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Introduction

Fractured teeth are common in dogs and cats. Trauma is usually the cause of canine and carnassial teeth in the dog. Tooth resorption is often the cause of crown fracture in cats, with root fragments remaining in the alveoli.

If trauma has exposed the pulp cavity, bacterial infection of the pulp occurs, resulting in pulpitis. If left untreated, pulpitis can progress to pulp necrosis, and periapical disease may develop. Endodontic therapy is then needed to prevent the possibility of tooth loss. Pulpitis and pulp necrosis can also occur without obvious pulp exposure; this may be due to mechanical or thermal trauma, e.g., after a blow to a tooth with leakage of blood into the pulp cavity, tooth displacement injuries, or excessive heat or cold to the tooth.

Dental radiography, special instruments and materials, knowledge of various techniques, and sufficient operator skills are required for performing endodontic procedures. Fractures that extend subgingivally deep into the root must be treated with periodontal surgery prior to endodontic therapy. Horizontal fractures below the alveolar crest may not require treatment if they are in the apical half of the root of a non-mobile tooth. Extraction is the treatment of choice for teeth fractured along the long axis of the tooth root(s) and teeth with advanced root resorption.

Endodontic Anatomy

The pulp is the innermost part of the tooth, consisting of undifferentiated mesenchymal cells, functional cells (fibroblasts and odontoblasts), blood and lymph vessels, and nerves. The pulp cavity consists of the pulp chamber in the crown and the root canal in the tooth root. Odontoblasts are the functional cells lining the inside of the pulp cavity, producing predentin which later becomes mineralized dentin. The outermost dentin is the ‘oldest’ produced dentin, while the innermost dentin is the ‘youngest.’

All permanent teeth of domestic carnivores should have fully erupted at about 6-7 months of age. However, root lengthening and apex closure (apexogenesis) require several additional months for completion. Dentin apposition along the inside of the pulp cavity continues throughout life, unless irreversible pulpitis or pulp necrosis occurs. Therefore, teeth of young adult animals have a fairly wide pulp cavity, while in old animals the pulp cavity is usually very narrow. The narrower the pulp cavity, the thicker are the dentinal walls, and thus the stronger is the tooth. Comparing the radiographic appearance of the pulp cavity between ipsi- and contralateral teeth is a very effective means to determine pulp vitality of teeth with suspected endodontic pathology.

Vital Pulp Therapy

Vital pulp therapy is primarily utilized for ‘recent’ tooth fractures or after intentional surgical crown reduction to preserve pulp vitality and increase strength of the tooth by allowing continued dentin formation. This technique may still be successful if pulp exposure has occurred up to 2 days ago in animals 18 months of age or older and up to 2 weeks ago in animals younger than 18 months of age. However, the veterinary dentist should keep in mind that several other factors are of importance that can determine success or failure of vital pulp therapy (e.g., other existing oral pathology, standard of oral hygiene, antibiotic history, size of tooth defect exposing pulp tissue, sterility of the procedure, quality of the restoration, etc.).
Instruments and materials coming in contact with vital pulp tissue must be sterile to prevent iatrogenic introduction of bacteria into the endodontic system. Systemic antibiotics are recommended pre-, intra- and post-operatively. The tooth to be treated and adjacent teeth should be scaled and polished followed by rinsing the surgical site with dilute chlorhexidine. If intentional surgical crown reduction is performed, it is accomplished by using a tapered cross-cut fissure bur in a high-speed handpiece with physiologic saline irrigation. Partial vital pulpectomy is performed using a round or pear-shaped bur in a high-speed handpiece with physiologic saline irrigation, removing 5-8 mm of coronal pulp tissue. Hemostasis is achieved by gentle irrigation with physiologic saline and the blunt end of multiple dry paper points.

When bleeding is controlled, direct pulp capping is performed. Calcium hydroxide powder is applied directly over the exposed pulp for a depth of 1-2 mm using a (retrograde) amalgam carrier. The powder is gently tamped against the pulp stump with the blunt end of a paper point. Then a 1-2 mm layer of calcium hydroxide cement is placed, followed by application of an intermediate filling material (e.g., glass ionomer) and a final restoration (e.g., composite). Dental radiographs are obtained in 4-6 months to confirm pulp vitality, which is determined by the presence or absence of a dentinal bridge formed under the previously placed calcium hydroxide, continued root development and apex closure. An apexification procedure or standard root canal therapy is indicated if death of the pulp is evident on follow-up examination.

Indirect pulp capping is indicated when there is near pulp exposure after trauma (very thin layer of dentin separating the pulp from the oral environment) or when a restorative preparation occurs within 1-2 mm of the pulp. A protective layer of calcium hydroxide cement (1-2 mm) is placed prior to restoration, and the tooth is re-checked radiographically in 4-6 months.

**Apexification Procedure**

Apexification is the process of stimulating the formation of a closed apex with hard tissue when a necrotic pulp is present in an incompletely developed permanent tooth in young adult animals or in teeth of adult animals that have ‘open’ apices due to apical root resorption.

The procedure is a type of root canal therapy and involves cleaning, minimal shaping and filling of the root canal with a calcium hydroxide paste, followed by temporary restoration of the coronal access opening (e.g., with a zinc oxide eugenol cement). Post-operative antibiotic therapy is not required. Radiographic re-check is performed in 3 months. If apical closure is seen, the temporary restoration and calcium hydroxide paste are removed, and a standard root canal therapy is performed. If apical closure is not yet evident radiographically (or when a file extends apically beyond the root apex), the root canal is refilled with fresh calcium hydroxide paste. The apexification procedure can be repeated multiple times in 3 month intervals until apical closure is achieved.

**Standard (Orthograde) Root Canal Therapy**

If the pulp is exposed for longer periods of time or has become necrotic, root canal treatment is performed. Standard root canal therapy consists of accessing the pulp cavity and debriding, shaping, disinfecting and obturating (filling) the root canal, followed by access restoration. Use of pre-, intra- and post-operative dental radiography is of utmost importance. The goal of treatment is removal of diseased or necrotic pulp tissue and providing a hermetic seal at the apex.

Coronal access is the first step of the procedure. An opening into the pulp cavity may already be present, in the case of a fractured tooth, or may need to be created to obtain a straight-line access to the apical portion of the root canal. Access holes are made at the mesial surface of canine tooth crowns about 2-3 mm coronal to the gingival margin. In two-rooted teeth, access holes are drilled into the crown over each root. In the upper fourth premolar tooth, the mesiobuccal and palatal roots can be accessed by creating one opening at the buccomesial crown surface approximately in the middle of an imaginary line drawn between the gingival margin and the tip of the main cusp (transcoronal approach).

Debriding, shaping and disinfecting the root canal involves removal of all inflamed or necrotic pulp tissue and softened dentin to prepare it for obturation. The root canal is shaped wider at the crown and tapered to a narrower diameter apically. Equipment used include barbed broaches, endodontic reamers and files (K-files and H-files) with rubber endodontic stops, sodium hypochlorite solution (5.25%), EDTA paste (ethylenediamine tetraacetic acid), sterile physiologic saline, and other instruments and materials (e.g., Gates Glidden drills, Peeso reamers, endodontic ruler, dressing forceps, syringes with blunt-ended endodontic irrigation needles, absorbent paper points, etc.). A modified crown-down technique is often utilized, but several other techniques have been described (including the use of power-driven instrumentation). The pulp chamber and
coronal end of the root canal are carefully enlarged to facilitate access to and preparation of the apical portion of the root canal. A small-diameter endodontic file is inserted into the root canal approximately 1 mm short of the apex to determine *working length*. Shaping of the root canal is performed by insertion of subsequently larger files to the predetermined working length. Use of EDTA paste alternated with sodium hypochlorite irrigation will help shape and disinfect the root canal. Each time file size is changed, a small-diameter file is inserted to remove any debris and dentinal filings (*recapitulation*) that may have been packed into the apical portion of the root canal by larger files used previously. Dentinal fillings and debris are also removed by frequent irrigation with physiologic saline. Cleaning and shaping of the root canal are completed when clean white dentinal fillings are seen and the next size file binds before reaching the working length. The root canal is recapitulated once more, disinfected with sodium hypochlorite, irrigated with physiologic saline, and then dried by successively inserting absorbent paper points into the canal with dressing forceps.

**Obturation** is the complete and dense sealing and filling of the prepared root canal and any accessory and lateral canals with nonirritating inert materials. A sealer containing zinc oxide eugenol (ZOE) has traditionally been used. Other sealers are made of glass ionomer, resin, or calcium hydroxide. Application of sealer alone without gutta-percha is not considered sufficient. Cold and warm gutta-percha obturation techniques have been described. The basic steps of *cold lateral condensation* are now described. A *dry master gutta-percha cone* of the same size (or one size smaller) than the last file used during instrumentation is inserted into the root canal. A radiograph is obtained to confirm its placement to working length. Little resistance or *tug-back* should be felt when removing it. The ZOE sealer is mixed with a spatula on a glass slab and introduced into the root canal with a spiral filler attached to a reduction gear on a low-speed handpiece. The master cone is then slowly inserted to working length, allowing excess ZOE to extrude out of the canal. A root canal *spreader* is inserted along the master cone to within 1-2 mm of the working length with apical pressure only, which will seat the master cone to the apical stop. The spreader is rotated on its axis several times, laterally condensing the malleable gutta-percha, and is then removed. Excess gutta-percha extruding out of the canal must be removed with a heated instrument below the access opening. An *accessory gutta-percha cone* slightly (smaller than the spreader) is placed in the space created by the spreader. Condensing with spreaders and introduction of accessory cones are repeated until it is impossible to insert an accessory cone farther than 5 mm into the root canal. A root canal *plugger* is then used to condense (compact) the gutta-percha apically. Residual sealer and gutta-percha must be removed from the coronal access area prior to restoration. A base of glass ionomer is placed over the gutta-percha ends, followed by restoration of the access site. Post-operative antibiotic therapy is not required. The tooth is re-checked radiographically in 6 months.

**Surgical Root Canal Therapy (Apicoectomy and Retrograde Filling)**

The success of *surgical root canal therapy* is improved when standard root canal therapy is performed first. In multi-rooted teeth, all roots should preferably be treated. However, it is technically very difficult to access surgically the palatal root of the upper fourth premolar tooth, which is therefore often resected and extracted to salvage the tooth.

Access to the upper canine, upper fourth premolar and lower first molar teeth is made over the roots through a semilunar incision in the alveolar mucosa and periosteum down to the bone. Access to the lower canine tooth is made through a ventral transcutaneous approach to the mandible. The soft tissues are undermined with a periosteal elevator and reflected. The *juga* (bulgy bone which is superficial to the root) is palpated, and alveolectomy is performed with a round bur in a high-speed handpiece under sterile physiologic saline irrigation.

Once the root apex is identified and outlined, *apicoectomy* is performed at a 10-45 degree angle with a tapered cross-cut fissure bur in a high-speed handpiece under sterile physiologic saline irrigation. Depending on the size of the tooth, 3-6 mm of the apical portion of the root is resected. Inflamed or necrotic periapical tissues are removed with bone curettes, the apical opening into the root canal is prepared with an inverted cone bur, pear-shaped bur or hand instruments to provide a 2-3 mm deep restorative cavity. The surgical site is rinsed with sterile physiologic saline to flush away debris and dried. *Retrograde filling* of the restorative cavity is performed with a zinc oxide eugenol cement, glass ionomer or zinc-free amalgam. Post-operative antibiotic therapy is not required. The tooth is re-checked radiographically in 6 months.

**Recommended Reading**


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