibers will be embedded in it both between fragment and bone and between fragment and root cementum.

Periodontal Ligament

The periodontal ligament performs a number of vital functions.

- shock absorption of the impact of occlusal forces
- transmission of occlusal forces to alveolar bone
- attachment of the teeth to the alveolus
- maintenance of gingival adaptation to the tooth
- provides a soft tissue casing to protect vessels and nerves in the periodontal space
- supplies nutrients to alveolar bone and cementum via arterioles and drainage via venules and lymphatics
- provides tactile and proprioceptive information which is essential in coordinating the neuromuscular activity of mastication.

The periodontal ligament is the connective tissue that fills the space between the tooth and alveolar bone and attaches one to the other. It is composed mainly of collagen fibers with some elastic fibers, blood vessels, nerves and lymphatics. The periodontal ligament is a relatively cellular region containing fibroblasts, endothelium, *cementoblasts*, osteoblasts, osteoclasts, macrophages, and the *epithelial rest of Malassez.*

The main component of the periodontal ligament is the principle fibers. These are bundles of collagen fibers, which follow a wavy course from root cementum to alveolar bone proper. The ends of the principle fibers, which are embedded in cementum and alveolar bone, are termed Sharpey's fibers.

The principle fibers are divided into five groups according to location and orientation. The largest group of periodontal fibers is the *oblique group*. They run from the cementum coronal obliquely to the alveolar bone. They absorb the bulk of the vertical forces on the tooth and transmit them to the alveolar bone as they support the tooth in the alveolus like a hammock.

As well as the principle fibers, there are well-formed bundles of collagen fibers running at various angles and interdigitating with the principle fibers. There are less organized collagen fibers in the interstitium between the principle fibers. These areas contain the blood vessels, lymphatics and nerves of the ligament space. There are a few elastin fibers and oxytalan fibers. The latter are mainly around blood vessels and embedded in the cementum of the cervical third of the root.

For the most part, it is felt that the principle fibers are continuous from bone to cementum. In continually growing incisors of some animals, such as the mouse, it appears that the fibers may be composed of two parts spliced together midway between cementum and bone. This would allow the tooth tissue to erupt without fiber attachments to cementum or bone being disrupted. The area of fiber splicing has been called the *intermediate plexus*. This plexus has also been identified in actively erupting human and monkey teeth, but not in teeth that have reached occlusal contact.

Fibroblasts are the most numerous cells in the ligament and are responsible for the production of the collagen. As well as producing new collagen, they have been shown to be able to phagocytose old collagen fibers and degrade them by hydrolysis, thereby recycling and remodeling the ligament.

The epithelial rests of Malassez are believed to be remnants of *Hertwig's epithelial root sheath* left after root development is complete. They are found in clusters near the cementum of most teeth and in greatest numbers near the apical and cervical thirds. With age, their numbers diminish through degeneration by becoming calcified to form *cementicles*. When stimulated, the rest cells may proliferate leading to periapical and lateral root cysts. It has also been suggested that the epithelial rests might be the tissue of origin for canine epulide tumors.

The vascular supply of the periodontal ligament arises from the inferior and superior alveolar arteries and reaches the ligament via apical vessels, penetrating vessels from alveolar bone and anastomosing vessels from the gingiva. The vessels form a plexus in the interstitium between the principle fibers and lie closer to the bone than to cementum. The venous drainage parallels the arterial supply. There are numerous capillaries as well as arterio-venous anastomoses known as glomera. The lymphatic drainage also parallels the vasculature and supplements venous drainage.

The periodontal ligament is well supplied with sensory nerve endings from branches of the trigeminal nerve. Nerve bundles enter the ligament space from the apical region or through openings in the alveolar bone in much the same way as the blood vessels. These nerves register tactile, pressure and pain sensation. Some nerve fibers end as free, demyelinated nerve endings or as spindle shaped proprioceptors.

Alveolar Bone

The *alveolar process* is the bone that surrounds and supports the teeth. It forms during tooth eruption and gradually disappears after the tooth is lost. It does not form at all in children with total anodontia. It consists of a thin wall of compact bone against the periodontal ligament (*cribriform plate, alveolar bone proper*) and the cancellous *supporting alveolar bone*. On the lingual and facial aspects, a thin layer of supporting alveolar bone is covered by a plate of compact bone. On radiograph, the cribriform plate appears as a radiodense line known as the *lamina dura*.

Alveolar bone is constantly remodeling internally, yet it remains relatively constant in form throughout adult life as bone deposition by osteoblasts is balanced by resorption by osteoclasts. Osteoclasts are multinucleated cells living in eroded depressions known as *Howship's* lacunae.

Sharpey's fibers embed deeply into the alveolar bone lining the alveolus. They are either completely calcified, or more often, have a calcified outer layer and uncalcified core. The socket wall consists of dense lamellated bone and *bundle bone*. Bundle bone is the term for the bone adjacent to the periodontal ligament because of its content of Sharpey's fibers. Bundle bone is gradually resorbed on the marrow space side and replaced by lamellated bone.

The cancellous supporting alveolar bone consists of trabeculae enclosing irregular marrow spaces lined with a layer of thin endosteal cells. The marrow is generally of the yellow, fatty type in mature individuals, though occasional foci of red marrow may be found near the posterior teeth. The trabecular pattern is quite variable and is affected by occlusal forces.

Like all bone, alveolar bone is constantly remodeling, being resorbed in areas where it is not needed and laid down where it is. When occlusal, orthodontic or other forces are applied to a tooth, it moves within the alveolus and the forces are transmitted to the bone via the periodontal ligament. In areas of tension, osteoblasts produce new bone, whereas in areas of compression, osteoclasts resorb bone. The trabeculae of the cancellous bone are aligned in the path of tension and compression to provide maximum mechanical support for the tooth with the least amount of bone. Forces that exceed these adaptive functions cause trauma to the periodontium and teeth.

When occlusal forces are increased, the number and thickness of trabeculae also increase. If occlusal forces are decreased, the bone undergoes disuse atrophy as bone is resorbed. The number and thickness of trabeculae decreases and bone height is lost. These changes are also influenced by local disease processes, vascular anatomy, systemic disease and the aging process.

Changes in the Periodontium with Age

With the passage of time several physiological changes occur in the periodontium, which are aside from the cumulative changes of periodontal and other oral disease processes.

In the periodontal ligament, there is an increase in the number of elastic fibers and a decrease in the vascularity, mitotic activity, fibroplasia, collagen fibers and muccopolysaccharides. The ligament space has been reported to get both wider and narrower with age in humans. The decrease in width is attributed to continued deposition of cementum and bone on either side of the ligament. In humans, there is a three-fold increase in the thickness of cementum between 11 years of age and 76 years. As the bone and cementum grow toward each other, the ligament may be obliterated. Ankylosis results as cementum and bone fuse. The widening of the ligament space may be due to fewer teeth being available to support the functional masticatory load.

The alveolar bone also undergoes aging changes, many of which are evident radiographically. In a healthy individual these radiographic changes include increased density and coarseness of the trabecular pattern of the cancellous bone, reduced definition of the lamina dura and slight regression of the alveolar crest. Physiologically, there is a decrease in vascularity, metabolic activity and healing ability of the alveolar bone. As resorptive activity increases and bone formation decreases, the porosity of the bone may be increased. Animals suffering from hyperparathyroidism (primary, secondary or pseudo), malnutrition, other systemic disease or local periodontal disease may experience osteoporosis and bone loss. This would not be considered a normal aging change, but is a result of some specific disease process.

Nerves

The periodontium is supplied with nerves from the maxillary and mandibular branches of the trigeminal nerve. The superior alveolar nerve supplies the buccal gingiva of the posterior teeth. The labial branch of the infra-orbital nerve supplies the facial gingiva of the maxillary incisors. The naso-palatine nerve runs to the palatal gingiva of the maxillary anterior teeth. The anterior palatal nerve supplies the maxillary posterior teeth. The long buccal nerve runs to the buccal gingiva of the mandibular molars. The mental nerve supplies the facial gingiva of the anterior mandibular teeth. The lingual nerve supplies the lingual gingiva of all the mandibular teeth.

Summary

Although this section has discussed the various components of the periodontium as separate entities, it should be apparent to the reader that there is intimate interconnection and interaction between all of them. The periodontal ligament can only exist where there is cementum on one side and alveolar bone on the other. Some gingival fibers are also considered to be periodontal principle fibers. Blood vessels running through the cancellous alveolar bone penetrate the alveolar bone proper and then go on into the periodontal ligament and gingiva. An integrated understanding of the structure and physiology of all of the components of the periodontium is essential to understanding the pathogenesis and treatment of periodontal disease.

Non-Dental Oral Anatomy

There are, of course, other structures, which make up the oral cavity and you must be familiar with these as well.

Salivary Glands and Ducts

Dogs and cats have a number of major and minor salivary glands located in and around the mouth. The saliva they produce helps in lubricating the food to aid swallowing and contains enzymes to start the digestive process.

Saliva serves many functions in maintaining the health of the oral tissues. As a fluid constantly bathing the oral cavity, saliva acts to dilute bacteria and rinse debris. Saliva has a buffering effect, which neutralizes acids in the mouth. It also contains minerals such as calcium and fluoride, which can be taken up by enamel to maintain its integrity. Saliva contains antibodies and compliment factors and so has a direct antibacterial effect.

A decrease in salivary flow, known as *xerostomia*, is associated with an increased risk of periodontal disease. Loss of the buffering and antibacterial effects of saliva as well as a drying of the oral tissue all contribute to this. Therefore, in evaluating a patient’s oral health and the prognosis for future problems, the character of the saliva should be assessed.

The major salivary glands in the dog are the parotid, mandibular, sublingual and zygomatic glands. The cat has these glands as well as the buccal and lingual molar glands.

The *parotid gland* lies at the base of the ear. Its duct runs rostrally to open into the oral cavity through the raised *parotid papilla* in the oral mucosa above the distal cusp of the fourth upper premolar.

The *zygomatic gland* lies ventral to the rostral end of the zygomatic arch. Its main duct opens at the *zygomatic papilla* caudal and dorsal to the maxillary second molar. Smaller zygomatic ducts end as tiny openings caudal to the zygomatic papilla.

The *mandibular gland* (sometimes called the submandibular gland) lies ventral to the parotid gland, caudal to the angle of the mandible. Its main duct runs rostrally, through the body of the *sublingual gland* (which lies under the oral mucosa at the base of the tongue). The duct for the mandibular gland travels rostrally under the tongue to end at the *sublingual papilla* or *caruncle* at either side of the rostral end of the lingual frenulum.

Portions of the sublingual gland (the polystomatic portions) empty directly into the oral cavity though tiny openings. The monostomatic portion feeds into the sublingual duct, which runs dorsal to the mandibular duct and ends 1 to 2 millimeters caudal to or in common with the sublingual caruncle.

In the cat, there are the two molar glands. The *buccal molar gland* lies under the mucous membrane of the lower lip adjacent to the mandibular molar. It empties through multiple tiny ducts into the buccal pouch. The *lingual molar gland*, previously known as the mucosal bulge, lies directly lingual to the mandibular molar in a loosely attached mucosal prominence. It also has multiple tiny ducts emptying towards the tongue.

The Tongue

Occupying the floor of the mouth, the *tongue* is a complex structure with a muscular core and a mucous covering. The muscles are arranged in various alignments that allow for very intricate movements in all planes.

The dorsum of the tongue is covered by thick, rough, cornified epithelium with a variety of papillae. Some have a mechanical function to aid in grooming, especially in the cat. Others contain the taste buds.

The tip of the tongue moves freely whereas the base of the tongue is attached to the floor of the mouth by the lingual frenulum at about the level of the second or third mandibular premolar in the dog. The ventral surface is covered by thinner, smoother epithelium.

On the ventral side of the tongue is the sublingual vein and the lingual artery. The latter is a ready site for the collection of arterial blood for blood gas analysis. It is also a good place to evaluate the peripheral pulse of the patient.

The Palates

The hard palate extends from just behind the maxillary incisors to a level distal to the maxillary third molars. It is named the hard palate because the mucosa is supported by the bones that make up the roof of the oral cavity.

The mucosa covering the bones of the hard palate is divided by a median raphe down the mid-line. There are transverse ridges, known as *rugae*. In a normal mouth, the rugae on one side are a mirror image of the other. In animals with a maxillary wry bite, the rugae on the right will not match those on the left. Asymmery of the rugae may also be associated with cleft palate.

Immediately behind the maxillary central incisors is a round prominence in the palatal mucosa known as the *incisive papilla*. This papilla is very sensitive to touch and trauma. Any malocclusion which allows mandibular teeth to contact the papilla would be uncomfortable for the animal.

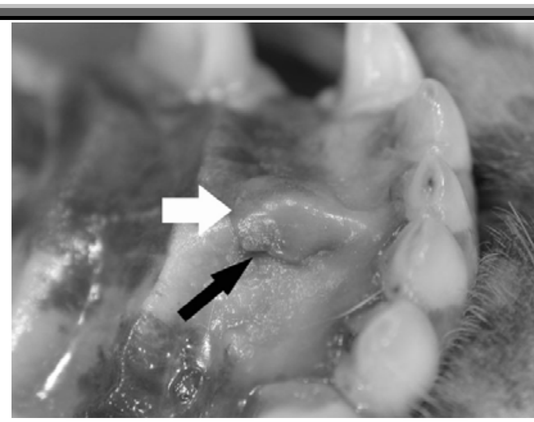

Figure #7.13. The structure indicated by the white arrow is the incisive papilla. To the sides of the papilla are the incisive ducts (black arrow), which lead into the nasal passage as part of the vomeronasal organ.

To either side of the incisive papilla are small opening known as the *incisive ducts*, which run through *palatine fissures* in the incisive bone. The ducts communicate with the *vomernasal organ* before opening into the floor of the nasal cavity. These structures play an important role in the sense of smell and the appreciation of the palatability of food.

Distal to the hard palate is the soft palate. It is composed of layers of muscle sandwiched between oral and nasal mucosa. An intact soft palate with a functional muscle layer is essential for the formation of the pharyngeal diaphragm. The diaphragm, composed of the tongue, lateral pharyngeal walls and the soft palate, closes as the animal is swallowing. Dysfunction or malformation of this structure makes swallowing difficult or impossible, leading to dysphagia or aspiration.

The palate of puppies and kitten should be checked carefully for any physical defects such as clefts. In mature animals, acquired conditions include trauma and tumors of the palate.

The Temporomandibular Joints

These are the joints by which the mandibles are attached to the base of the skull. The condyloid process in dogs and cats projects distally from the caudal portion of each mandible into the mandibular fossa at the rostro-ventral region of the temporal bone. The joint in carnivores is a hinge joint, which allows considerable movement in the opening and closing of the mouth but very limited lateral movement.

Diseases of the temporomandibular joint are likely more common than diagnosed. The joint is subject to dislocations, fracture and degenerative joint disease.

The Lips

The mouths of carnivores must open wide to allow for the collection and ingestion of prey animals. Therefore, the lips of dogs and cats extend well back to the level of the molars. The outer surface of the lips is covered by normal, fur bearing skin. The inner surface is covered by non-keratinized squamous epithelium. Where the two meet is the muco-cutaneous junction. This junction is a common site for lesions in many immune mediated diseases such as pemphigus.

The upper lip hangs freely from the maxilla for most of its area. It is attached to the alveolar mucosa by a frenulum directly above the incisors at the mid-line. There are also less prominent frenulae in the alveolar mucosa above the third maxillary premolar.

The lower lip has less redundant tissue than the upper. It is held to the mandible by very obvious frenulae ventral to the first mandibular premolar teeth.

In some giant breeds, the lower lip is excessively long between the frenulae and the corners of the mouth. The lip then sags down, allowing saliva to drain from the oral cavity. In others, such as the Shar Pei, the lower lip rostral to the frenulae may be too short. This is Tight-Lip syndrome in which the lower lip curls over the top of the mandibular incisors and is traumatized by the maxillary incisors when the mouth is closed.

Summary

This has been but a brief over view of dental and oral anatomy. Further reading in standard anatomy texts is suggested in order to become familiar with the named blood vessels and nerves as well as the architecture of the craniofacial bones.