Dentistry is truly a branch of medicine and surgery. A strong knowledge of normal anatomy and pathology is cornerstone to adequate diagnosis and treatment of diseases of the oral cavity. The majority of oral related disease is inflammatory (periodontal disease) or traumatic (fractured teeth, orthopedic injuries) in nature. However other causes are not rare and need to be recognized.

The basic dental unit is the tooth and surrounding periodontium. The tooth consists of the crown and root. The crown is covered in enamel and the root by cementum. Deep to the crown and cementum is the dentin. Dentin is a porous hard tissue which continuously grows toward the center of the tooth as long as the tooth is vital. Deep to the dentin is the pulp which consists of nerves, blood vessels, connective tissue, fibroblasts and odontoblasts.

The periodontium is composed of the cementum, periodontal ligament, alveolar bone, and gingiva. The periodontal ligament serves to anchor the cementum to the alveolar bone, act as a shock absorber and aid in sensation. The gingiva is attached to the bone (attached gingiva), tooth by connective tissue and the most apical extent is not attached and is known as the free gingiva. The potential space between the free gingiva and tooth and ending apically at the sulcular epithelium is the gingival sulcus. In health this should be less than 3mm in depth in dogs and 1mm in cats.

When addressing the teeth and periodontium, directional nomenclature is not similar to directional nomenclature of the rest of the body. The terms dorsal and ventral are replaced by coronal, meaning towards the cusp of the tooth and apical, meaning toward the tip of the root. Rostral and caudal are replaced by mesial, toward the interproximal space between the first two incisors and distal, away from this space. Thus mesial and distal are not a straight line, but curve along with the incisors. The “rostral” surface of the incisors is facial and the “caudal” is palatal for the maxillary incisors and lingual for the mandibular. Lateral and medial surfaces of the premolars and canines are known as buccal (surface facing the cheeks), palatal (surface of maxillary teeth facing the hard palate) and lingual (surface of mandibular teeth facing the tongue).

The bones which hold the mandibular teeth are the left and right mandibles. These are not “hemimandibles” in the cat and dog as the bones connect by a synchondrosis and are not joined by a bony connection. The bones which hold the maxillary teeth are a single incisive bone (incisors and mesial aspect of canine teeth) and paired maxillae. Cats and dogs have three incisors and one canine in each maxillary and mandibular quadrant. Dogs have four premolars in each quadrant and cats have three in the maxillary (2nd, 3rd and 4th) and two in the mandibular (third and fourth). Dogs have two molars in each maxillary quadrant and three in each mandibular quadrant. Cats have only one molar in each maxillary and mandibular quadrant.

When naming the teeth, two systems are accepted, anatomic labeling and the modified triadan system. With anatomic labeling, the first qualifier is left or right, second is maxillary or mandibular, third is number of teeth if necessary (i.e. first second or third incisor) and fourth is type of tooth (incisor, canine, premolar or molar). It is important to remember cats do not have a maxillary first premolar or mandibular first or second premolar, as this will aid in using the modified triadan system. The modified triadan system is a numbered system based off the quadrant (left or right maxillary or mandibular) and the type of tooth. The first number qualifies the quadrant and is 100, 200, 300 or 400. The right maxillary is the “100” quadrant, left maxillary the “200” quadrant, left mandibular the “300” quadrant and right mandibular the “400” quadrant. If facing the animal, these numbers increase by 100 in a clockwise fashion. The first incisor is -01, second -02 and third -03. Thus the right maxillary first incisor is tooth 101, the left maxillary first incisor is 201, left maxillary second incisor is 202. The canine teeth are -04. The premolars begin at -05 and end at -08. Because the cat does not have a maxillary first or mandibular first or second premolar, the maxillary -05 and mandibular -05 and -06 are not used for cats. The molars start at -09 and proceed to -10 in the maxillae for dogs and -11 for the mandibles in dogs. Cats only have the -09. A hint to quickly remember which tooth is which is the canine teeth are always -04 and the fourth premolar is always -08 and first molar always -09. For example the left mandibular fourth premolar is tooth 208 and the adjacent molar is 209. The right maxillary canine is 104 and right mandibular canine is 404.

Structures of note of the hard palate are the incisive papilla which is a raised structure just palatal to the maxillary first incisors which is flanked on the left and right by paired palatine fissures. Palatal rugae are raised ridges of mucosa coursing across the hard palate from left to right. The major palatine arteries, veins and nerves are paired structures coursing between the midline of the palate and the ipsilateral arcade exiting via the major palatine foramen. Under the tongue and just lingual to the mandibular incisors are paired sublingual caruncles, where the mandibular and sublingual salivary glands exit. Lingual to the mandibular molar in the cat is the “fleshy” molar salivary gland. Within the mucosa of the cheeks is papilla which the parotid duct exits (adjacent to the maxillary fourth premolar) and papilla which the zygomatic duct exits (adjacent to the maxillary first molar). In each maxillae at the distal extent of the third premolar and just dorsal is the infra-orbital foramen. In each mandible at the extent of the second premolar in the
dog and labial frenulum of the cat is the middle mental foramen. In each species, on the medial aspect of the mandible and distal to
the third molar in the dog and first molar in the cat is the mandibular foramen.

The most commonly diagnosed disease in dogs and cats according to one study is periodontal disease. Periodontal disease is the
loss of normal periodontal tissue secondary to inflammation or periodontitis and seen clinically as periodontitis. The inflammation is
the body’s response to bacterial accumulation within a biofilm known as plaque. As with most biofilms, antibiotics alone are not
effective. Thus the best response is via mechanical removal via means such as brushing and mechanical chews. If plaque persists, the
saliva aids in mineralizing the plaque into dental calculus or tartar. This hard accumulation must be removed via mechanical scaling.
With persistent periodontitis, free and attached gingiva are lost, periodontal bone is resorbed and the cementum may be resorbed.
Clinically these changes are found as gingival recession, periodontal pocketing, mobile teeth and root and furcation exposure.
Eventually tooth loss and localized pathology such as jaw fracture and cellulitis are possible. There is potential for systemic disease
secondary to chronic periodontitis, the extent to which is not completely understood. There is a correlation between periodontal tissue
loss and histopathologic changes in the myocardium, kidneys and liver. It is important to note that these changes are not necessarily
related with disease of these organs. There are other studies comparing incidence of heart disease with incidence of periodontal
disease with mixed results. There are numerous studies in other species including humans which show an increase in the risk of
several diseases when periodontitis is present. Simply there is a lack of evidence in dogs and cats currently.

When the periodontal tissue is lost, it cannot be generated without surgical intervention. Procedures such as bone grafting and
and sliding gingival flaps can be used to regain lost periodontal tissue. However this requires elimination and control of periodontal
inflammation as well as the correct anatomic conditions. Often times extraction of teeth with advanced periodontal disease is
required. It is important to note that the best treatment for periodontal disease is not treatment, but prevention. This includes daily
plaque removal via providing tooth brushing and treats and diets which aid in removing plaque and preventing calculus accumulation.
Treats with the Veterinary Oral Health Council (VOHC) seal of approval are proven to do this and a list can be found at VOHC.org.
The other key to prevention is regular professional care, which includes supra and sub-gingival scaling and polishing under balanced
general anesthesia. Scaling without general anesthesia is not recommended and is potentially dangerous. Frequency is dependant on
the patient, breed, plaque control and previous disease state and may be as little as every 18 months and often as every 3 months.

Severe periodontitis can be seen with certain idiopathic inflammatory conditions. These are gingivitis and stomatitis seen in cats
(known as lymphocytic plasmacytic gingivostomatitis) and chronic ulcerative paradental stomatitis (CUPS) seen in dogs. The cause
of these diseases is unknown, however the feline version may be related to calici virus infection. Depending on the severity, CUPS
may be controlled with strict plaque control and modulation of the inflammatory response. However if daily brushing is not possible
or the disease state is severe, selective or whole mouth extraction is warranted. In cats, the only proven effective treatment is
extraction of all the molars and premolars and potentially the canine teeth and incisors. This treatment is still not 100% effective.

Another common pathologic condition seen in the oral cavity is tooth injury. This is generally seen as crown damage. Increasing
in severity is injury to the enamel, injury to the dentin and injury to the pulp. Injury to the enamel may be seen as enamel infraction
which is cracking of the enamel without loss of dental structure or enamel fracture which results in loss of enamel without exposing
the dentin. These do not require treatment unless radiographic evidence demonstrates otherwise. Injury exposing the dentin is known
as an uncomplicated fracture. Although the pulp is not directly involved, it may become infected as the dentin is porous and can allow
leakage of bacteria into the pulp. This risk increases in younger dogs and as the fracture approaches the pulp. These teeth should be
assessed for vitality via radiographs and if found to be vital, restoration is recommended to cover the exposed dentin. If found to be
non-vital extraction or root canal therapy is required. Injury exposing the pulp is known as a complicated fracture. All of these teeth
should either be extracted or treated via endodontic therapy. It is recommended root canal therapy only be performed by a well
experienced individual as complications are possible and the skills required take years to develop completely. Uncomplicated and
complicated fractures can be further classified into crown and crown root fractures. Crown fractures are completely coronal to the
gingiva. Crown root fractures course below the gingiva and pose a periodontal risk due to pseudopocket formation and bone
exposure. Trauma to the teeth may also result in pulpitis without fracture. This may become irreversible pulpitis and is often seen as
a discolored crown (pink, purple, gray, beige). These teeth often are dead due to venous congestion and should be extracted or treated
with root canal therapy.

Idiopathic tooth resorption occurs in many species including dogs and cats. Formerly this was known as feline odontoclastic
resorptive lesions (FORL) in cats. The cause for this is unknown. This is a progressive destruction of the tooth via odontoclastic
resorption of the hard tissue of the tooth. Often times this is painful and will progress until the tooth weakens to a point it fractures.
Attempts have been made to restore these lesions. However in feline patients, the result is always progression of the destruction and
eventual tooth loss. Current treatment is either complete extraction of the affected tooth, or if the bone is replacing the root, crown
amputation with intentional root retention. It is of the upmost importance that root is being replaced by bone. This is seen by a lack of
a periodontal ligament space and difficulty distinguishing root from bone. When in doubt the root should be completely extracted.
Unfortunately once tooth resorption begins, other teeth will likely be affected in the future. Hence it is important to periodically re-
examine these patients for further resorption.
There are two diseases of the enamel which are of importance are caries and enamel hypocalcification. Caries, commonly known as cavities, are due to the by-products of bacterial fermentation of carbohydrates. These by-products demineralize the enamel and dentin and if the pathology progresses, eventually lead to loss significant dental hard tissue and infection of the pulp. These lesions are uncommon in the dog and are generally found on the occlusal surface of the maxillary first molar, although any tooth can be affected. If discovered soon enough, these lesions can be treated with a cavity preparation and restoration. If severe, extraction is generally the treatment of choice. Caries do not affect cats.

Enamel hypoplasia is due to interruption of normal formation of enamel during tooth development. This leads to dentin exposure at tooth eruption or soon thereafter and may lead to infection of the pulp. Potential causes are systemic diseases which may cause the patient to be febrile, localized infection and localized trauma. If dental radiographs do not demonstrate involvement of the pulp or abnormal root formation, restoration with a resin composite is generally recommended.

Maxillary and mandibular fractures are not uncommon after facial trauma. In addition to injury, other common causes are periodontal disease and iatrogenic damage. The majority of these fractures is open and require soft tissue apposition first. The primary goal when treating jaw fracture is re-establishment of normal occlusion. If not obtained, self trauma and potential stress to the TMJ are possible. It is important to note that traditional fracture fixation methods such as IM pins, plates and external fixation devices may lead to iatrogenic trauma to the teeth or neurovascular structures. Often these fractures can be reduced and stabilized with interdental wires and composite intra-oral splints. In the case of pathologic fractures secondary to periodontal disease, the prognosis for healing is lowered.

Oral neoplasia is non uncommon and thus abnormal swellings should be biopsied. In the dog, the documented top three malignant lesions are melanoma, squamous cell carcinoma and fibrosarcoma, in that order. However it is the presenter’s experience squamous cell carcinoma is most common followed by fibrosarcoma then melanoma. In addition to malignancies, acanthomatous ameloblastoma is commonly seen. Although benign, this tumor is locally aggressive and requires resection with adequate margins. In cats the most common oral malignancy is squamous cell carcinoma.
Most topics in small animal dentistry are interchangeable between dogs and cats. However there are important differences in anatomy, pathology and technique that should be recognized.

**Anatomy**

**Dentition**
- The deciduous dentition of the cat consists of 26 teeth
- I 3/3  C 1/1  PM 3/2  X2
- The permanent dentition consists of 30 teeth
- I 3/3  C 1/1  PM 3/2  M1/1 X2

Cats are missing their maxillary first and mandibular first and second premolars. All incisors and canines are single rooted teeth. The maxillary third premolar and mandibular premolars and molar have two roots. The maxillary fourth premolar has three roots. The maxillary second premolar and molar may have a single root, two fused roots or two independent roots. A developmental groove, often called the bleeding groove, is present on the buccal side of the canine teeth. However variation of any of these is possible.

The tongue contains caudally directed conical papillae. Between the tongue and each mandibular molar is a molar salivary gland, unique to cats.

A plexus of arteries called the maxillary rete is present near the coronoid process and located between the masseter and pterygoid muscles. When the TMJs are over extended (such as with a spring loaded speculum) this rete can be compressed, leading to cerebral ischemia.

**Dental radiography**
The techniques used to image the teeth of the dog can for the most part be utilized when making radiographs of the cat. However the maxillary premolars and molar may be masked by the zygoma. Two techniques exist to counter this; intentional elongation and extra-oral imaging.

**Pathology**

**Tooth resorption**
Tooth resorption is the progressive uptake of dental hard tissue by odontoclasts. Although this is reported in many mammals; including dogs and man, the incidence in cats is much higher. The etiology of this disease is unknown. It is known that cats with tooth resorption have increased serum vitamin D levels, increased blood urea nitrogen, and lower urine specific gravity.

When a tooth is affected by resorption odontoclasts migrate into the dentin through the cementum. As dentin resorption progresses the enamel collapses and tooth sensitivity occurs. Teeth undergoing resorption should be extracted. Teeth in which the roots are complete, type I resorption, should undergo complete extraction. If the roots are being replaced by bone, type II resorption, the roots may be intentionally retained and allowed to continue to resorb.

**Feline chronic gingivitis and stomatitis**
Refractory inflammation of the oral mucosa is often seen in cats. The severity and distribution varies. The inflammation is often a lymphocytic/plasmacytic infiltrate. The etiology is not clear, but studies demonstrate that most patients are seropositive for feline calicivirus. Other etiologic agents have been investigated (herpes virus, Bartonella) but a clear relationship is not established. It is possible this is a multifactorial disease.

Physical exam findings and presenting complaints include; severe inflammation of the gingiva and other oral mucosa, missing teeth, mandibular lymphadenopathy, unkempt hair coat, anorexia, bad breath, obvious oral pain, drooling.

Serum chemistry may reveal an increase in globulin and radiographs often reveal horizontal bone loss.

In mild cases it may be possible to clean the teeth, extract teeth with attachment loss, and provide daily plaque prevention with frequent rechecks.

In most cases extraction of all affected teeth (often all teeth) is the only effective treatment. In a study published in JAVMA in 2015, 28.4% and 39% of cats receiving whole or partial mouth extraction achieved resolution or clinical improvement respectively, 26.3% had little improvement and 6.3% had no improvement. Of those experiencing improvement or resolution, 66.8% required medical management past two weeks after surgery. However there is still a population of patients who do not respond to this treatment (1). A study published in 1997 showed a slightly better response rate of 80% improvement or resolution (2).
Refractory cases may respond to feline recombinant omega interferon (Virbac Virbagen Omega) or cyclosporine. Feline recombinant omega interferon may be given as a subcutaneous or intra-lesional injection or orally. A study comparing the efficacy or oral transmucosal omega interferon to oral prednisolone showed a significant improvement of oral pain scores and alveolar mucosal inflammation of the interferon group compared to the prednisolone group and similar decreases in caudal mucositis (3). This may be due to anti-viral properties decreasing calici virus load.

Cyclosporine has been reported to decrease the clinical signs associated with stomatitis in cats when given at 2.5mg/kg BID. Nearly 80% of cats receiving cyclosporine demonstrated a grater than 40% improvement in the stomatitis disease activity index compared to a placebo (4). Although not statistically significant, previous corticosteroid administration before cyclosporine administration may decrease the success of cyclosporine.

A recent study published in Stem Cells Translational Medicine demonstrated remission or significant improvement in 5 of 7 cats who received a transfusion of autogenous stem cells (5). It should be noted that the stem cells were prepared via a different means than current commercially available means.

**Symphyseal separations**
The most common oral orthopedic injury in cats is traumatic separation of the cartilaginous mandibular symphysis. This is painful and can lead to debilitating malocclusions. Radiographs should always be assessed as fractures of the rostral aspect of the mandibles may resemble symphyseal separation clinically. However treatment for symphyseal separation will not stabilize a fracture.

**Squamous cell carcinoma**
Squamous cell carcinoma is the most common oral malignancy in cats (~70%). This is a potentially painful neoplasia. The prognosis for cure is poor. Additionally treatment requires surgical excision with wide margin. In the case of mandiblectomy, cats have a high rate of immediate post operative morbidity at 98% acutely and 76% long term with 72% dysphagic and 12% unable to eat on their own (6). However 83% of owners were happy with the outcome.

**Trauma after extraction**
When the maxillary canine teeth are extracted, there is risk that the superior lip may droop, causing the ipsilateral mandibular canine tooth to traumatize the lip. Because of this, when possible, root canal therapy should be performed on fractured canine teeth. However when this is not possible, lip drooping can often be minimized by adequate periosteal release. If the trauma persists, the ipsilateral mandibular canine tooth may be extracted or crown reduced if root canal therapy is performed on the tooth.

**Uncomplicated fractures of the canine teeth**
The pulp chamber of canine teeth approaches closely to the cusps of the tooth. When a fracture exposes the dentin, there is potential bacterial ingress to the pulp through exposed dentin tubules. Due to the high risk of pulpitis, it is often recommended to treat these teeth as complicated fractures.

**Feline oral pain syndrome**
Recently a phenomenon has been described in cats manifesting in severe oral pain. This may be secondary to previous oral trauma, but a history of trauma is not always present. It should be noted that feline oral pain syndrome has only been described in the UK, and the majority of the cats are Abyssinian.

**Post-anesthesia blindness**
There have been anecdotal reports of cats becoming blind after dental procedures for several years. Two recent studies implicate the cause may be ischemia secondary to use of spring loaded speculums. This may cause compression of the maxillary artery by the masticatory muscles or ramus. Although the exact pathogenesis is not known, it may be due to cortical ischemia (7) or retinal ischemia (8).

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Periodontal disease is due to inflammation of the periodontal tissues (periodontitis) and the resulting tissue loss and change in architecture. The tissues affected by periodontitis are gingiva, cementum, periodontal ligament and alveolar bone. The majority of the inflammation is due to the body’s own reaction toward plaque bacteria. Other causes are the direct destruction by the bacteria and irritation by dental calculus and foreign materials. Thus the successful prevention is elimination of plaque.

Anatomy
The periodontal tissues are the gingiva, cementum, periodontal ligament and alveolar bone. Gingiva is a modified oral mucosa which has a higher collagen content than other oral mucosa. It should form a collar around each tooth. Gingiva has an attached and free portion. The attached gingiva is connected to the alveolar bone and most coronal portion of the tooth root and periodontal ligament. The free gingiva surrounds the most apical portion of the crown. The epithelium of the free gingiva reflects toward the tooth to form the gingival sulcus which is the normal space between the gingiva and the tooth.

The cementum covers each tooth root. It contains vital cells and connects to the periodontal ligament via Sharpey’s fibers. The periodontal ligament connects the tooth root to the alveolus and also serves as a shock absorber and has sensory functions. The periodontal ligament also has fibers which connect to the gingiva and adjacent teeth.

The alveolar bone houses the tooth and periodontal ligament and provides support for the dentition. The interior of the alveolus is cortical bone with surrounding trabecular bone.

Periodontal irritants
Plaque
Plaque is bacteria housed within a protective glycocalyx. Plaque begins as a non-vital pellicle which forms within hours of a dental cleaning. Bacteria begins to colonize this pellicle and is surrounding by a glycocalyx biofilm. This biofilm protects the bacteria from antibiotics and antiseptics. However it can be mechanically debrided. If allowed to mature, the bacterial population shifts form gram positive aerobic bacteria to gram negative anaerobic (mainly rod) bacteria. Bacteria can damage the periodontal tissues through both direct means such as enzymatic destruction and volatile sulfur compound release or indirectly due to the immune response through the release of cytokines, prostaglandins and neutrophilic enzymes (1).

Calculus
When plaque is in contact with salivary minerals after 72 hours, it begins to mineralize. This mineralization is known as calculus, sometimes called tartar (subgingival calculus). Calculus can serve as an irritant and as a plaque retentive surface, making it’s removal and prevention necessary for periodontal disease maintenance.

Prevention
The key to preventing periodontal disease is to prevent periodontitis. The first stage in defense is plaque removal. Daily removal is most effective. The gold standard is daily toothbrushing. Toothbrushing is still effective if performed every other day (2). Less than this becomes ineffective. Brushing provides a mechanical debridement of plaque. Other mechanical means of plaque removal include diets and treats such as Greenies, Tartar Shield chews and Hill’s T/D.

Periodontitis may also be reduced by reducing calculus formation. This is commonly achieved through mineral chelators like polyphosphates. This can be found in Eukenuba products with the dental defense system. Obviously if a product reduces plaque, it will likely reduce calculus.

Regardless of home preventative methods, some calculus accumulation occurs. Calculus must be mechanically debrided with hand and/or power scalers. This can only be adequately performed under general anesthesia. Hand scalers are very effective, although inefficient to use alone. Hand scalers must be kept sharp. The most commonly used mechanical scalers are ultrasonic scalers. These function by turning electric energy into mechanical energy causing the tip of the scaler to vibrate with high frequency. These effectively knock calculus from the tooth. Due to the pattern and frequency of vibration the tip should not be directed toward the tooth and the scaler should not stay on a tooth for more than a few seconds at a time and should be water cooled. Otherwise tooth damage is likely.

Other mechanical scalers include sonic and rotary scalers. Sonic scalers are relatively safe, but less efficient. Rotary scalers are even less efficient and damage the teeth. These are considered below the standard of practice for DDS’s and are thus not used.

Subgingival scaling and be performed with ultrasonic tips or hand curettes. Ultrasonic subgingival tips are thinner and the power setting on the scaler must be decreased to prevent damage to the softer enamel. Hand curettes are similar to hand scalers, except the
tip is rounded to prevent soft tissue trauma. If used subgingivally, hand scalers can lacerate the soft tissue and cause more periodontitis.

Regardless of the scaling method, microabrasions are produced in the enamel. These are removed via polishing with a prophylaxis angle and paste.

Frequency of dental cleanings is dependent on three basics
- Effectiveness of home hygiene
- Individual patient anatomy/physiology/immunity
- Presence of established periodontal disease

Essentially our goal is to clean the teeth when calculus is present and before gingivitis occurs.

Assessment
Complete assessment of periodontal disease prognosis and treatment options depends on complete oral examination and dental radiographs. It is well documented that intra-oral radiographs are valuable/necessary for diagnosing oral pathology including periodontal disease (3,4). The complete oral examination includes periodontal probing, measurement of any gingival recession, examination for furcation exposure, assessment of presence of gingivitis and assessment of tooth mobility as well as quantifying the amount of calculus and plaque accumulation. Dental radiographs are necessary to quantify and qualify bone loss. Examination findings should be recorded in the medical record to refer to during continued assessment.

The total of periodontal attachment loss determines the stage of periodontal disease.
- Stage 0: no inflammation or attachment loss
- Stage 1: gingivitis only without attachment loss
- Stage 2: less than 25% attachment loss
- Stage 3: 25-50% attachment loss
- Stage 4: greater than 50% attachment loss

Treatment
Stage 0 periodontal disease requires only periodontal prophylaxis including supra and subgingival scaling and polishing followed by instituting appropriate plaque control at home.

Stage 1 periodontal disease is treated as stage 0. Home care should be stressed as the inflammation present may lead to periodontitis. Reassessment after six months is highly recommended to assure home care guidelines are being followed and are successful.

Stages 2 and 3 periodontal disease require treatment via dental cleaning and the associated attachment loss needs to be addressed.

If suprabony pockets are present and three millimeters of attached gingiva are present, the pocket may be treated with closed root planing (pockets less than 6mm) or open root planing (pockets greater than 6mm). Often the cleaned pocket can be treated after cleaning with a perioceutic. The most commonly used perioceutic in veterinary medicine is Doxyrobe gel.

If infrabony pockets exist, it is possible to surgically expose and debride the pocket, add a bone graft and a barrier to prevent re-epithelialization in a process known as guided tissue regeneration.

In the case root dehiscence and gingival clefts, gingival crafts can be performed to re-establish attached gingiva.

All of these advanced procedures require
- Client dedication to home hygiene an follow up
- Adequate existing periodontium to allow re-establishment
- Clinician skill and proper materials

If the client cannot or will not comply, extraction may be the best choice

Stage 4 periodontal disease requires extraction. However pre and post-operative radiographs are still required.

Systemic health
Chronic periodontitis will affect systemic health. The full effect on canine and feline patients is not fully realized. Human data has demonstrated a positive correlation between periodontitis and the following: coronary heart disease, stroke, poor diabetes regulation, low birthweight and premature birth. Data exists which points toward a correlation between periodontitis and histopathologic changes in the kidneys, liver, papillary muscle and mitral valve leaflets (5,6). Additionally there is evidence of changes on serum chemistry including an increase in C-reactive protein in dogs with periodontitis (7). It should be clear that none of this establishes a causative relationship.

Stomatitis and aggressive periodontitis
Some canine patients have severe inflammatory lesions of the gingiva and other oral mucosa. These lesions appear aggressive and are refractory to simple dental cleaning. These patients may present with drooling, marked to severe halitosis and anorexia. On
physical examination the following may be noted; severe gingivitis, paradental buccal mucositis, glossitis, mandibular lymphadenopathy and oral pain. CBC and serum chemistry profile is often unremarkable or may show hyperglobulinemia (IgG).

**Other diseases causing oral inflammation**

Serum chemistry should always be performed to rule out uremic ulcers. Other diseases which may cause focal or generalized mucositis or gingivitis include erythema multiform (EM), epitheliotrophic T-cell lymphoma (ETCL) and Wegner’s granulomatosis. These diseases are rare. EM will typically demonstrate non-oral lesions (8). ETCL likely will be present on mucocutaneous junctions and is often focal or multi-focal vs. generalized (8). Werner’s granulomatosis is very rarely diagnosed. It may affect the kidney’s and affected gingiva has an appearance of an overripe strawberry (9).

Other diseases causing oral inflammation

- Feline gingivostomatitis will be covered in the feline dentistry lecture.

Before deciding which is the best treatment for the patient, it must be determined if the client and patient are capable of daily plaque control. The client must be able and willing to brush the patient’s teeth daily. The patient must be willing to have it’s teeth brushed daily. This may not be possible due to poor behavior or pain. In this case extraction of all teeth associated with buccal, labial and lingual inflammation is required. This is often all of the remaining teeth.

If the patient and client can comply to daily tooth brushing, these patients may benefit from the following:

- Complete dental cleaning including subgingival debridement
- Extraction of all teeth with bone or gingival recession (dental radiographs are necessary)
- Extraction of crowded teeth
- Daily tooth brushing
- Other home hygiene and oral health promoting products including esterified fatty acids
- Doxycycline at 5mg/kg BID for 21d then 2mg/kg SID for one month. If the soft tissues are still not inflamed, the regimen is changed to EOD for one month then discontinued if the tissues continue to be not inflamed.

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In order to effectively treat dental related diseases, the practitioner must work to prevent these diseases. This is most important with periodontal disease. More detail on prevention of periodontal disease is presented elsewhere. However an common ‘pitfall’ in veterinary dentistry is not recommending dental cleanings frequently enough. There is no hard and fast rule to how often a dog or cat needs its teeth cleaned and not every patient is the same. Annual dental cleanings may not be enough for small breed patients or patients prone to periodontal disease. Annual may be too often for some patients. The goal is to professionally clean the teeth when calculus is first noted and before gingivitis occurs. This may be as frequently as every four months in some patients if home hygiene is not performed. This leads to the second pitfall of prevention, not recommending daily plaque control. What we perform as professionals only brings the mouth back to a normal state. Plaque accumulates within hours and if left unchecked will cause gingivitis within days. Daily plaque control is extremely important.

Another preventative measure the practitioner can make is recommending against toys and treats which may damage the teeth. Often times, pets, especially dogs, chews on toys that are too hard. This can often lead to fracture of the maxillary fourth premolars. My rule of thumb, if you think it is too hard for you to chew, it’s too hard for your dog to chew.

The common complications seen in small animal dental practice are; fractured and retained roots, iatrogenic trauma, suture dehiscence, persistent dental calculus, post-anesthetic blindness, anesthetic complications, and self trauma after extraction.

Fractured and retained roots
Retained roots occur by three means; trauma, tooth resorption leading to weakened dental hard tissue, and intra-operative mishap. When present, retained roots can lead to any combination of the following; non clinical signs, low grade inflammation, local gingivitis, moderate discomfort to severe pain, draining sinus tracts and more severe signs such as anorexia or diabetic crisis.

The only preventable cause of retained roots is intra-operative mishap. This is often due to forceful elevation and/or inadequate alveolar bone removal. The keys to prevention are:

- Creating a buccal cortical bone window large enough to allow the tooth to be extracted
- Using the correct instruments
- Assuring the instruments are sharp
- Using small, prolonged movements to elevate the tooth and deform alveolar bone vs. forceful action
- Assessing pre-operative radiographs to address possible complications and post-operative radiographs to assure complete extraction of the root

However even the most seasoned dentists have intra-operative mishaps and there are roots which are fragile and fracture during elevation regardless of technique. The following is the order sequence to remove fractured roots

1. Identify root
2. Remove buccal cortical bone to level of tooth apex, not beyond
3. If periodontal ligament space can be identified, luxate between root and bone
4. If it cannot be identified, a “moat” can be cut in the bone, around the root to allow luxator placement
5. Elevate gently
6. Confirm extraction via radiographs

When examining a patient which has missing teeth, always confirm there is no unerupted/impacted tooth or tooth root remnants via radiography. In the case of fractured roots from previous trauma, the steps to removal are the same. However granulation/connective tissue may be covering the root. In this case, after the root is identified radiographically, debride the area with a water cooled highspeed diamond bur. This will allow visual identification. The steps to extraction are identical at that point.

Iatrogenic trauma
In addition to fractured roots, iatrogenic trauma in the form of penetration of surrounding structures with dental instruments and mandibular fracture.

Penetration of surrounding structures is easily avoided by using the short finger stop grip on elevators and luxators. In this technique the butt of the handle is rested in the palm and the thumb, middle, ring and pinky fingers are used to grasp the instrument. The index finger is laid over the shaft of the instrument with the tip of the finger resting near the working blade. This way if the instrument slips, the index finger prevents penetration of the mucosa, eye and possibly brain.

Mandibular fracture is not a rare occurrence when extracting the mandibular canine teeth in dogs and cats. This can occur even when surrounding bony structures are healthy and intact. Often the case is inadequate buccal cortical bone removal, as is the cause of fractured roots. However in the case of the mandibular canine tooth, the excessive force is transferred to the thin interdental bone.
between the third incisor and canine, resulting in fracture. This is prevented much like prevention of fractured roots. The caveat the presenter recommends not elevating between the canine and third incisor until the tooth is slightly mobile. And then using gentle elevation only.

**Suture dehiscence**

Although there are causes of suture dehiscence which are not preventable by the clinician, the most common cause is; excessive suture line tension.

   Tension on suture is easily preventable by using a periosteal releasing incision. When the mucoperiosteal flap is created, the associated periosteum is raised with the flap. Separating the periosteum from the mucosa and incising the periosteum will allow the mucosal flap to easily cover the extraction site without tension. When testing for tension, lay the flap over the alveolus so the epithelial edges are apposed. If the flap lays without recoil, it is free enough to close.

   In addition to mucoperiosteal release, two other steps to prevent dehiscence are suturing over a bony ledge and freshening the epithelial edges. Suturing over a bony ledge will support the suture. In the case of a maxillary canine extraction when an oronasal fistula is present, if sutures are over a void, tension may be caused by air moving through the nasal cavity. It should be noted that suturing over a bony ledge is not always possible such as with minor extractions and maxillary first molar extractions. In these cases as long as the alveolus is intact, the risk is minimal. Freshening the epithelial edges entails removing the sulcular epithelium from the gingiva so cut edges are apposed. If intact epithelium is apposed, primary healing will not occur.

**Persistent calculus**

Calculus remaining after a dental cleaning can cause gingival irritation and provide a more plaque retentive surface. Prevention is simple. After tooth surface should be visually inspected AFTER the dental cleaning to assure complete calculus removal. The intact tooth has five surfaces; buccal, lingual/palatal, mesial, distal and occlusal or the cusp. It is extremely important to visualize the sulcus as well to assure subgingival calculus is not present. This is performed via sulcular insufflation. The three way air water syringe is directed toward the sulcus and air is blown into the sulcus to open it away from the tooth. At this time the subgingival surfaces are inspected for calculus. Additionally drying will allow tooth colored calculus to be visible as dry calculus is chalky in appearance and intact enamel is shiny.

   As with all dental procedures, sharp instruments and proper instruments are also key.

**Post anesthetic blindness**

In cats there are numerous anecdotal reports of cortical blindness and even death post-dental procedure. This is most likely secondary to compression of the maxillary arterial rete, which is located near the coronoid process between the masseter and pterygoid muscles. When the TMJs are overextended, as happens with use of spring loaded speculums, the rete is compressed and causes cerebral ischemia. This is easily prevented by not using spring loaded speculums in cats. If a prop is needed for visualization, a cut 1cc syringe can provide adequate opening of the TMJs.

**Anesthetic complications**

Anesthesia is a requirement for a proper dental cleaning and evaluation. However many dental patients are older and a higher anesthetic risk than their younger counterparts. With age there is a higher risk of diseases affected by anesthesia including renal insufficiency, valvular heart disease and osteoarthritis. It is imperative that we support our patients and monitor before, during and after anesthesia and tailor each anesthetic protocol to the patient. With certain health conditions, drugs such as NSAIDs need to be avoided.

**Trauma after extraction**

When the maxillary canine teeth are extracted, there is risk that the superior lip may droop, causing the ipsilateral mandibular canine tooth to traumatize the lip. Because of this, when possible, root canal therapy should be performed on fractured canine teeth. However when this is not possible, lip drooping can often be minimized by adequate periosteal release. If the trauma persists, the ipsilateral mandibular canine tooth may be extracted or crown reduced if root canal therapy is performed on the tooth.
Endodontic therapy involve the treatment of injuries and disease of the dental pulp with the intention of preserving the function of the tooth. The benefits in our patients are; retention of a functional tooth, decreased morbidity compared to surgical extraction and aesthetics which may be important to the client. Endodontic procedures performed include standard root canal therapy, surgical root canal therapy and direct pulp capping. The indications for endodontic therapy include pulp exposure via trauma or iatrogenic means, pulp necrosis and crown reduction for orthodontic treatment.

Anatomy and physiology
The pulp is central vital mass of the tooth. It is made of blood vessels (arterioles, venules, and capillaries), nervous tissue, lymphatics in some species, connective tissue, odontoblasts and reserve mesenchymal tissue. The odontoblasts sit at the periphery of the pulp and produce new dentin. The odontoblasts also have projections that reach into tubules found within the dentin (dentinal tubules). As odontoblasts produce new dentin these cells migrate centrally, effectively making the root canal more narrow as the vital tooth ages. The dentinal tubules course between the enamel and pulp. These tubules are more numerous and wider nearer the pulp, nearer cusps and in younger animals. There are approximately 29-52,000 dentinal tubules per square mm of dentin in the dog. The pulp enters and exits the tooth primarily through multiple foramina at the root apex called the apical delta in the dog and cat although there may be communications through the root in other locations.

Pathophysiology
The pulp may become injured through several means including; direct exposure, indirect exposure via the dentin, concussive force, thermal trauma or carious lesions (cavities).

The typical route of pulp injury in the dog and cat is through direct exposure. This is often due to dental fracture from chewing on inappropriate items or concussive force (complicated crown fracture). It can also occur through iatrogenic exposure. When the pulp is exposed, inflammation occurs. Additionally, it will become septic if no treated.

When the dentin is exposed without pulp exposure (uncomplicated crown fracture), the pulp may become inflamed due to odontoblastic process injury or septic due to bacteria reaching the pulp via exposed dentinal tubules.

Concussive force can cause pulpitis without damaging the hard tissue of the tooth. When the tooth is concussed and the pulp swells, venous congestion can occur leading to a sterile necrosis. In turn the hemoglobin from RBC destruction can move into the dentinal tubules. This will give the tooth a pink, purple, gray or beige discoloration. This may also occur from thermal necrosis via iatrogenic means (scaler use) or accident such as electrical chord injury.

Rarely caries or cavities can occur in dogs. The loss of dentinal hard tissue can expose the dentin leading to pulpitis. Additionally the pulp can be inflamed from noxious by products of bacterial metabolism.

When the pulp becomes necrotic, periapical inflammation can occur. The consequences of periapical inflammation are periapical granuloma, periapical abscess, draining tract, osteomyelitis. The lesion can be a combination of any of these and is dynamic.

Root canal armamentarium
The majority of instrumentation for root canal therapy are for machining and removing damaged dentin and pulp and for irrigating the root canal to dissolve organic debris and flush away inorganic debris.

The depth of root canal instrumentations prevents a thorough discussion of the subject in this lecture. The basics will be discussed.

The instruments which remove dentin are called files. Root canal files can be divided into two basic categories, hand files and rotary files. The classic hand files are H type and K type. H type are made by machining tapered round metal to produce cutting flutes which cut on the up pull. K type files are made by twixting a tapered square blank to create cutting edges on the sides. These function by either a twist and pull motion (K-files) or a twisting only motion (K-reamers). Dozens of variations on these exist.

Rotary files are attached to a mechanical hand piece and cut either by a reciprocating motion or a twisting motion. As with hand files, there are too many variations to fully discuss here.

In addition to the instruments used to mechanically decried the root canal, chemical irrigants must be delivered to the entire root canal. These irrigants are generally placed through an endodontic irrigation needle which is fluted on the side to prevent extruding irrigating through the apex. Other delivery systems are available which are variations of this.

There are a number of irrigants available. The most widely used is full or half strength bleach. Bleach will dissolve organic debris including pulp and bacteria. It is caustic and if pushed beyond the root canal can be caustic to the periapical tissues. Additionally it may cause ulceration of the oral mucosa if left in contact with these tissue.
Standard root canal process
Standard root canal therapy involves the removal of all diseased pulp and dentin, shaping the canal to a gradual taper and filling the canal to prevent re-infection of the periapical tissues. In order to remove the disease tissue and shape the canal, the operator must first access the canal. This may be possible through the original fracture site, or may required access through the crown at other locations. The goal of access is to achieve a direct route to the root canal so that files are not excessively bent which can lead to damage of the root canal.

Removal of gross debris and tapering the canal is performed with root canal files. A tapered shape is preferred because it allows irrigants to reach the apex and aids in obdurating the canal via hydrostatic pressure. This is performed in conjunction with irrigation to one work synergistically (instrumentation and irrigation) to remove diseased tissue, two to aid in flushing out debris and three to keep the canal lubricated and decrease the risk of instrument separation or breakage. Once the canal is fully derided and shaped, it is dried and the canal is filled with a root canal sealant and solid material, often gutta percha. The sealant reduces the instance of bacterial reinfection of the periapical tissues and the solid material aids in spreading the sealant against the dentinal walls. After the canal is completely obdurated the tooth is restored (see below).

In a 2002 study looking at 12 cases, root canal therapy was deemed as successful in 69% of cases, no evidence of failure in 26% of cases and failed in 6% (helena).

Vital pulpotomy and direct pulp capping
Vital pulpotomy and direct pulp capping is removal of inflamed pulp and placement of a material on the pulp to encourage new dentin formation, followed by restoration. This is also necessary when performing crown reduction to treat traumatic malocclusion. The materials classically used are calcium hydroxide (CaOH) and mineral trioxide aggregate (MTA).

In a 2014 study of 190 cases, vital pulpotomy with direct pulp capping was successful in 85% of cases overall with the use of MTA (92% success) vs. CaOH (58% success) and depth of pulp capping material being the biggest factors of success (Luotonen)

Surgical root canal therapy
Surgical root canal therapy involves the surgical excision of the root apex and filling of the root end with an appropriate material. This may be required in the case of instrument failure and separation, unsuccessful initial root canal therapy or a diseased root apex.

In a 2012 study of 15 cases, 10 showed complete resolution, 5 no evidence of failure (fulton, fiani)

Restoration
Restoration of the tooth after endodontic therapy may be either a composite restoration or a prosthodontic crown. The choice is dependent on the tooth treated, the procedure performed and the client’s wishes.

A composite restoration is a quicker, less costly way to restore a tooth. The missing dental hard tissue is replaced by a bonded resin/particulate composite which wears similar to natural tooth. Composite restorations can fracture and become lost. These should always be used when performing vital pulpotomy and direct pulp capping due to the risk of failure of the endodontic procedure. Composite restoration can be performed when performing standard root canal therapy but the client should be warned that the restoration may become damaged. This is more of a concern in teeth under high stress (chewing teeth, canine teeth of apprehension dogs).

A prosthodontic crown is either a metal, porcelain on metal or ceramic sleeve replacing the lost hard tissue of the natural crown. Placement of a crown requires shaping the tooth to accept a crown, making impressions of the prepared tooth and use of a dental laboratory to fabricate the crown. A second anesthesia is required to cement the crown. The presented only recommends metal crowns due to their durability. A metal crown will not break and should not be lost, although the natural tooth within the crown can still fracture if enough bending force is applied. Not all teeth can accept a metal crown due to the height and shape of the tooth.
Taking the Bite Out of Tooth Extractions

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Tooth extraction is a surgical procedure with serious potential complications and should only be performed by a trained veterinarian. Additionally extraction should only be performed after a diagnosis is made and other treatment options have been presented to the client.

The reasons for performing dental extractions include; complicated fractures (pulp exposure) when root canal therapy is not possible, impacted and unerupted teeth, advanced periodontal disease or marked periodontal disease when plaque control cannot be performed, tooth resorption, treatment of certain malocclusions and persistent deciduous teeth.

Extractions may be either simple extractions and surgical extractions. Simple extractions are performed by freeing the gingiva from the tooth and elevating the tooth from the alveolus without bone removal with or without tooth sectioning. Surgical extractions involve elevating a mucoperiosteal flap, and some bone removal.

The equipment and instruments used for dental extractions are; a scalpel (15, 15c or 11) to incise the gingiva, a periosteal elevator to raise the mucoperiosteal flap, a water cooled air driven highspeed handpiece (drill) to section the teeth and remove bone, a variety of shapes and sizes of dental elevators and luxators, extraction forceps, small bladed sharp scissors, a needle driver and thumb forceps.

**Short finger stop**
The short finger stop is the method of holding a dental elevator or luxator which reduces the risk of iatrogenic damage to the patient. The butt of the handle is palmed and the remainder of the handle is grasped with the thumb, middle, ring and pinky finger. The index finger is held along the shaft on the instrument with the tip of the finger just behind the working edge. This way if the instrument slips, the operators finger serves as a “brake” to prevent damaging the oral tissues, eye, and/or brain with the sharp instrument.

**Slow is smooth, smooth is fast**
When one skips steps in the extraction or forcefully elevates the tooth, the result is often fractured root tips, which take more time to retrieve. By working efficiently but carefully, one will achieve optimal surgical time.

- Take care in designing and elevating the mucoperiosteal flap to achieve optimal exposure and easier closure
- Always section multi-rooted teeth no matter how loose the tooth seems
- Remove adequate alveolar bone
- Elevate with minimal force, hold and fatigue the ligament, repeat.

**Suture size, type and pattern**
The presented prefers to use Monocryl or a similar suture. Reverse cutting needles are used. 4-0 is preferred in dogs, 5-0 in cats. For most single extractions a simple interrupted suture is preferred. When closing multiple adjacent extractions, the presented uses a Ford interlocking pattern.

**Mucoperiosteal flaps**
The first step in performing a successful surgical extraction (after proper diagnostics) is the creation of a mucoperiosteal flap. These flaps are made of the free and attached gingiva, alveolar mucosa and periosteum. The three types of incisions involved in a mucoperiosteal flap are a sulcular release, a horizontal release and a vertical release. All flaps involved in routine extraction require a sulcular release. This is simply pushing a scalpel between the free gingiva and tooth into the sulcus to free gingival connective tissue from the tooth. A horizontal release continues this incision in a mesial or distal direction. A vertical release is nearly perpendicular to the occlusal plane and is extended into the alveolar mucosa in an apical direction. The vertical releases are always made off of a line angle of the tooth. These line angles are at the buccal or facial surface of the tooth and either at the mesial or distal extent. Releases between two roots or along a root are in danger of future dehiscence secondary to masticatory force. If two vertical releases are made, they should be divergent in an apical direction rather than convergent or parallel to aid in closure and to preserve blood supply. The design of the flap should be that to 1) expose enough root for extraction 2) preserve attached gingiva of neighboring teeth and 3) to cover, without tension, the defect created by extraction. When closing these defects, often the attached periosteum prevents apposition without tension. This is addressed by a periosteal releasing incision. Simply, this is a partial thickness incision through the periosteum only which allows the stretch of the mucosa to aid in covering the defect. This can be done with a scalpel or by separating and incision with scissors. One modification (which the presenter prefers for cats) is to use the non-cutting side of the scalpel to “strum” the periosteum and in turn separating it.
Elevation and luxation
In order to remove the tooth from the alveolus, the periodontal ligament must be severed and the alveolus deformed to allow the tooth to be completely extracted. This is achieved through luxation and elevation. Luxation is the severing of the periodontal ligament with an extremely sharp, thin bladed instrument called a luxator. A luxator is a sharp, thin instrument which is pushed apically to sever the ligament. Elevation with this instrument should be avoided as it can damage the blade.

Elevation is the process of placing slight torque on the tooth in order to stretch the periodontal ligament, slightly deform the alveolus and ultimately mobilize the tooth for extraction.

Simple or closed extractions
Extraction without removal of bone is termed a simple extraction. This can be performed on most incisors, first premolars, maxillary molars (after sectioning the tooth) and mandibular second (after sectioning) and third molars.

This technique involves making a gingival releasing incision and elevating the gingiva from the tooth without damaging neighboring gingiva, followed by luxation and gentle elevation. If the operator is overzealous in elevation, root fracture will occur. The alveolus is debrided. The free gingival margins are then debrided and the edges apposed without tension.

Extraction of the maxillary canine tooth
The presenter prefers a single mesial release and modifying by extending a horizontal release to the first premolar. The flap is raised so that the apical extent of the juga can be visualized. An appropriate sized round or pear bur on a water cooled high speed handpiece is used to remove the buccal cortical bone plate from the root to allow elevation of the tooth without root fracture or iatrogenic trauma. A sharp luxator is pushed in an apical direction along the mesial and distal aspect of the tooth. An elevator is placed between the root and bone as the mesial extent of the tooth and pressed apically. The elevator is rotated until slight pressure is felt and held for 10 seconds. This action is repeated until the tooth is finger loose and can be extracted. Always be cognizant of the apex in relation to the nasal cavity as not to perforate the cavity. After extraction the bone is smoothed and alveolus debrided. The periosteum is incised to allow closure. The epithelial edges are debrided and the palatal side of the gingiva is elevated off the bone. The flap is closed by first suturing the mesial corner of the flap to the mesial aspect of the palatal mucosa. The distal aspect is closed next and the two ends met with enough sutures to prevent gaping and placement of closed forceps between two sutures. The vertical release is closed next. A post operative radiograph is made to assure complete removal of the tooth.

Extraction of the mandibular canine tooth
The presenter prefers a mesial release based of the faciodistal line angle of the third incisor and a distal release angled to incise through the labial frenulum at its most dorsal extent. The flap is raised so that the apical extent of the juga can be visualized. It is important to avoid traumatizing the neurovascular bundle which exits the middle mental foramen. Bone removal and elevation is similar to the maxillary canine except care should be taken placing an elevator or luxator between the canine tooth and third incisor because a) it may loosen the incisor and b) this area of bone is weaker in cats and brachycephalic dogs and may lead to iatrogenic fracture. Alveoplasty and closure are similar to before except the labial frenulum is closed first then the mesiobuccal corner.

Extraction of the maxillary fourth premolar
There are two common flap designs; a single mesial vertical releasing incision or mesial and distal releasing incisions. It should be noted that a vertical releasing incision between the fourth premolar and first molar may lead to lack of gingival coverage of the molar and potentially root dehiscence. The presenter prefers a single mesial release and modifying by extending a horizontal release midway along the crown of the molar. This allows for better closure at the end of the procedure. The flap is raised so that the apical extent of the jugum of the mesial and distal roots can be visualized. Because the infra-orbital foramen is just rostral to the fourth premolar, care should be taken not to extend the flap into the neurovascular bundle as it exits the foramen. An appropriate sized round or pear bur on a water cooled high speed handpiece is used to remove the buccal cortical bone plate to expose the furcation between the mesial and distal roots. The buccal cortical bone plate of the distal root is then removed. Enough bone is removed to allow elevation of the tooth without root fracture or iatrogenic trauma. This may be as little as half the buccal bone with an experienced surgeon with sharp elevators and luxators or to just the extent of the apex for the beginning surgeon. A side cutting bur such as a 701 or 557 is used to separate the mesial and distal roots. If crowding between the fourth premolar and first molar are evident, the buccal bulge can be removed from the fourth premolar with a side cutting bur. A sharp luxator is pushed in an apical direction along the mesial and distal aspect of the distal root. An elevator is placed between the root and bone as the distal extent of the tooth and pressed apically. The elevator is rotated until slight pressure and held for 10 seconds. This action is repeated until the tooth is finger loose and can be extracted. Additionally, the elevator can be placed between the mesial and distal aspects of the fourth premolar and rotated if the two mesial roots are intact and not resorbing (based on radiographs). If the tooth does not move during attempted elevation, more buccal bone is removed. The buccal bone of the mesial root is removed in a similar fashion. A side cutting bur is used to separate the buccal and palatal root by transecting between the primary cusp and the palatal cusp. An elevator is placed between the buccal and palatal...
portions of the crown and rotated to check for independent movement which indicates complete separation. A sharp luxator is placed along the mesial and distal aspects of the buccal root, followed by an elevator. The elevator is rotated as before and the root is removed after it is finger loose. A round or pear shaped bur is used to remove the inter-radicular bone which was between the buccal and palatal roots before the buccal was extracted. A sharp luxator is placed along all aspects of the root and an elevator used to elevate the root in a buccal direction. Closure is as described before with the gingiva closed around the maxillary first molar first.

**Extraction of the mandibular first molar**

The mandibular molar is extracted in a similar fashion to the fourth premolar. The differences are there is only one mesial root and the buccal cortical bone plate tends to be thicker along this tooth. Additionally as with the mandibular premolars, care needs to be taken not to press against the root in an apical fashion as this may cause the root to be pushed into the mandibular canal. It is extremely crucial with this tooth that pre-operative radiographs be evaluated before extraction because with marked periodontal disease, the risk of pathologic/iatrogenic fracture is high.
Dental radiographs have become a medical and financial necessity in small animal general practice. Dental radiographs are now the standard of care when diagnosing dental related disease, pre-planning treatment, documenting complete root removal after extraction and monitoring disease progression. In two separate studies, clinically relevant findings were discovered after full mouth radiographs in 27% of canine and 41% of feline patients and provided essential data when clinical lesions were radiographed in 22% of canine patients and 32% of feline patients (1, 2)). Pathology such as uncomplicated fractures and tooth resorption cannot fully be assessed without radiographic capability.

Techniques

There are two techniques utilized to make most dental radiographs; parallel technique and bisecting angle technique.

Parallel technique involves placing the film on the lingual aspect of the tooth and pointing the tube head perpendicular to the tooth. The film should be positioned so one edge of the film is in line with the occlusal plane and even with the cusp of the tooth. This technique is only effective for the mandibular fourth premolar and molars of the dog and if utilizing a size 0 film, the mandibular premolars and molar of the cat.

Because of the anatomy of the oral cavity, many teeth cannot be imaged with a parallel technique (tube head pointed perpendicular to film and film parallel to long axis of tooth) and a bisecting angle technique is required. The teeth which can be imaged via a parallel technique are the mandibular premolars and molars in the cat (using a size 0 film) and the third and fourth mandibular premolars and all three mandibular molars in the dog. Hence the need for the bisecting angle technique. This involves placing the film as close to parallel to the tooth as possible and aiming the tube head perpendicular to the line which bisects the long axis of the tooth and film. This allows for the most correct geometry projection possible. If the tube head is angled to close to “horizontal” the image will appear shorter than normal and if too close to “vertical” will appear longer than normal. When imaging the premolars and molars, the x-rays are aimed from lateral to medial and when imaging the incisors and mandibular canine teeth the x-rays are aimed from rostral to caudal. When imaging the maxillary canine teeth, the film and tube head are set up as taking a bisecting angle as in the premolars then the tube head is rotated to 45 degrees to midline (as apposed to 90 degrees) to provide an image which does not have superimposition of adjacent teeth on the canine tooth. When imaging the mesial roots of the maxillary fourth premolar, the tube shift technique is used. The radiograph is set up as normal, then the tube head is shifted to point from distobuccal to mesiopalatal and the film or sensor is slid rostrally to allow the image to be projected forward. This will provide a radiograph with the two mesial roots separated and the most “rostral” root is the mesiobuccal root and the “middle” root is the mesiopalatal. This technique can also be used when deciding if a radiographic finding is adjacent to a tooth root or within the tooth root. If a structure is adjacent, it will appear to move mesial or distal to the tooth when the cranial to caudal angle is changed. Conversely, it if is within the root, it will not move away from the root when the angle is changed.

An extra-oral technique can be used to image the maxillary premolars and molar of the cat. Regular means may cause superimposition of the zygoma over the teeth. By putting the cat in lateral recumbency, the depending maxilla can be imaged. The head is tilted slightly so the dependent side is more ventral with the film under the maxilla. The tube head is aimed through the mandibular maxilla. This film will need to be inverted to properly view as it is an extra-oral technique.

Normal structures to recognize on the radiograph are

- Crown and root
- Root Canal/Pulp Chamber
  - Relatively radiolucent to tooth
  - Becomes thinner as the tooth ages
- Periodontal Ligament (PDL) Space
  - Radiolucent space around root
  - Widest at apex and near crown
- Lamina Dura
  - Relatively radiodense line around PDL space
  - Due to superimposition of cortical bone
- Trabecular Bone
  - Palatal shelf of the maxilla
  - Nasal concha / turbinates
Periodontal assessment
When assessing periodontal health, the first change seen on radiographs is loss of crestal bone. Afterword, either vertical or horizontal bone loss or a combination thereof occur.

- Horizontal Bone Loss
  - Bone loss affects more than two proximal teeth
  - The coronal plane of bone loss is parallel to the occlusal plane
  - Furcation bone loss may be seen.

- Vertical Bone Loss
  - Bone loss affects one or two proximal teeth
  - The coronal plane of bone loss is oblique to the occlusal plane
  - Often difficult to differentiate between one, two and three walled defects

Endodontic disease
Any teeth with fracture (with or without pulp exposure) or discoloration should be radiographed before deciding what treatments are available. When assessing endodontic health of the tooth, the presence of the following may indicate pulp compromise

- Periapical Lucency
- Widening of the Periodontal Ligament Space
- Loss of the Lamina Dura
- Relatively Wide Root Canal Space
- Focal Widening of the Root Canal or Focal Radiolucency on the Root

It is important to note, even without radiographic change, teeth with pulp exposure should always be treated with endodontic therapy or extraction.

- Mixed periodontal and endodontic lesions can occur and need to be recognized.

Tooth resorption
When assessing tooth resorption, radiographs are available in diagnosing as well as treatment planning. When cats with tooth resorption are assessed with radiographs and gross examination, 2.5 times more resorbing teeth are discovered vs. with examination alone (3). Additionally, when it is assessed the tooth root is completely replaced by bone and the root can no longer be distinguished from bone, extraction may be difficult, and it may be acceptable to leave the root behind after removing the crown.

Tooth resorption of the crown will appear as a relative or completely radiolucent focus. This is due to loss of enamel with or without loss of dentin. The periphery of the root may be irregular or a portion of the root replaced with bone. It is important to note that apparent loss of the periodontal ligament space alone may not be tooth resorption, only a thin periodontal ligament space which can happen has the patient ages. This finding alone should not prompt the clinician to recommend crown amputation with intentional root retention.

Injuries
Dental radiographs are essential for assessing maxillofacial fractures. Intra-oral techniques will allow the clinician to view the fracture without superimposition of apposing jaws or the contralateral side. Additionally the teeth near a fracture can be assessed for root pathology which is often common with fractures.

The rami and TMJs can also be imaged via extra-oral techniques with #4 film. However when radiology alone is used to assess fractures of the maxilla and temporal bone, lesions may be missed, which can be assessed with CT (4)

Missing teeth
Radiographs are needed for assessing if a missing tooth is truly missing, unerupted or has been damaged and has tooth structure remaining which requires extraction. In the case of retained roots of the maxilla, it may be useful to make an occlusal (DV) radiograph in the region of the suspected root. This causes the root to appear more radiodense and easier to identify.

References
Oral neoplasia is not uncommon. Both benign and malignant neoplasia is seen in the dog and cat. There are several oral enlargements that are not neoplastic but still abnormal and anatomic structures that may appear neoplastic which are normal anatomy.

Anatomic structures which resemble neoplasia

Incisive papilla
The incisive papilla is found at the most rostral portion of the hard palate immediately caudal to the first incisors. It is small in the cat, but in the dog can be large and pronounced making it appear as a mucosal mass.

Molar salivary gland
The molar salivary gland is a structure unique to the cat. It is located immediately lingual the the mandibular molar. It is soft and lined with simple mucosa.

Salivary ducts
The salivary ducts of the dog and cat are the zygomatic found in the buccal mucosa near the first molar, the parotid found in the buccal mucosa near the fourth premolar and the mandibular and sublingual found at the base of the lingual frenulum within the sublingual caruncles.

Non-neoplastic and non-cystic swellings

There are a number of enlargements of the oral cavity which may resemble neoplasia, but are signs of other oral diseases.

Gingival hyperplasia
Gingival hyperplasia is a non-neoplastic enlargement of the gingiva. The gingiva is of normal architecture an likely is present because of lack of normal gingival epithelial apoptosis (1). It may be idiopathic and suspected familial as seen in boxers xxx or can be drug induced (cyclosporine, amlodipine).

Expansive osteitis of the canine teeth
Periodontitis of the maxillary canine teeth in the cat can lead to expansion of the buccal cortical bone plate. This appears as a large osseous swelling and may resemble a bone based tumor. This typically appears as a spherical expansion of the alveolar bone of the maxillary canine teeth with concurrent vertical bone loss of the canine tooth. The lesion should be confined to the canine tooth.

Pyogenic granuloma of the cat
In the case of occlusal trauma of the premolars, a soft tissue mass may be present. This lesion appears as red to yellow and ulcerated. There may be associated horizontal periodontal bone loss. The histopathology shows infiltration with neutrophils, lymphocytes and plasma cells as well as ulceration and granulation tissue (Riehl). Treatment is soft tissue resection of the mass and removal of the occlusal trauma.

Malignant tumors

Oral tumors are 6% of all malignancies in the dog and less common in the cat (2). Permanent or long term control may be possible when some of these tumors are detected, diagnosed and treated early. With all oral malignancies, prognosis for complete removal is poorer the further caudal the neoplasia is located.

Squamous cell carcinoma
Squamous cell carcinoma has a low metastatic rate in the dog. If found quickly it can often be surgically treated if it has not metastasized with wide (>1cm) margins. Grossly it often appears as an exophytic growth with rupture of the surrounding epithelium although variations exist. Typically the radiographic appearance shows loss of normal bone density without new bone formation. Tonsillar squamous cell carcinoma of the dog has a much more guarded prognosis.

A histologic variant of squamous cell carcinoma is often seen in dogs. This is known as papillary squamous cell carcinoma. It is generally amenable to treatment via wide surgical excision, however it it an aggressive lesion and should be dealt with quickly.

In the cat this lesion is much more aggressive. Treatment with wide or radical excision alone rarely is effective past six months. Surgical excision followed by radiation therapy may give a better prognosis. This lesion is most commonly found under the tongue or within the mandibles. The gross lesion may appear as an ulcerated lesion or as a large swelling within the bone of the mandible. Radiographs of mandibular lesions often show what appears as a osteolytic/osteoprodutive lesion, although what appears to be new bone formation may only be expansion of the bone due to osteitis.
Fibrosarcoma
Fibrosarcoma has a guarded prognosis for one year survival after surgical treatment (~50%). It has a moderate metastasis rate to the lungs. Wide excision followed by radiation therapy may be the most effective treatment. It often appears as a soft tissue mass of the palate or maxilla with intact epithelium. The radiographic appearance shows major to complete loss of bony density in the region of the mass. There is a variant known as histologic low grade, biologic high grade (HiLo) fibrosarcoma. This variant may appear as a fibroma histologically while still being an aggressive neoplasm.

Melanoma
Oral melanoma is a quick to metastasize oral neoplasia. Often it will spread to regional lymph nodes and lungs. These will often have a black appearance. Prognosis greatly depends on staging at the time of diagnosis and treatment but chemotherapy is often required.

Osteosarcoma
Osteosarcoma is a locally aggressive neoplasm with potential to metastasize. Recurrence after surgical resection occurs in 90% of maxillary lesions and half of mandibular lesions and metastasis is around 45% (Verstraete). Radiographic lesions can be productive, lytic or both. Treatment is by wide surgical margin and use of radiation or chemotherapy after is not consistent among oncologists.

Epulides
The term epulis is technically describes an exophytic growth of the jaws. In veterinary literature it is used to describe benign odontogenic tumors. Recently more precise descriptions have been proposed.

Odontogenic fibroma
Odontogenic fibroma is a non-invasive growth of the gingiva. It is made of odontogenic epithelium which may be from epithelial rests found in the periodontal ligament. These were formerly known as fibromatous epulis or ossifying epulis. The current accepted nomenclature is peripheral odontogenic fibroma or ossifying odontogenic fibroma. These lesions do not invade into bone. The most common risk is development of a pseudo pocket or a gap between the tumor and tooth which may lead to periodontitis. Treatment is varied. Some have advocated close excision to the bone. The presenter has successfully treated these by close excision followed by extraction of the associated tooth, debridement of the bone and closure of the soft tissues. Rim excision as been advocated by others. If the lesion is associated with a strategic tooth such as a canine tooth, close excision and treatment of recurrence as needed has been elected.

Acanthomatous ameloblastoma
Canine acanthomatous ameloblastoma is a locally aggressive benign epithelial neoplasm of the jaws. Several variations exist including extra-osseous, intra-osseous and cystic. This neoplasm will not metastasize or spread to other areas in the jaws. It will continue to grow unless treated definitively. Treatment options include excision with at least a 1cm margin, radiation therapy and intralesional bleomycin. Radiation therapy was originally thought to put the patient an unacceptable risk for developing a second tumor at the radiation site (3). This was later rebutted and showed 3.5% of patients undergoing radiation therapy for for acanthomatous ameloblastoma (4). Intralesional injection of bleomycin showed efficacy in 7 dogs with 6 being cured and one having reduction in size (5). It should be noted that if the periodontal architecture is destroyed, teeth may need to be extract post-operatively and bone exposure may be present requiring additional surgery.

Odontomas
Odontoma is an inductive oral tumor producing both tissue of epithelial origin (enamel) and mesenchymal origin (dentin, pulp). These may have organized tooth like structures called denticles (compound odontoma) or disorganized tissue (complex odontoma). Often a missing tooth is noted in the region of a large swelling. These may be treated by enucleation or with a near margin.

Odontogenic cysts
Dentigerous cyst
A dentigerous cyst cyst may occur when a tooth does not erupt. This is due to reduced enamel epithelium normally shed during eruption continuing to produce fluid around the crown of the unerupted tooth. This fluid causes additional inflammation, which causes additional inflammation and so on. The cyst can cause resorption of bone and loss of adjacent teeth. Treatment is by extraction of the tooth and cystic debridement. It is recommended to extract unerupted teeth before cysts occur. The most common tooth causing this is the mandibular first premolar and it is often seen in brachycephalic dogs.

Cyst associated with the maxillary fourth premolar
Odontogenic cysts of the maxillary fourth premolar have been recently described. The cause at this point is unknown although trauma is suspected. Treatment of the cyst includes debridement of the cystic epithelium. Often the cyst encroaches on the apices of the fourth premolar, necessitating either extraction or possibly endodontic therapy and bone grafting.
**Odontogenic keratocyst**  
The odontogenic keratocyst is a rare cyst or cystic neoplasia of the dog. It differs from the dentigerous cyst in that it does not come from an unerupted tooth and its interior is solid vs. fluid. It also cannot be treated by simply debridement. The cyst has projections that may cause recurrence and thus excision with a 1cm margin may be required.

**Osteoma of the jaws of the cat**  
This is not an odontogenic mass. Osteomas may behave locally aggressive in the jaws of the cat. These do not metastasize but may continue to grow unchecked and may require wide excision (6).

**Techniques for oral neoplasia diagnosis**

**Imaging**  
Performing full mouth dental radiographs on every patient may provide a chance to diagnose neoplasia in its early stages. Additionally dental radiographs will aid in differentiating between less serious dental related disease and neoplasia masquerading as lesser disease.

When a diagnosis of neoplasia has been made, CT imaging is more sensitive for evaluation of the size of the tumor and for assess pulmonary fields. When not possible, high quality dental radiographs and a three view thoracic radiographic study is recommended to assess bone involvement and the possibility of pulmonary metastasis.

**Biopsy**  
When assessing an abnormal growth in the oral cavity, biopsy is always recommended. When obtaining a biopsy, a representative sample is required. This entails obtaining a biopsy deep into the stroma of the lesion. If the lesion is soft to firm (not hard) a 6 or 8mm punch works well. The punch is pressed to the hub of the instrument in the center of the lesion, slightly tilted and removed with a scooping motion. If the sample is still within the lesion, it can be detached with small sharp scissors. Avoid crushing or using cautery on the sample. It is useful to place the sample in a cassette before submitting. If in doubt, a second sample can be achieved through the same hole. Avoid obtaining only superficial samples.

If the lesion is hard, a sample may be obtained by incising over the epithelium and obtaining a sample with a bone trephine or rongeurs.

If submitting a sample of a cystic lesion, or abnormal bone noted during an extraction, obtaining a piece of bone with rongeurs during surgery is useful. Additionally, extracted teeth can be submitted in addition to the obtained sample.

Closing the sample site can be difficult. If the epithelium is intact, it may be possible to close with two or three simple interrupted sutures. However if the epithelium is friable, hemostasis can be obtained by placing hemostatic foam into the defect and placing a horizontal mattress suture over the foam.

**Working with the pathologist**  
Signalment, description of the lesion and imaging findings are pertinent information for the pathologist. Without all information available, a pathologist is at risk to make a misidentification. An illustration of this is the HiLo fibrosarcoma. Without location and radiographic findings, this may be identified as a benign fibroma. It is strongly recommended to develop a report with a pathologist familiar with oral lesions.

**References**


Kelly JM et al “Acanthomatous Ameloblastoma in Dogs Treated with Intralosomal Bleomycin” Vet Comp Oncol 8(2) 2010 pp. 81-6