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A Nutritional Approach to the Prevention of Insulinomas in the Pet Ferret

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Peer-Reviewed Article

Insulinoma is a common endocrinopathy afflicting adult pet ferrets (*Mustela putorius furo*) in the United States. These insulin-secreting nodules within the pancreas are also referred to as *islet cell tumors* and *beta cell tumors*. The hypoglycemia resulting from insulinomas accounts for the various clinical signs: lethargy, episodic weakness, weight loss, nausea (manifested by ptyalism and/or bruxism), seizures, and death. The underlying etiology of this condition is unknown.

Insulinomas may be treated medically or surgically, although the ferret is rarely cured of this malady regardless of the treatment modality. While surgery offers the best long-term survival and disease-free interval,[1] recurrence is common. In one large, retrospective study, approximately half of the ferrets undergoing surgery remained hypoglycemic during the immediate postoperative period and another third developed recurrence within 1 to 23.5 months.[2]

Insulinomas often lead to the ferret's demise while inflicting an emotional and financial toll on the owner. Veterinarians are often frustrated by the inability to cure this condition. The high prevalence of insulinomas makes ferret ownership less attractive for many pet owners.

As of yet, there is no known method of preventing insulinoma formation. This paper presents a nutritional hypothesis and offers a prevention strategy to minimize the chance of insulinoma formation in pet ferrets.

FERRETS AS OBLIGATE CARNIVORES

Ferrets are obligate carnivores. As such, they would normally consume a diet high in proteins and fat and low in carbohydrates and fiber. (This author defines high protein as 42% to 55%, low carbohydrate as 8% to 15%, and low fiber as 1% to 3% of the diet. Throughout this paper, all nutrient analyses will be expressed on a dry-matter basis.)

Related mustelids of the domestic ferret include the black-footed ferret (*Mustela nigripes*), the European ferret (*M. putorius furo*), the European polecat (*Mustela putorius putorius*) and the Steppe polecat (*Mustela eversmanni*). All of these species are effective hunters known to consume whole, small prey such as rodents, lagomorphs, and birds. The nutritional content of such prey would qualify as being high in protein and low in carbohydrates. For example, the nutrient analysis of a rat carcass is 55% protein, 38.1% fat, 1.2% carbohydrate, and 0.55% fiber.[3] These proportions are considerably different than foodstuffs fed to pet ferrets in the United States. Commercial ferret diets typically fed in this country consist of dry kibble containing the following approximate nutrient ranges: protein 22% to 42%, fat 15% to 28%, and carbohydrate 10% to 45%. At least a moderate amount of carbohydrate is generally required for processing a dry kibble product. In addition, many ferret owners feed treats containing high sugar content to their pets. Clearly, this high carbohydrate load greatly exceeds the level found in the natural diet of ferrets.

It is interesting to note that insulinomas are uncommon in Europe, New Zealand, and Australia.[4] While this may be explained on the basis of a different genetic pool, it is worth noting

Diagnosis and Treatment of Dental Disease in Pet Rabbits and Rodents: A Review

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Peer-Reviewed Article

Dental disease is common in pet rabbits and rodents and can produce a wide variety of clinical presentations, many related to the significant anatomic and physiologic differences among these species. While some debate lingers on the exact etiology of dental disease, treatment options rely on the return of dental anatomy and function to as near normal as possible and control of associated infection and inflammation.

ANATOMY AND PHYSIOLOGY[1-9]

The teeth of lagomorphs and rodents are similar to those of other orders of mammals in that the evolutionary process has adapted them to accommodate their unique diets. However, the dental formulas, anatomy, and physiology of lagomorphs are rather different from those of carnivorous, insectivorous, or omnivorous mammals (Table 1).

All lagomorphs and rodent species lack canine teeth and have hypsodont (open-rooted) incisor teeth, which grow throughout life. All lagomorph species have two pairs of upper incisors (a third pair is present before or immediately after birth, then shed); by contrast, all rodent species have just one pair of upper incisors. Another difference, albeit less important to practitioners, is that lagomorphs are diphyodont, with two sets of teeth (the first set is shed immediately before or after birth), while rodent species are monophyodont. The appearance of incisors is different between lagomorphs and rodents. Rabbits, hares, and pikas have a vertical ridge on the labial surface of upper incisors. However, the labial surface in many species of rodents is covered by a thick layer of enamel, which makes these teeth stronger. The size and development of incisors vary greatly among rodent species, but generally they are relatively bigger and stronger than the incisor teeth of the lagomorph species.

Premolar and molar teeth are called *cheek teeth*. They are open-rooted in lagomorphs and in most herbivorous rodent species. The base of the root (the apical end) is called the *apex*. From a zoologic standpoint, rodent species are classified into three main groups: "miomorph" or "rat-like" rodents (golden and Russian hamster, gerbil, fat-tailed gerbil [*Pachyuromys duprasis*] rat, mouse); sciuromorph or "squirrel-like" rodents (prairie dog, chipmunk); and hystrychomorph or "porcupine-like" rodents (guinea pig, chinchilla, degu). Rat-like and squirrel-like rodents have hypsodont incisors and brachyodont (short crowns and anatomically formed roots) cheek teeth; porcupine-like rodents have all open-rooted teeth (both incisor and cheek teeth), similar to lagomorphs.

The cheek teeth of herbivorous species are flat but not smooth, with crests of enamel and grooves in dentine for the proper crushing of food. The anatomy of the cheek teeth of rabbits and porcupine-like rodents is very similar, but guinea pigs show an important structural peculiarity. The lower cheek teeth of guinea pigs are curved medially, while their roots are curved laterally; their upper cheek teeth are curved laterally, while their roots are curved medially. This results in an occlusal plane that slopes down about 30 degrees from lateral to medial. Deviation from and maintenance of proper occlusal surfaces have important significance in the diagnosis and treatment of dental disease in this species.

Despite being herbivorous, prairie dogs are brachyodont and do not have open-rooted cheek teeth as is sometimes reported in the literature. The significance of this is that malocclusion of premolar and molar teeth is not as much of a concern in this species as it is in porcupine-like rodents because the cheek teeth of prairie dogs do not continue to grow throughout life.

CLASSIFICATION AND DEFINITION OF DENTAL DISEASE

Dental disease has been extensively studied in laboratory animals and also well described in pet rabbits and some rodent species.[1,2,5,6,8,10-18] Different etiologies have been demonstrated, and different classification schemes have been proposed.[5,7,19,20] Classification of dental disease based on etiology must take into consideration the fact that there may be more than one underlying cause. In addition, diseases of incisors and cheek teeth may occur independently, although they are frequently linked. Therefore, pet rabbits and rodents may present with incisor disease alone, cheek teeth disease alone, cheek teeth disease following incisor malocclusion, and vice versa.[5]

Many early texts suggest the terms "lumps" or "slobbers" when referring to dental disease. These terms related to clinical signs frequently associated with dental disease, specifically abscesses and hypersalivation due to intraoral lesions. As more work on pathophysiology led to a better understanding of this disease, the term "acquired dental disease" was proposed.[7] This definition, however, necessarily excluded congenital abnormalities.

Simple "dental disease syndrome" (abnormalities of the teeth, including molars, incisors, cheek teeth, and gums) appears to be the most comprehensive definition. Definition aside, however, the most important thing to consider is that this disease is a syndrome, with a complex combination of clinical signs.[5,8]

TABLE 1. Dental Formula and Physiology of Lagomorphs and Rodents

Species	Incisors Upper/Lower	Cheek Teeth: Premolars Upper/Lower	Cheek Teeth: Molars Upper/Lower	Number of Cheek Teeth (Upper/Lower)	Total Teeth
Lagomorphs (rabbits, hares, pikas)	2/1 Open-rooted	3/2 Open-rooted	3/3 Open-rooted	22 (6/5) Open-rooted	28
Porcupine-like rodents (guinea pigs, chinchillas, degus)	1/1 Open-rooted	1/1 Open-rooted	3/3 Open-rooted	16 (4/4) Open-rooted	20
Rat-like rodents (e.g., rats, mice, hamsters, gerbils)	1/1 Open-rooted	0/0	3/3 Rooted	12 (3/3) Rooted	16
Squirrel-like rodents	1/1	1–2/1	3/3	16–18 (4–5/4)	20–22
Prairie dogs	1/1 Open-rooted	2/1 Rooted	3/3 Rooted	18 (5/4) Rooted	22

PATHOPHYSIOLOGY OF DENTAL DISEASES[1–8,11,13–18,21–26]

The pathophysiology of dental disease in pet rabbits and rodents is mostly related to the continuous growth of incisors (in all species) and cheek teeth (in species with open-rooted premolars and molars). Four different primary etiologies have been reported: congenital and developmental abnormalities, traumatic injuries, abnormal wear (sometimes due to improper nutrition) and metabolic bone disease.

Congenital and developmental abnormalities (agenesis of the dentition, cleft palate, exposure to teratogens, and maternal malnutrition) have been demonstrated but are undoubtedly rare and, for this reason, do not represent a frequent concern for practitioners. Congenital or hereditary jaw length mismatch may be due to true prognathism of the mandible, or secondary to brachygnathism of the maxilla. This anatomic condition is more frequently recognized in purebred dwarf rabbits weighing less than 1 kg. A rounded brachymorph skull leads to malocclusion of incisors. In addition, functional mandibular prognathism may occur and is described later.[5,6]

Traumatic injuries due to falls or improper caging are a common presentation in pet rabbits and rodents. Injuries can range from fractures of the incisors to much less common fractures of the mandible or maxilla, which often carry a poor prognosis. Trauma can damage the apical germinal tissue, which impacts the growth of incisor teeth, frequently leading to malocclusion. Incisor fractures that expose the pulp can result in pulpitis and abscesses. It should be noted that these types of injuries occur iatrogenically secondary to improper or unnecessary trimming of incisors, particularly in rodents and guinea pigs.[5,24]

The largest and most important etiologic group relates to improper nutrition and abnormal wear.[5,6] Vitamin A deficiency has been reported to cause malocclusion of incisors in rats, but this condition rarely occurs in pets. More frequently, vitamin C deficiency is a predisposing factor for malocclusion in pet guinea pigs. Nevertheless, the most significant etiology is abnormal wear due to the consumption of improper food. Lagomorphs and herbivorous rodents have very specific nutritional requirements, and their natural food is rich in mildly abrasive silicates. With the exception of those kept free in the garden, pet rabbits and rodents fed with hay and vegetables do not receive the same types and variety of food as free-ranging animals. This is critical in understanding why all pets are potentially susceptible to the development of at least some degree of acquired dental disease during their lifetime. Despite the popularity of rabbits and rodents as pets, and our increased understanding of proper nutritional requirements, many are still fed substandard diets deficient in hay and containing such items as fruit, seeds, breads, and other treat items.

Since open-rooted teeth grow continuously, inadequate wear leads to overgrowth. Incisors tend to deviate from their normal resting position, where the end of the lower incisors contacts the space between the main upper and peg incisors. The earliest change is the loss of the chisel-like shape of the end of the incisors. Elongation and deformation of crowns and roots lead to further severity in degrees of malocclusion, predisposing to fracture, pulpitis, and periapical infections. Severely deviated incisors can produce soft tissue lesions to the lips, tongue, hard palate, and nose. These types of lesions are more typical in rat-like rodents.

The development of cheek teeth malocclusion often follows a typical pattern, with few exceptions. Improper wear leads to excessive elongation of crowns and roots. This may not be apparent during inspection of the oral cavity because the gingiva often elongates with the crown, masking the elongation.[5,6] Elongation of teeth is partially counteracted by the strength of masticatory muscles. The apposing forces result in curving of cheek teeth as they continue to grow. Lower cheek teeth typically begin to bend medially

with lateral convexity while upper cheek teeth begin to bend laterally with medial convexity. This change is similar to the normal anatomy of the cheek teeth in guinea pigs but is abnormal in rabbits and chinchillas, which normally have a horizontal occlusal plane. Therefore, these conditions are more difficult to recognize in guinea pigs and other porcupine-like rodents.[1,4,8] The result is that the occlusal plane begins to malocclude, and lateral masticatory movements are not enough to fill the gap. Other forms of abnormal occlusal planes are described as "step mouth," when individual molars elongate at different rates, or as "wave mouth," when the entire occlusal plane is curved rather than flat.[6,22] Worsening malocclusion results in improper wear, which again contributes to malocclusion. Typical molar malocclusion results in lack of wear between the lingual aspect of the lower cheek teeth and the buccal aspect of the upper cheek teeth. The result is an advanced stage of acquired dental disease leading to growth of spurs and spikes. These can be very sharp, creating lesions and ulcerations to the tongue (usually from lower cheek teeth) and the cheek mucosal surface (usually from upper premolars and molars).[6,22]

Besides elongation of crowns, excessive elongation also occurs at the apex of tooth roots. The result is the stretching of cortical bone of the alveolus and possible perforation. Abnormal tooth roots cause a widening of the alveolar bone, which is an important predisposing factor for periapical abscessation.

Excessive elongation of crowns of the cheek teeth, particularly the premolars, may also lead to functional mandible prognathism. The jaw is forced open wider and more rostrally, which initially results in the malocclusion of incisor teeth. This condition is often improperly diagnosed as congenital and occurs most frequently in porcupine-like rodents. In these species, primary malocclusion of the incisors does not occur as frequently as in pet rabbits and is mostly related to acquired dental disease of cheek teeth.

Guinea pigs and chinchillas usually show less evidence of elongation malocclusion of crowns compared with pet rabbits.[1,5,6,8,22] Spurs are rarely present, are not so long and sharp, and rarely cause lesions to the tongue. A typical lesion in guinea pigs is mesial elongation of either one or both lower premolars, creating a "bridge" over the tongue.[1] In chinchillas, obvious cheek teeth elongation occurs in the late stage of acquired dental disease.[13,26]

The most common pathologic changes following acquired dental disease are periapical abscessation and osteomyelitis but can also include longitudinal fractures, the loosening of teeth, food impaction, and abscess fistulas. In cases of osteomyelitis, bone infection is usually focused at the apex of one tooth, but other teeth can be involved as well as maxillary or mandibular bone.[1,6,8,10,21,23] Because of rapid tooth wear, plaque accumulation, periodontal disease, and caries are very rare in herbivorous species with open-rooted cheek teeth.[5]

Harcourt-Brown proposed metabolic bone disease as a cause of acquired dental disease in pet rabbits.[7,19,20] Patients affected by severe malocclusion show poor calcification of the alveolar bone and, in general, all of the bones of the skull. This theory has been supported by a study performed on 81 pet rabbits that demonstrated abnormally high parathyroid hormone concentrations and low calcium concentrations, suggesting that acquired dental disease in pet rabbits is associated with alterations in calcium metabolism.[20] Loss and weakness of alveolar bone lead to loosening of the teeth, distortions, change of positions, deformation, and eventually perforation of the periosteum. Malocclusion of crowns and the growth of spurs occur secondarily to improper wear as a result of abnormal position of cheek teeth. This condition has not been investigated in guinea pigs, chinchillas, or other rodent species.

The pathophysiology of odontoma of the apex of incisors in prairie dogs is still unknown but may be related to frequent incisor trauma.[5,11,27] Incisor fractures are common in this species because they typically habitually chew the metal bars of their enclosures.

In rat-like and squirrel-like rodents, the pathophysiology of dental diseases of cheek teeth is mostly due to infections and abscessation following cavities and fractures of cheek teeth.

CLINICAL PRESENTATION[1,2,5–8,12,13,15–18,24,26]

Presenting clinical signs and related pathologies have been described in the literature both for pet rabbits and rodents affected by dental disease. The most common are anorexia, dysorexia, dysphagia, excessive salivation, weight loss, poor general condition, poor coat conditions, digestive problems, changes of fecal droppings, ocular discharge, skin disease, and facial lumps.

Practitioners who are presented with a patient having suspected dental disease must consider a wide range of possible clinical signs. Among potential signs, one group can be considered specifically for dental disease (anorexia, dysorexia, dysphagia), another group is indicative of lesions closely related to dental disease (excessive salivation, ocular discharge, changes of fecal droppings, facial abscesses), and yet a third group indicative of systemic diseases (weight loss, digestive problems, poor general condition, skin diseases, death).

Among this wide range of presentations, some are more typical for selected species. In the author's experience, pet rabbits typically present for overgrowth of incisors, reduced food intake, dysphagia, and/or the presence of facial abscesses. Usually, infection of soft tissues presents as a large, firm, nonpainful facial mass and is more frequently located ventral or lateral to the mandible. However, infection may also involve the skull or the eye and present as a retrobulbar abscess. Abscesses are delimited by a thick capsule and contain white, very dense creamy purulent exudate.

Guinea pigs typically present with anorexia, and it is not uncommon for owners to report this as sudden onset. Chinchillas commonly present for excessive salivation, poor coat

TABLE 2. Diagnostic Options in Suspected Dental Disease of Rabbits and Rodents and Related Significance

	Species			
Diagnostic Test	*Rabbits*	*Porcupine-Like Rodents*	*Rat-Like Rodents*	*Squirrel-Like Rodents*
Dental examination without anesthesia	Always	Always; sometimes difficult in chinchillas; often not feasible in degus	Difficult with exception of selected individuals	Mostly not feasible
Dental examination with anesthesia	Always	Always	Always	Always
Skull radiography	Always	Always	Always	Always
Oral endoscopy	Very useful	Very useful or mandatory; mandatory in degus	Mandatory	Mandatory for most species; very useful in prairie dogs
Blood work and other examinations	In case of other diseases and/or complications related to dental disease	In case of other diseases and/or complications related to dental disease	In case of other diseases and/or complications related to dental disease	In case of other diseases and/or complications related to dental disease
Culture and sensitivity testing	In case of periapical infections or abscessations	In case of periapical infections or abscessations	In case of periapical infections or abscessations; less useful due to poor prognosis	In case of periapical infections or abscessations
Hystopathologic examination	Useful in selected cases	Useful in selected cases	Useful in selected cases	Useful in selected cases; useful in case of dental disease of incisors in prairie dogs
Computed tomography	Feasible, very useful, but not yet practical	Feasible, very useful, but not yet practical	A future perspective; no reported experiences	A future perspective; no reported experiences

condition, and digestive problems but often are not anorexic.

Stretching and deformation of periosteum can produce subtle but important differences among species. This is usually most evident in pet rabbits, especially on the ventral edge of the mandible. Periosteal and apex deformation of the upper cheek teeth predisposes to occlusion of the nasolacrimal duct, exophthalmos, and retrobulbar abscessation. Guinea pigs typically have much more severe deformation without as much clinical evidence. However, this condition appears to be much more painful, which is why the simple restoration of a proper occlusal plane can be unrewarding in this species.[1,5,8] Chinchillas usually develop very severe root deformation and perforation of periosteum.[5,12,13,26] Some show no clinical signs and seem to be able to tolerate severe disease much better and for a longer duration when compared with guinea pigs. Because disease tends to be severe by the time signs appear, early diagnosis is even more critical in this species, and for porcupine-like rodents in general, than for pet rabbits.

The most common presentation of hamsters and other rat-like rodents is malocclusion of incisors and facial abscesses.[1] Prairie dogs present with fractured incisors and, in some cases, dyspnea related to development of odontoma.[1,5,27]

DIAGNOSTIC WORKUP

The diagnostic workup in cases of suspected dental disease must be thorough (Table 2). During physical examination of pet rabbits, it is mandatory to perform a complete examination of both incisor and cheek teeth. The practitioner must never neglect inspection of the oral cavity and cheek teeth because this can lead to misdiagnosis or omissions. Initial intraoral inspection can be performed with an otoscope if proper restraint is used. It can also be useful to introduce a finger into the mouth to check for the presence of sharp spurs, but this technique cannot replace intraoral inspection. If dental disease is suspected, a complete dental examination under anesthesia is critical. Inspection of the cheek teeth and oral cavity is even more difficult in porcupine-like rodent

species, particularly in degus; therefore, examination under anesthesia is even more important. Occasionally, very calm rats or golden hamsters may allow intraoral examination without anesthesia, but this is an exception.

Anesthetic protocols for rabbits and rodents are described in the literature. Endotracheal intubation can be performed in rabbits and in selected species of rodents. However, in the author's experience, the endotracheal tube impedes oral examination.[1,22]

Specialized instruments have been designed to facilitate small, exotic mammal dentistry. Several companies manufacture rabbit and rodent mouth gags, cheek dilators, rasps, and even table-top mouth gags, which optimize the operator's view and reduce the need for assistants.

A thorough dental exam must include a radiographic examination of dental roots and apices.[1,5–8,23] High-resolution radiography film is recommended. At least five radiographic projections of the skull are useful for each patient: lateral, right oblique, left oblique, ventrodorsal or dorsoventral, and rostrocaudal (skyline). Smaller films for dog intraoral radiographs can also be used to obtain smaller views of the incisors and cheek teeth of pet rabbits.

It is also mandatory to know the normal radiographic anatomy of each species for a proper evaluation of pathologic changes. The most important peculiarity is related to guinea pigs. Due to the normal bending of cheek teeth in this species, the skyline projection is the only one that allows evaluation of the occlusal planes.[1,4,5,8]

Optimal visualization of the oral cavity of rabbits and rodents is greatly facilitated by endoscopy, especially in smaller patients. Many avian and exotic practitioners are already familiar with the 2.7-mm endoscope and accessories and find it ideal for this purpose. Normal and pathologic patterns are described in the literature.[1,22,24,28,29]

The use of computed tomography (CT) has been described in chinchillas.[26] Although it is currently not practical, CT represents a viable future diagnostic option.

Culture and sensitivity are important in cases of dental disease-related infection and abscessation. Rabbits and guinea pigs have long been used as laboratory models for human gingivitis and periodontal disease, and studies indicate anaerobic bacteria play a large role in infections and abscesses. Therefore requests for culture should specify screening for both aerobic and anaerobic organisms.[10,30] Purulent material from the core of an abscess is usually sterile, which necessitates collection of samples from the abscess capsule wall.[23]

Histopathology can also be useful in selected cases, particularly when bone neoplasia or dental dysplasia is suspected.

DIAGNOSIS AND PROGNOSIS

Accurate diagnosis and especially prognosis of dental disease in pet rabbits and rodents must be based on the results of a thorough diagnostic workup. Prognosis must be expressed in terms of severity of disease, age and condition of the patient, estimated level of continued care required, likelihood of owner compliance, and expected cost. Resolution of dental disease is possible, but a more common scenario is lifetime management. Dental abscesses carry the possibility of recurrence, even with aggressive therapy. The presence of osteomyelitis carries a guarded prognosis.

In general, the prognosis for pet rodents with dental disease is worse than that in rabbits due to anatomic and pathophysiologic peculiarities as well as the relative difficulty of surgical intervention.[1,5,8] In cases of cheek teeth malocclusion in guinea pigs and chinchillas, the apices are usually overgrown and deformed with severe stretching of cortical bone.[1,5,8,13] For this reason, reduction of dental arcades back to a normal occlusal plane may be partially or completely unrewarding due to the lack of pain relief.[1,5,8] Guinea pigs seem also to be more severely affected by the stretching of masticatory muscles after prolonged elongation of dental arcades and can show delayed willingness to eat after treatment.[8]

Prognosis for rat-like rodents with abscesses is guarded to poor due to the difficulties of early diagnosis, surgical intervention, and extraction. Odontoma in prairie dogs carries a poor prognosis because of the presence of deformation of the apices and ankylosis within the alveolous.[11,27,31]

MEDICAL TREATMENT

Most authors agree that medical therapy alone is generally inadequate for the treatment of dental disease, but it is an important adjunct to surgical therapy.[10,21,23,32] Medical therapy should address several concerns, the first of which is control and management of systemic and soft tissue infections and osteomyelitis. As mentioned previously, antibiotic selection should be based on aerobic and anaerobic culture and sensitivity. Antibiotic selection must also take into consideration species-specific contraindications, such as oral penicillins in rabbits.[33] It must be emphasized that appropriate antibiotic selection for one species may be completely contraindicated in another species. Analgesia is critical for successful management of dental disease and to help prevent common, pain-related anorexia. Anorectic animals must be encouraged to eat as soon as possible. Commercial hand-feeding products for convalescing small exotic mammals are excellent for this purpose. Adjunct fluid therapy may be necessary in some patients.

Several strategies have been described for local therapy of abscesses, including frequent flushing, antibiotic-impregnated beads, honey and sugar therapy, and others.[10,21,23,34–38]

SURGICAL TREATMENT AND OUTCOMES[1,2,5–8,10,11,18,21–24,31,34–41]

Treatments of dental disease of incisors include coronal reduction, coronal amputation and partial pulpectomy, and extraction (Table 3). The first two options are limited to selected cases in which the malocclusion is not severe and has been detected early and proper restoration of occlusion of incisors and cheek teeth is possible. Coronal reduction of both incisors and cheek teeth must be performed using proper den-

TABLE 3. Surgical Treatment Options for Dental Diseases in Rabbits and Rodents

	Species			
Tooth Test	*Rabbits*	*Porcupine-Like Rodents*	*Rat-Like Rodents*	*Squirrel-Like Rodents*
Incisor teeth	Coronal reduction Crown amputation and partial pulpectomy Extraction	Coronal reduction Extraction	Coronal reduction Extraction	Coronal reduction Extraction in prairie dogs; check for indications in other species
Open-rooted cheek teeth	Coronal reduction and burring of spurs Extraction (intraoral or extraoral technique) Debridement of abscessations	Coronal reduction and burring of spurs Extraction (intraoral or extraoral technique) Debridement of abscessations	N/A	N/A
Rooted cheek teeth	N/A	N/A	Extraction (intraoral technique) Debridement of abscessations	Extraction (intraoral technique) Debridement of abscessations

tal low-speed power equipment and burs.[5,6,22] Alternatively, many authors use rotating hobby tools for this purpose.[22]

Trimmers, clippers, and rasps must not be used to reduce the length of elongated incisors, especially when repeated treatment is necessary.[5,24] Repeated use can result in tooth fracture, exposure of pulp, and eventual infection. Moreover, this rough technique is painful when performed without anesthesia. Severe elongation or deformation of roots is also a common sequela, leading to other complications such as obstruction of nasolacrimal ducts, dacriocystitis, chronic ocular discharge, and ocular diseases such as conjunctivitis and retrobulbar abscess.

The only definitive and completely effective treatment for severe malocclusion of incisors is extraction. The technique and special dental instruments for extraction of incisors have been extensively described in literature.[5–8,24,39,42] With rare exception, extraction of the entire set of incisors is necessary. Experience has shown that rabbits and herbivorous rodents adapt easily to the lack of incisors and readily learn to use lips for prehension of food.

Extraction can be extremely difficult in rat-like and squirrel-like rodents, particularly in smaller hamsters and mice.[1] In these cases, frequent trimming may become necessary. Some mammals like squirrels may not completely adapt to complete excision of incisors.

Another challenging extraction is the incisors of prairie dogs affected by odontoma or pseudo-odontoma. Severe deformation, adhesions, and ankylosis within the alveolar bone increase the difficulty of this procedure.[11] Some authors have reported use of techniques such as rhinotomy and access to teeth via the hard palate, again illustrating the difficulty of extraction in these cases and the overall poor prognosis.[27,31]

Different options for treatment of dental disease of cheek teeth have been described, depending on the severity of pathologic changes and the anatomic type of the affected teeth.[1,5–8,22–24] The most common indication is removal of sharp spikes and spurs from the lingual and buccal aspects of the teeth and reduction of overall length of open-rooted cheek teeth of herbivorous species. In some cases, extraction can also become necessary. All these treatments can sometimes be combined in a single patient, especially in rabbits.

Radiographs may give the best indication for the amount of coronal reduction that must be done in specific patients because in many cases overgrowth of gingival tissue may give a false impression of the overall length of cheek teeth when they are viewed directly. In some cases, it is necessary to remove excessive gingival tissue as well.[5,6]

Early and repeated treatments are critical to prevent bending of crowns and apical changes because normalcy cannot be restored once they occur. These changes are much more frequent in guinea pigs and chinchillas than in rabbits, and this can make a great prognostic difference in cases of advanced, acquired dental disease.

In cases of fracture, loose teeth, and/or periapical abscessations, it may be advisable to extract one or more cheek teeth. Small mammal dental luxators have been specially designed for this purpose.

Extraction of cheek teeth may be very challenging, depending on the species, position of the tooth to be extracted, and conditions of the tooth. Even after proper luxation, it is easy to fracture the tooth during extraction. Sometimes it is necessary to cut the crown during extraction

because the narrow opening of the mouth won't allow one extraction of the entire cheek tooth. In most cases, where an advanced stage of acquired dental disease is present, complete intraoral extraction of cheek teeth is impossible due to root fracture or ankylosis into the alveolar bone.

When the intraoral approach to extraction is not feasible or not effective, the extraoral approach for extraction of lower cheek teeth has been described.[5,23] Surgical access to the apex is performed on the ventrolateral edge of the mandible. The cortical bone is burred to create a fenestration under the apex. The entire tooth or some remaining fragments can be extracted from this site or pushed into the oral cavity and removed from there. After an extraoral approach, soft tissues may be sutured or not, depending on the aseptic level maintained during the procedure.

After intraoral extraction, the socket must be protected to prevent food impaction and infection. After cleansing with chlorhexidine, the gingiva can be sutured to cover it or the socket can be filled with Doxirobe gel.[6,8] When a single tooth is extracted in open-rooted species, the opposite tooth continues to grow, necessitating extraction or frequent trimming.[5,6] Alternative techniques to arrest the growth of the opposing tooth have been described. These include apical cryotherapy and surgical apicoectomy.[5]

Surgical treatment of periapical infections must include excision of the entire abscess and capsule, as well as infected bone, diseased teeth, and/or fragments.[10,23,24] Local and systemic antibiotic therapy is also mandatory to resolve infections after surgical debridement.

In the majority of cases, simple incision of the abscess and flushing of purulent exudates is not effective to prevent recurrences. In addition, the thick pus is often sterile and the bacteria involved, both aerobic *(Streptococcus, Staphylococcus, Pasteurella)* and anaerobic *(Fusobacterium, Actinomyces)*,[10,21,30] are present on the inner surface of the capsule. For this reason, the capsule has to be surgically removed and a sample submitted for culture and sensitivity testing.

Surgical guidelines for excision of abscessations and debridement of the osteomyelitic site have been described.[10,23] The capsule of the abscess should ideally not be perforated until it is completely dissected from surrounding soft tissues. Then, the capsule attachment to the cortical bone is dissected and the abscess removed. The osteomyelitic site is flushed with sterile saline, periosteal necrotic tissue is removed, and bone is debrided down to bleeding tissue. Usually, the tooth or teeth (or their fragments) from which the periapical infection originated appear in the bone cavity and are removed. In the author's experience, removal of tooth fragments is mandatory to prevent recurrence, even if other anecdotal reports show complete healing without this step.

Different options have also been reported at the end of this surgical procedure.[10,21,23,29,34-37] Antibiotic-impregnated polymethylmethacrylate beads can be placed into the bone defect after debridement, and the surgical site is sutured.[10,21,34,43] This will prevent additional flushing after surgery, while the beads release antibiotics locally, maintaining therapeutic levels. Beads can be removed or left in place if removal is not practical. In addition to beads, wounds have been packed with antibiotic-moistened gauze strips. Antibiotic selection was based on culture and sensitivity but included drugs such as penicillins, cefazolin, and metronidazole.[38]

Calcium hydroxide has been used to fill the osteomyelitic site. The basic pH (12.0) of this product is very effective as an antimicrobial.[37] Nevertheless, this material can severely damage surrounding soft tissues, and unsuccessful outcomes have been reported.

The bactericidal effects of natural substances such as honey and sugar have been reported in other species for different infections and may be useful in the management of infections in pet rabbits.[35,36] Anecdotal reports of the successful use in the abscesses of pet rabbits have been reported.

Bioactive ceramics are used to fill bone defects after dental surgery. These products can attach to both soft tissues and bones and are osteoconductive.[10]

The author's treatment of choice for dental abscesses is marsupialization of soft tissues around the osteomyelitic socket.[23] This allows continuous flushing and debridement of both hard and soft tissues. Surgery is followed by the introduction of antibiotic ointment for 3 to 4 weeks until second-intention healing occurs. This requires intensive postsurgical care and initially results in an unaesthetic appearance, which must be discussed with the owners in advance.

Systemic antibiotic therapy that is effective for both aerobic and anaerobic bacteria is administered after surgery and maintained or modified on the basis of results of culture and sensitivity tests for at least 3 to 4 weeks.[10,32]

Patients surgically treated for periapical abscessations should be monitored closely due to the high incidence of recurrence. Follow-up should be continued until radiographs demonstrate healing of bone tissue at the initial site of osteomyelitis.

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