DENTAL PROBLEMS IN RABBITS, GUINEA PIGS AND CHINCHILLAS

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Faculty of Veterinary Medicine
Equine and Small Animal Medicine
Heidi Hermiö
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Dental problems are very common among pet rabbits and rodents. Rabbits and rodents have continuously growing teeth which makes them very susceptible to problems in their dentition. The primary cause of acquired dental disease is typically insufficient or improper wearing of the cheek teeth. This is usually caused by improper diet and nutrition lacking sufficient fibre content to ensure proper wearing of the teeth. Inappropriate diets can cause metabolic disturbances for example through lack of necessary vitamins or an improper Ca:P ratio. These metabolic disturbances can and usually will affect the dentition via the loss of the supporting structures of the teeth. Genetic causes can also be a predisposing factor in the development of dental disease. Brachycephalic dwarf rabbits in special are more susceptible to dental problems because of their shortened skulls and altered masticatory forces that affect the teeth. Trauma can also be the instigating cause. Because a dental problem usually primarily affects the dentition and secondarily other organs and systems, it is best to be defined as a syndrome.

Pet rabbits and rodents are typically presented in veterinary practise with a wide scale of non-specific clinical signs. These include loss of body condition and appetite, dysphagia, anorexia, changes in faecal size, quantity and appearance, facial swellings or masses, salivation, epiphora and nasal discharge, just to mention some of the more common symptoms.

Diagnosing dental disease usually requires a thorough clinical examination, intraoral examination (preferably under sedation) and diagnostic imaging. Computed tomography may provide a more accurate diagnosis and prognosis as well as more detailed treatment planning than conventional radiography.

The aim of dental disease treatment is to restore the function and anatomy of the dentition to as normal as possible. Supportive treatment, control of inflammation and infection are also fundamental. As dental disease causes pain, sufficient analgesia should be provided until optimal masticatory function is achieved.

Owner education on proper husbandry and nutrition plays an important role in the prevention and control of dental disease in these species.
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GLOSSARY

**alveolar bone** = one of the three tissues that support the tooth (other two being periodontal ligament and the cementum)

**anelodont** = a tooth that has limited period of growth

**anisognathism** = “upper and lower jaws” are unlike (maxilla wider than mandibula or vice versa)

**ankylosis** = union of separate bones or hard parts to form a single bone or parts

**apex** = the uppermost point or the narrowed or pointed end

**apical** = relating to or situated at an apex

**aradicular** = no anatomical root, open rooted

**bilateral** = relating to, or affecting the right and left sides of the body, or right and left members of paired organs

**brachycephalic** = short headed

**buccal** = cheek side

**caudal** = directed toward or situated in or near the tail or posterior part of the body

**cementoblast** = one of the specialized osteoblasts of the dental sac that produce cementum

**cementum** = a specialized calcareous layer of connective tissue covering the dentin

**clinical crown** = the part of the tooth that projects above the gums

**contra** - = in opposition or contrast to

**dacryocystitis** = inflammation of the lacrimal sac

**deciduous tooth** = a temporary tooth of a young mammal

**dentine** = a calcareous material similar to but harder and denser than bone that composes the principal mass of a tooth

**diastema** = a space between the teeth in a jaw

**diphyodont** = two sets of teeth, deciduous and permanent
**distal** = situated away from the point of attachment or origin or central point especially in the body

**dorsal** = relating to or situated near or on the back

**duplidentata** = suborder of rodentia that has two pairs of maxillary incisors

**dysphagia** = difficulty of swallowing

**dystrophic** = relating to or caused by faulty nutrition

**elodont** = a type of tooth that increases its height or length on the pulpal axis throughout life

**elodontoma** = odontoma of elodont teeth

**enamel** = hard calcareous substance that forms a thin layer capping the teeth

**endodontic** = denoting or relating to the soft tissues inside the tooth (the dental pulp)

**emaciation** = to lose flesh and to become very thin

**epiphora** = excessive watering of the eye

**exophthalmos** = abnormal protrusion of the eye

**germinal** = being in the earliest stage of development

**homogenous** = same or a similar kind or nature

**hyperplasia** = an abnormal or unusual increase in the elements composing a part (such as cells composing a tissue)

**hypsodont** = teeth that have anatomical crowns which are greater in height than their roots

**iatrogenic** = induced inadvertently by a physician or surgeon or by medical treatment or diagnostic procedures

**labial** = relating to or situated near the lips

**lateral** = relating to the side

**lingual** = relating to the tongue or situated near the tongue

**macrodont** = unusually large tooth
**marsupialization** = is the surgical technique of cutting a slit into an abscess or cyst and suturing the edges of the slit to form a continuous surface from the exterior surface to the interior surface of the cyst or abscess. Sutured in this fashion, the site remains open and can drain freely.

**mesial** = relating to or directed towards the mid line of the body

**monohyodont** = an animal in which the permanent dentition does not have a primary precursor or a successor

**odontoblast** = any of the elongated radially arranged cells on the surface of the dental pulp that secrete dentin

**odontoclast** = one of the large multinucleated cells that are active during the root resorption

**odontoma** = a tumour originating from a tooth and containing dental tissue (as enamel, dentin, or cementum)

**omnivorous** = feeding both animal and vegetable substances

**osteomyelitis** = an infectious usually painful inflammatory disease of bone often of bacterial origin that may result in the death of bone tissue

**periapical** = relating to, occurring in, affecting, or being in the tissues surrounding the apex of the root

**perioceutic** = pharmacological agent specifically developed to manage periodontitis

**periodontal** = surrounding a tooth

**periosteum** = the membrane of connective tissue that closely invests all bones except at the articular surfaces

**prognathism** = typically a lower jaw that projects forward especially to an unusual degree

**propalineal** = longitudinal translation

**ptyalism** = hypersalivation

**pulpectomy** = removal of the pulp of a tooth

**reserve crown** = portion of the tooth below the gingival level and within the alveolus

**retrobulbar** = situated, occurring or administered behind the eyeball
rostral = situated toward the oral or nasal region

simplicidentata = suborder of rodentia, with one pair of maxillary incisors

unilateral = relating to or affecting one side of a subject

ventral = being or located near the belly or lower surface of the animal, opposite to the back
1 INTRODUCTION

Rabbits, guinea pigs and chinchillas are often presented in veterinary practice with dental problems. Dental problems with these pets arise from the fact that they have continuously growing (elodont) dentition with long anatomic crowns. Veterinarians should be aware of factors that contribute to dental disease as well as diagnostic techniques, treatment options and preventive measures. Veterinarians must also be aware of the normal dental anatomy and physiology (Lennox 2008). Husbandry and genetics may contribute to the development of dental disease (Brenner et al. 2005). Clinical signs and symptoms that are associated with dental disease can be secondarily related to other organs and systems and that is why dental disease is best defined as a syndrome (Cappello 2008a). Underlying causes of dental disease usually refer to either congenital or acquired dental disease (Lennox 2008). Acquired dental disease is associated with nutritional factors, trauma or age-related attrition (Lennox 2008). Dental disease diagnostics should include diagnostic imaging because that is the only way to evaluate the condition of the reserve crown, apex and the adjoining bone (Meredith 2007). Diagnostic imaging allows for more accurate diagnosis and supports the prognosis, which is important to the owner of the pet (Meredith 2007). The aim of the treatment of dental disease is to return the anatomy and function to as normal as possible, and to control inflammation and infection which are typically associated with dental disease (Lennox 2008). Animals affected with dental disease need appropriate diet and probably regular dental care throughout the rest of the pet’s life.
2 DENTAL ANATOMY AND PHYSIOLOGY

2.1 General

Rodents belong to the largest mammalian order Rodentia. Rodents are grouped into three suborders and this division is based on the anatomical and functional differences of their jaw muscles. Suborder Myomorpha are rat or mouse-like rodents and suborder Sciurromorpha are squirrel like rodents. The suborder Hystricomorpha and infraorder Caviomorpha contain the guinea-pig-like rodents (Cappello 2006b). Caviomorphs have open-rooted dental systems where all teeth grow continuously (Legendre 2002). Rodents are monohyodont (single set of teeth) and the incisors are well developed (Cappello 2006b). Rodents and their extinct relatives (Mixodontia) have one pair of maxillary incisors and are grouped in a clade called Simplicidentata (McKenna and Bell 2000). The anatomy and physiology of premolars and molars in guinea-pig-like rodents do not differ. Rodents do not have canine teeth, instead there is a wide diastema separating the incisors from the cheek teeth.

Chinchilla, guinea pig and degu are the most commonly kept pets in the Caviomorpha infraorder (Cappello 2006b). Guinea pig and chinchilla share the same dental formula (Mans and Jekl 2016). They are true herbivores with elodont dentition, which means that their teeth are open rooted and keep growing continuously throughout their life. Rat-like rodents have only elodont incisors, whereas their cheek teeth are anelodont, which means they only grow for a limited period of time. Rat-like rodents are also omnivorous. Rodent species have temporomandibular joint and masticatory muscles that allow marked rostrocaudal movement, to a much greater extent than lagomorphs. Rodents can subluxate their mandible rostrally during gnawing. When a rodent’s jaw is at rest, their cheek teeth are in occlusion, unlike in lagomorphs. The rodent mandibular diastema is shorter than the maxillary diastema (Cappello 2006b).

Rabbits belong to the mammalian order Lagomorpha. They have also been ascribed to the (synonymous) order Duplicidentata, because they have two pairs of incisor teeth in their maxillae (Vella and Donnelly 2012). Rabbits have the skull morphology of a true herbivore, which is very similar to larger species like the horse. Lagomorphs are diphyodont which means they have two set of teeth, deciduous and permanent. There is no practical relevance of rabbits being diphyodont for dentistry because deciduous teeth are shed either before or very soon after birth (Cappello and Lennox 2012).
Enamel microstructure in rabbits is known as irregular where enamel rod bundles crisscross in an asymmetrical pattern. Rabbit enamel microstructure is different from rodents and provides resistance to fractures in multiple directions. This irregular enamel gives a whitish appearance to rabbit teeth (both incisors and cheek teeth). The white appearance of rabbit incisor teeth is in contrast to rodent incisor teeth which are pigmented yellow to orange (Donnelly and Vella 2016). Exception to this is the guinea pig with enamel much whiter than in other caviomorphs (Cappello 2008a). Rodent incisors have a thin layer of enamel that is rich in iron and makes it harder than regular enamel. Rodents have iron levels ten times higher than rabbits in their enamel (Donnelly and Vella 2016).

Rodents and lagomorphs have also significant differences in their chewing patterns, jaw relationship and dentition (Crossley 2003). Chinchillas and guinea pigs (Reiter 2008) have wider mandible than maxilla, contrary to rabbits with wider maxilla (Brenner et al. 2005).

2.2 Rabbit (*Oryctolagus cuniculi*)

![Figure 1. Rabbit dental chart. (Adapted from Crossleys dental chart by Paula Ahola)](image)
Rabbits have 28 teeth with a dental formula of 2(12/1 C0/0 PM3/2 M3/3). Rabbits have two incisors, three premolars and three molars in each side of maxilla. Each side of mandible has one incisor, two premolars and three molars. Premolars and molars are called cheek teeth and are not typically differentiated in practise (Donnelly and Vella 2016). In the triadan system, the rabbit teeth are numbered in maxilla 01,02, 06-11 and in mandible 01, 07-11 (Fig. 1.). There is no significant interproximal space between incisors, nor between cheek teeth (Lennox 2008). The rabbit mandible is narrower than the maxilla and this feature is called anisognathism (Verstraete and Osofsky 2005). Rabbits have deciduous and permanent sets of teeth and this feature is called diphodonty (Donnelly and Vella 2016). Deciduous first incisors are usually shed around birth, so they usually go unnoticed. The second incisors and premolars are also present at birth and are exfoliated within a month (Verstraete and Osofsky 2005). At birth the mandibular deciduous molars are completely developed. Four days after birth root resorption is initiated. Nine days after birth, permanent mandibular molars start to erupt. Twenty-three days after birth mandibular premolars start to erupt and by day 32 all permanent cheek teeth in the mandible have erupted. Rabbits have elodont teeth which means they grow continuously, and they are aradicular meaning they have no anatomical root (Donnelly and Vella 2016). Rabbit teeth are also called hypsodont, basically meaning they have long clinical crowns (Verstraete 2003). Rabbits dentition type allows for an increase in tooth size concurrent with the growth of the rabbit (Donnelly and Vella 2016).

Behind the maxillary incisors, lagomorphs a have pair of much smaller incisors called “peg teeth” (Lennox 2008); it is because of these two sets of maxillary incisors that rabbits are called duplicidentata (Cappello and Lennox 2012). The maxillary incisors are shorter than the mandibular incisors (Lennox 2008). Enamel is only present at the labial side of the maxillary incisors which are strongly curved. The mildly curved mandibular incisors have enamel both on the labial and the lingual side of the teeth (Verstraete 2003). Mandibular incisors occlude between the first and second maxillary incisors (Verstraete and Osofsky 2005). The mandibular incisors wear to the secondary incisors at approximately right angles (Donnelly and Vella 2016). Rabbits also grind their mandibular incisors along the arc of their maxillary incisors to wear them effectively (Crossley 2003). Maxillary incisors grow approximately 2 mm per week and mandibular incisors 2,4 mm per week, although growth rate can vary depending on age, diet and pregnancy (Donnelly and Vella 2016). Rabbits incisors have a single pulp.
cavity, which is wider near the apex and tapers down toward the tip, so that pulp is replaced with dentine closer to the occlusal surface (Harcourt-Brown 2009a).

As for the cheek teeth, the occlusal plane in rabbits is approximately $10^\circ$ to the horizontal (Verstraete 2003), the lingual side being slightly higher than the buccal side in the mandible (Böhmer 2015). Each cheek tooth has margins and ridges composed of enamel across the occlusal surface. Series of enamel crests are created by removal of cementum and thin enamel from the cusp tips due to the abrasion. Enamel wears at a slower rate than dentin and that is why enamel crests eventually project above dentin and develop an uneven surface which makes grinding of fibrous food efficient (Donnelly and Vella 2016). These transverse ridges interlock with opposite teeth during chewing (Crossley 2003). Peripheral enamel is thickest on the buccal surfaces of the mandibular cheek teeth and the lingual surfaces of the maxillary cheek teeth (Verstraete and Osofsky 2005).

Cheek teeth have a single pulp chamber which, except for the last molars, divides in to two chambers toward the clinical crown (Donnelly and Vella 2016). There are nerve fibres that are pain receptive and extend from the pulp cavity into the dentine and towards the occlusal surface (Harcourt-Brown 2009a).

The periodontal ligament of the incisors is weakest in the basal region of the tooth where the development occurs. Ligament is strongest near the crown where intrusive forces need to be resisted (Donnelly and Vella 2016).
2.3 Guinea pig (Cavia porcellus)

The dental formula of guinea pigs is 2(I 1/1, C 0/0, P 1/1, M3/3) (Legendre 2016). This means they have one incisor, one premolar and three molars in each of the jaw quadrants (Reiter 2008). In triadan system guinea pig teeth are numbered in all quadrants 01, 08-11 (Fig. 2). Guinea pigs are monophyodont, meaning they have a single set of teeth without deciduous precursors or permanent successors (Reiter 2008). Premolars and molars are anatomically similar, and like in rabbits, they are called cheek teeth (Verstraete 2003). Guinea pigs have aradicular teeth which means they are open-rooted with germinal cells producing dental tissue at their apical end (Legendre 2016). Also, like rabbits, guinea pigs have elodont (continuously growing and erupting) and hypsodont (long-crowned) dentition (Verstraete 2003). Guinea pigs are also anisognathic, but the mandibula is wider than the maxilla (contrary to rabbits) (Reiter 2008).
The reserve crown of guinea pig cheek teeth is curved, with a buccal convexity for mandibular cheek teeth and a palatal convexity for maxillary cheek teeth. This causes the occlusal plane to have an approximately 30° angle from dorsobuccal to ventrolingual (Legendre 2016). Guinea pig cheek teeth have a much shorter clinical crown than reserve crown as compared to rabbits (Cappello 2008a).

Guinea pig incisors are covered with enamel which is thicker on the labial surface and thins out on mesial and distal aspects toward the lingual surface where there is no enamel. Guinea pig has maxillary incisor growth approximately 1.9 mm per week and mandibular incisors grow approximately 2.4 mm per week (Legendre 2016). Mandibular incisors are normally three times the length of maxillary incisors (Cappello 2008a).

2.4 Chinchilla (Chinchilla lanigera)

Figure 3. Chinchilla dental chart. (Adapted from Crossleys dental chart by Paula Ahola)

Chinchilla teeth lack an anatomic root (aradicular), they have a long crown (hyp sodont) and they are continuously growing (elodont) (Mans and Jekl 2016). Chinchillas are also monophyodont as they have a single set of teeth (Reiter 2008). Chinchillas have a dental formula of 2(I 1/1, C 0/0, P1/1, M3/3), meaning they have one incisor, one premolar and three
molars on each quadrant (Mans and Jekl 2016). In triadan system, chinchilla teeth are numbered the same as in guinea pig teeth; all quadrants 01, 08-11 (Fig.3). Also like in guinea pigs, the mandibles are spaced further apart than the maxillae (contrary to rabbits) (Reiter 2008).

Incisors have enamel only on the labial surface and the enamel extends from the apical area to the occlusal edge. Chinchillas produce rostrocaudal jaw movements during normal feeding causing the incisors to wear to a chisel-shaped cutting edge (Mans and Jekl 2016). Chinchilla enamel is pigmented orange (Cappello 2008a). The radius of the curvature of the maxillary incisor teeth is less than half of that of the mandibular incisors (Reiter 2008).

Chinchilla premolars and molars have similar structure and form a functional grinding unit. Cheek teeth have horizontal occlusal surfaces that are rough and uneven with enamel ridges and dentinal grooves. Each cheek tooth in the maxilla is in occlusion with the opposite cheek tooth in the mandibula. Occlusal planes of the cheek teeth are almost in contact in a resting jaw position. In a chinchilla with normal dentition, the clinical crowns of cheek teeth are short, occlusal surfaces are flat and there should be no interproximal spaces (Mans and Jekl 2016).
3 MASTICATION

3.1 Rabbit

Rabbits use incisors to cut foliage. Foliage is masticated by the cheek teeth only on one side of the mouth at a time. Rabbits can have up to 120 jaw movements per minute (Donnelly and Vella 2016). Rabbits have a wide range of lateral chewing action (Reiter 2008). The temporomandibular joint structure allows four basic movements (Crossley 2003):

1. the movement of opening and closing
2. caudo-dorsal retraction and rostral protrusion (Crossley 2003), a feature that is primarily seen in rodents (Reiter 2008)
3. rostrocaudal movement of the mandible shifts mandibular condyle up or down a step in the mandibular fossa. When the mandible is in caudal position the cheek teeth are aligned and incisors are separate. If the temporomandibular joint is maintained in this position it allows the opposite mandible to slide down the temporal step into a more rostroventral position thus separating the cheek teeth on that side and bringing the cheek teeth on the first side into occlusion for chewing (Reiter 2008)
4. horizontal chewing action is achieved when eating vegetation such as grass or hay. Normal resting position for rabbits is to position both temporomandibular joints on the temporal step thus separating the occlusal plane in rabbit cheek teeth slightly and bringing the incisors into occlusion. Rabbits occlusal plane in the cheek teeth is approximately $10^\circ$ to horizontal, so separation of the cheek teeth is necessary for the normal lateral slicing action of the incisors (Reiter 2008).

Grass or hay is inserted in to the mouth to the depth of the diastema and then sliced with the incisors. The caudal end of the food is then manipulated between the first cheek teeth with the tongue. Grass or hay is moved progressively toward the caudal end of the mouth between the cheek teeth. This way all the cheek teeth are used evenly (Crossley 2003).

Harder and thicker food, such as pellets, grain or carrots for example, lead to chewing action which is more vertical. If there is too little horizontal chewing and too much vertical chewing, it may lead to reduced wearing of the teeth. It may also lead to an increase in vertical forces producing more pressure on the growing apex of the tooth (Donnelly and Vella 2016).
Watson et al. 2014 made simulations that showed that the rabbit masticatory system applies low muscle activations in processing food through several cycles. They hypothesise that this way rabbits prevent rapidly fatiguing fast fibres during repeated chewing cycles.

### 3.2 Guinea pig

Guinea pigs have long mandibular fossae in which the mandibular condyles glide in the rostrocaudal direction (Reiter 2008). The temporomandibular joint in guinea pigs does not allow much lateral movement (Böhmer 2015). Guinea pigs have a propalineal chewing action, where the mandible is repeatedly moved diagonally forward and to the contralateral side of the one in contact of the food (Legendre 2016). Jaw movement result from the work of the masticatory muscles. Masseter is the largest and strongest of the masticatory muscles. Guinea pigs have prominent grooves and ridges in their skull to increase the surface area for masticatory muscles to attach. The temporomandibular joint does not subluxate during lower jaw movements (Reiter 2008). At rest, the condyle lies in the caudal area of the mandibular fossa. When masticating, the condyle head moves rostrally in longitudinal direction. In the process of grinding the food, one condyle moves forward while at the same time the contralateral condyle moves backwards and vice-versa. The guinea pig does not open its jaws during this grinding movement, only the teeth move against each other, one side is grinding, and the other side is moving apart allowing new food to be placed between the chewing surfaces. The fact that the cheek teeth move longitudinally against each other during mastication helps to keep the occlusal surfaces even. When guinea pig gnaws and bites, a two-sided rostral sift of the mandible occurs and this movement always associates with opening of the jaws. The jaw slides backward again when the mouth is closed (Böhmer 2015).

### 3.3 Chinchilla

Incisors and cheek teeth in chinchillas work as separate functional units. Incisors and cheek teeth are not in occlusion at the same time because the maxilla and mandible are not the same length. That is why chinchillas have two different chewing modes. One is a rostrocaudal displacement of the mandible with simultaneous occlusion, called propalineal bilateral chewing. Other is called oblique unilateral chewing where jaw is displaced rostrolingually
(towards the centre and the front) and the occlusion of the right and left cheek teeth alternate. Chinchillas (as well as guinea pigs) have specific muscle and temporomandibular joint anatomy associated with these chewing modes. The deep part of the masseter muscle attaches on the muzzle rostrally to the eye, with a broad extent providing very powerful gnawing action. The lateral masseter is used only for closing the jaw. The temporalis muscle in chinchillas is small. The temporomandibular joint of chinchillas has a long and deep glenoid fossa where the articular process of the mandible slides along. This allows jaw movement both rostrally and caudally. In rostral position the incisors are in occlusion and the cheek teeth are not; in caudal position the cheek teeth are in occlusion and the incisors are not. Such rostrocaudal movement of the jaw is shown during normal feeding (Mans and Jekl 2016).
4 ETHIOPATOGENESIS OF DENTAL DISEASE AND CONGENITAL ABNORMALITIES

4.1 General

Dental disease is common in pet rodents and rabbits. Clinical signs and symptoms are primarily related to dental function and secondarily related to other organs and systems. That is why a dental disease is rather defined as a syndrome. Rabbits may have congenital dental disease more often than rodents. In rodents, dental disease commonly defined as an acquired dental disease syndrome. The primary cause of acquired dental disease is usually insufficient or improper wearing of the cheek teeth, generally caused by improper diet lacking sufficient fibre content (Cappello 2008a). Genetic causes are also proposed to be a predisposing factor for developmental dental disease (Mans and Jekl 2016). Continuously growing teeth have a high metabolic activity in apical germinal tissues and odontoblasts, which makes them susceptible to systemic problems and metabolic disturbances. Rabbit dental tissue has high affinity for calcium, which protects the tooth growth (although growth rate might be reduced) and mineralization of dentine, even during prolonged hypocalcemia (Crossley 2003).

In acquired dental disease, improper mastication and ineffective dental wear progress into derangement of the shape, position and structure of the teeth and associated supportive structures (Donnelly and Vella 2016). Incisor malocclusion and cheek tooth malocclusion may both be either primary or secondary (Reiter 2008) although incisor disorders are often secondary to disorders of the cheek teeth. Primary incisor diseases relate less often developmental disorders; they are usually caused by trauma (Mans and Jekl 2016). Incisor malocclusion may lead to cheek tooth malocclusion if it prevents normal mastication (Verstraete 2003). Irregularity of the cheek occlusal plane can result in “step mouth”, “wave mouth” and spike formation (Verstraete and Osofsky 2005). Enamel spikes and spurs form on lingual surface of the mandibular cheek teeth or the vestibular surface of the maxillary cheek teeth. Spikes and spurs may cause mucosal trauma and may result also in oral pain (Reiter 2008). Elongation of the clinical crown is often accompanied with reserve crown elongation but can occur in its absence. Intraoral elongation of the cheek teeth may entail buccal or lingual deviation (Verstraete And Osofsky 2005). Apical elongation causes pressure to the nerve endings, growth through the periosteum and intrusive pressure of the tooth to the germinal tissue associated with ischemia (Mans and Jekl 2016) Apical elongation deforms the
adjacent cortical bone and can result in perforation and palpable surface irregularities of the ventral mandibula (Legendre 2016). Extension of the tooth apices into periapical tissues usually follows, leading to palpable swellings on the ventral surface of the mandible. In guinea pig, an intraoral overgrowth of the clinical crown is more typical than elongation of the reserve crown, which is why palpable swellings on the ventral mandible are less common (Reiter 2008). Abscessation is also less common in guinea pigs than in rabbits (Legendre 2016).

Pathologies of the enamel, dentin and cementum include depigmentation, horizontal enamel ridges, cementum and dentin demineralization. These changes usually correspond to germinal tissue disorders due to metabolic imbalance or chronic trauma. Metabolic imbalance can develop because of wrong diet or systemic disease. Chronic trauma can be caused by biting the cage bars (Mans and Jekl 2016).

Guinea pigs cannot synthetize vitamin C. If not given dietary vitamin C, guinea pigs can develop scurvy. Scurvy can lead to periodontal disease, gingival haemorrhages and tooth loosening (Legendre 2003).

Excessive intake of selenium can interfere with collagen metabolism in a similar manner to vitamin C deficiency. Excessive selenium in the diet can cause weakening of the fibres in the periodontal ligament and, if continued, tooth instability and problems with eruption. If the problem is recognized before the occurrence of secondary changes, correcting the diet can cure the problem (Legendre 2003).

Basically, any process that interferes with normal eruption and detrition of continuously growing teeth typically leads to dental disease (Lennox 2008). Neoplasia or traumatic fracture are also possible causes (Donnelly and Vella 2016).

### 4.2 Incisors

Incisor malocclusion is less frequent in chinchillas and guinea pigs than in rabbits. When incisor malocclusion occurs in guinea pigs or chinchillas, it is almost always secondary to dental disease in the cheek teeth (Cappello 2006b). Incisors can overgrow if the opposite incisor is lost or fractured (for example after chewing on the cage bars). Fracture can result in pulp necrosis, periapical disease and cessation of dental growth and eruption (Verstraete and
Trauma is typically the cause of primary incisor disease, developmental disorders are less often the cause (Mans and Jekl 2016).

Lateral deviation due to an oblique occlusal plane in the incisors may lead to asymmetrical elongation and malocclusion of the clinical crowns of the cheek teeth, situation which is often worsened by subluxation of the temporomandibular joint contralateral to the deviation of the mandibular incisors (Legendre 2016).

Harcourt-Brown (2006) has established classification for the incisor malocclusion in rabbits and it is presented in table 1.

Table 1. Rabbit incisor malocclusion classification, (Harcourt-Brown 2006).

<table>
<thead>
<tr>
<th>Class</th>
<th>Description</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1</td>
<td>Normal</td>
<td>The tip of the lower incisor rests against the upper peg tooth but is not in contact with the upper primary incisor</td>
</tr>
<tr>
<td>Class 2</td>
<td>Contact between primary incisors</td>
<td>Full closure of the mouth is prevented by the tip of the lower primary incisors resting against the upper primary incisor</td>
</tr>
<tr>
<td>Class 3</td>
<td>Edge to edge contact</td>
<td>Full contact between the occlusal surfaces of the primary upper incisors and the lower incisors</td>
</tr>
<tr>
<td>Class 4</td>
<td>Slight protrusion of the lower incisors</td>
<td>The lower incisors anterior surface is no longer in contact with the upper primary incisor</td>
</tr>
<tr>
<td>Class 5</td>
<td>Partial overgrowth of the lower incisor</td>
<td>The anterior surface of the upper primary incisor is in contact with the occlusal surface of the lower incisor. This partial overgrowth of the lower incisors occurs due to a reduction in wearing against the upper primary incisors</td>
</tr>
<tr>
<td>Class 6</td>
<td>Overgrowth of both upper and lower incisors but still in contact</td>
<td>Still contact between the upper primary incisor and lower incisor even though there is insufficient wearing</td>
</tr>
<tr>
<td>Class 7</td>
<td>Complete malocclusion</td>
<td>The upper and lower incisors are no longer in contact. The lower incisors grow forward, and the upper incisors grow toward the mouth</td>
</tr>
<tr>
<td>Class</td>
<td>Non-occluding stumps</td>
<td>Description</td>
</tr>
<tr>
<td>---------</td>
<td>----------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Class 8</td>
<td>The tooth growth ceases and the crowns have broken off or been removed leaving stumps behind</td>
<td></td>
</tr>
</tbody>
</table>

| Class 9 | Root resorption | In extreme cases the roots have resorbed and there are only remnants of visible crowns |

| Unclassified | Incisors have been removed surgically |

### 4.3 Cheek teeth

#### 4.3.1 Rabbit

In the cheek tooth malocclusion enamel spikes and spurs may form on the buccal surface of the maxillary teeth and lingual surface on the mandibular teeth, and they can cause mucosal trauma and oral pain. Elongation of the clinical crown is often accompanied by elongation of the reserve crown with extension of the tooth apices into periapical tissue (Reiter 2008). Deviation of the overgrown cheek teeth can result in apical eruption of the teeth laterally through the associated cortical bone. Exceptions are first and last mandibular cheek teeth which more often erupt medially. Bone and soft tissue abscessation and infection usually follows. This abscessation can be caused by many different factors like endodontic infection, penetrating foreign bodies, trauma and hematogenous spread (Donnelly and Vella 2016).

#### 4.3.2 Guinea pig

In guinea pigs, cheek tooth elongation may lead to an inability to fully close the mouth (Reiter 2008). Increased slope of the occlusal planes increases the leverage effect. In the worst case, a non-symmetric coronal elongation may force the mandible into lateral position. This may even lead to the subluxation of the temporomandibular joint and possibly chronic deviation of the mandible. When masticatory muscles prevent further elongation of the clinical crowns, it causes the reserve crown and apices to elongate (Legendre 2016). Secondary incisor malocclusion may result from the cheek tooth elongation. As the lower jaw is rostrally displaced into a prognathic position, the first mandibular and last maxillary cheek teeth no
longer occlude with corresponding teeth in the opposite jaw. If this happens, the mandibular cheek teeth grow across the mouth making a bridge-like formation and entrapping the tongue (Reiter 2008). In such a case the tongue cannot move normally, and normal deglutition is prevented. Long-haired guinea pigs can get hair impaction within the gingival sulcus; this can cause discomfort and laboured chewing and may result in coronal elongation and malocclusion (Legendre 2016). Because of the very specific mastication of guinea pigs a pathological occlusal plane with a “step formation” is unlikely to develop (Böhmer 2015).

In guinea pigs, the cheek tooth elongation may be the result of insufficient dietary abrasion, nutritional factors, metabolic deficiencies and genetic factors. Nutritional factors may include vitamin D deficiency and excessive selenium, for example (Reiter 2008). Vitamin C is necessary for the production of dentin, so deficiency can cause irregular dentin formation and decrease tooth eruption (Legendre 2016). Calcium and phosphorous metabolic disorders may lead to metabolic bone disease where damage to the periodontal ligament and loose teeth can cause pain and less vigorous chewing action (Minaríková et al. 2016).

Elodontoma has also been reported in guinea pig (Legendre 2016). Elodontoma is a benign tumour-like proliferation of dental tissue. Elodontomas are basically odontomas, but the name elodontoma refers to the specific relationship with elodont teeth (Böhmer 2015).

### 4.3.3 Chinchillas

In chinchillas, nutritional and genetic causes are proposed for the development of dental disease. An insufficiently abrasive diet diminishes tooth wear resulting in elongation of the cheek teeth that are continuously growing. Less abrasive diets often also have too high phosphorus content and inappropriate Ca:P ratio which, like with rabbits, can induce secondary dietary hyperparathyroidism and consequent dental disease (Mans and Jekl 2016).

Cheek tooth elongation in chinchillas can affect the reserve or clinical crown and is the reason for most of the clinical signs and symptoms associated with dental disease (Mans and Jekl 2016).

In chinchillas, reserve crown elongation usually occurs with the apical portion of teeth extending into periapical tissues, resulting in distortion of the ventral mandibular surfaces, caused by the teeth perforating the adjacent bone (Mans and Jekl 2016) and maxillary alveolar
bullae. Perforation of the adjacent bone may present as palpable swellings on the ventral aspect of the mandibula (Reiter 2008). Apical tooth elongation can lead to pressure onto the nerve endings and cause pain. Reserve crown growth can cause pressure to the germinal tissue which may lead to ischemia (Mans and Jekl 2016). In chinchillas, soft tissue trauma caused by spurs can lead to gingival hyperplasia very commonly around maxillary cheek teeth (Mans and Jekl 2016).

As dental disease progresses, and cheek teeth continue to elongate intraorally, the mandible is displaced more and more distally. As the angle between the jaws increases, the incisors elongate secondarily (Mans and Jekl 2016).

4.4 Periodontal disease

Etiology of periodontal disease is unknown. Periodontal disease can be secondary to dental disease; different factors such as genetics, age, oral microflora and nutrition can also contribute to its development (Mans and Jekl 2016). Accumulation of bacterial plaque on the teeth is classical in periodontal disease (Crossley 2003). If left untreated periodontal disease can lead to bone and tooth resorption. Periodontal disease is a source of chronic intraoral pain which can lead to insufficient food intake and weight loss. This may lead to metabolic complications like hepatic lipidosis and ketoacidosis (Mans and Jekl 2016). Rabbits rarely have classical, primary periodontal disease. It is rather secondary to reduced dental growth and altered conformation of the teeth leading food to become impacted into abnormal interproximal spaces. Impacted food favours bacteria and plaque accumulation. Unsuitable diets containing high levels of carbohydrates increase bacterial growth and accumulation. The periodontal ligament consists of thin collagen fibres, which allows continuous eruption of the tooth. Those fibres are rapidly resorbed in the presence of inflammation. This leads to tissue loss and periodontal pockets which can be then colonized by more pathogenic bacteria that initiate disease and allow the infection to extend to the apex. This infection can spread to surrounding tissues typically leading to abscessation and possibly osteomyelitis (Crossley 2003).

In guinea pigs, a predisposing factor for periodontal disease could be acquired dental disease with abnormal chewing patterns. In healthy guinea pigs, with normal dentition and continuous
eruption and attrition, there is no time for plaque accumulation and caries to develop (Minarikova et al. 2016).

In chinchillas, periodontal disease is very common (Mans and Jekl 2016). Chinchillas can develop periodontal disease when food and debris accumulate between widened interproximal spaces. Periodontal disease may involve tooth elongation. Periodontal disease occurs with increased mobility of the cheek teeth and a pathologic diastema between them (Verstraete And Ososky 2005).

In many species opportunistic pathogens that are commonly associated with periodontal disease are *Fusobacterium nucleatum* and *Prevotella buccae*, which are part of the normal oral flora (Minarikova et al. 2016).

### 4.5 Tooth resorption

Tooth resorption leads to reduction of clinical crowns in the cheek teeth in chinchillas, which can cause food impaction in wider interproximal spaces, and very often resulting in periodontal disease (Mans and Jekl 2016).

Resorptive processes can affect the tooth itself and the alveolar bone (Mans and Donnelly 2013). Tooth resorption is often found in direct association with periodontal disease and gingival pockets (Mans and Donnelly 2013). This odontoclastic resorption is usually secondary to periodontal infection or trauma to the periodontal structures and affects the non-erupted part of the tooth (Crossley 2003, Mans and Donnelly 2013). When inflammation occurs, the layer cementoblasts becomes disrupted and stops forming those areas. Sometimes this resorption is quickly resolved but if there is a long-going inflammation it can lead to ankylosis of the tooth and eventually the entire reserve crown may be replaced by bone (Crossley 2003). Resorption can result in occlusal surface defects in absence of part or the entire clinical crown of cheek teeth (Mans and Donnelly 2013).
4.6 Caries

Caries has been reported in chinchillas (Reiter 2008). Caries is more common in chinchillas than other rodents or rabbits and the etiology is not fully understood. Caries is defined as demineralization and destruction of the tooth substance after bacterial infection (Mans and Jekl 2016). Caries is a disease associated to bacterial plaque and therefore does not typically occur in animals fed a natural diet (Crossley 2003). Caries is also associated with easily digested carbohydrates, like sugars and starch (Legendre 2003). Owners like to give their chinchillas sugary treats, like raisins and other dried berries. This raises a question could this be the reason for such a high occurrence of caries in pet chinchillas. Another predisposing factor suggested is reduced attrition due to low-fibre diets, which can cause increased plaque formation and reduced salivation. Large amounts of bacterial plaque can accumulate onto cheek teeth due to the elongation of the clinical crowns, possibly predisposing to the development of caries. When cariogenic bacteria produce lactic acid, demineralization of the tooth substance follows. In caries of chinchillas both gram-positive and gram-negative bacteria have been reported (Mans and Jekl 2016). Caries lesions can appear as discoloration and roughening of the surface, up to destruction of most of the clinical crown (Crossley 2003). Caries lesions are usually brown to black coloured and mainly in the interproximal and occlusal surfaces of the cheek teeth (Mans and Jekl 2016).

In rabbits, caries is usually found in elongated teeth. Caries has also been found in rabbits that have reduced or arrested tooth eruption and which have been on supportive feeding for a while. In these cases, the loss of attrition is probably the cause (Crossley 2003).

4.7 Advanced dental disease (ADD)

It has been suggested that the main cause of advanced dental disease (ADD) in rabbits could be nutritional osteodystrophy caused by calcium and vitamin D deficiency (Verstraete and Osofsky 2005). Another major causational theory suggested is improper dental wear (Donnelly and Vella 2016).

It is suggested that poorly abrasive diets also have high phosphorous content and inappropriate Ca:P ratio which can lead to secondary hyperparathyroidism and could cause dental disease within six months (Mans and Jekl 2016). In a study conducted in UK, pet rabbits
found with advanced dental disease had lower serum calcium concentrations than free-ranging rabbits. That same study found that PTH concentrations were higher and calcium concentrations were lower in rabbits kept in hutches than those kept in free-range conditions. These results suggest that husbandry is related to advanced dental disease in pet rabbits and that it is also associated with calcium metabolism alterations (Redrobe 2002). Rabbits have constant dental growth and attrition which causes a high demand for calcium to secure the continuous formation of dental tissue (Harcourt-Brown 2006). Nutritional secondary hyperparathyroidism causes early loss of supporting alveolar bone at the apex of the teeth allowing their intrusion to the surrounding bone. Especially in the mandibula where teeth apices penetrate the mandibular cortex, weakness of the surrounding bone by nutritional secondary hyperparathyroidism, may lead to distention of the tooth socket. This causes alteration of the dental shape and orientation which leads to malocclusion. Further loss of alveolar bone loosens the teeth and widens the periodontal space. This allows food and bacteria to get more easily between the teeth. Secondary infections may develop and possibly lead to osteomyelitis and periapical abscessation (Donnelly and Vella 2016).

4.8 Progressive syndrome of acquired dental disease (PSADD)

Most dental problems in pet rabbits are part of a progressive syndrome of acquired dental disease that affects the structure, position and shape of the teeth (Harcourt-Brown 2007). PSADD has different stages (Harcourt-Brown 2006).

In her thesis Harcourt-Brown (2006) proposed the following grading for the progression of acquired dental disease. Grade 1 refers to normal dentition. In grade 2 there is root elongation and uneven teeth, with or without enamel defects. Grade 3 refers to acquired malocclusion. In grade 4, the dental growth ceases. Grade 5 is end-stage dental disease (Harcourt-Brown 2006).

In the early stages of grade 2, root elongation is the first change to occur (Harcourt-Brown 2006, 2007). Root elongation precedes other abnormalities, including coronal elongation. As PSADD proceeds, shape, position and structure of the teeth change and their occlusal relationship alters (Harcourt-Brown 2007). In the early stages of acquired malocclusion which is grade 3, spurs usually develop first in the second and third mandibular cheek teeth
As a result of this malocclusion, maxillary first and second cheek teeth usually curl toward the cheek. As PSADD progresses, further alterations appear. The shape of the fourth and fifth mandibular cheek teeth can be altered, and they may curve toward the cheek (instead of the tongue). Fifth mandibular cheek tooth may also start to curve rostrally and grow along the occlusal surfaces of the mandibular cheek teeth. Dental structure continues to deteriorate as the PSADD progresses, which may include enamel loss, dysplastic dentine and closure of the pulp cavities (Harcourt-Brown 2007). This may eventually lead to cessation of tooth growth and grade 4 of PSADD. As a result, the patient may not need regular trimming anymore, which is often mistakenly thought to be the result of successful treatment (Harcourt-Brown 2006, 2007). Progression of this syndrome is usually not homogenous, and some teeth may rapidly deteriorate while others may retain good structure (Harcourt-Brown 2006). There is usually an improvement in rabbit’s condition as the teeth stop growing, because spur formation also stops and therefore no more mucosal trauma appears. Pulp cavity closure and loss of sensation makes chewing painless (Harcourt-Brown 2007). At the end-stage of the disease, the crowns of most, if not all teeth, disintegrate or break below gingival line (Harcourt-Brown 2006, 2007). Sometimes the dystrophic mineralization can calcify remnants of the tooth and surrounding bone (Harcourt-Brown 2007).

4.9 Congenital abnormalities

4.9.1 Relative mandibular prognathism in rabbits

The most commonly recognised malocclusion in rabbits is relative mandibular prognathism. This is often associated with scissor bite leading to unrestricted tooth elongation (Reiter 2008). Maxillary primary incisors curl inside the mouth, mandibular incisors grow rostrally and protrude from the mouth (Verstraete 2003). Maxillary brachygnathism and brachycephalism in dwarf rabbits often results in scissor bite (Reiter 2008). Dwarf rabbits have brachycephalism and mandibular prognathism that manifests as a short broad facial profile because of the restricted growth of the skull base. Their maxilla is relatively narrower than normal. Especially dwarf rabbits can manifest absence of second incisors (Donnelly and Vella 2016).
4.9.2 Macrodontia in guinea pigs

Macrodontia is only seen in guinea pigs. Macrodontia has been described as an ongoing pathological process. The entire tooth is thickened and can be associated with pain and inflammation. Macrodontia usually leads to malocclusion. It is not established whether macrodontia is acquired or inherited but because of its occurrence also in very young animals, macrodontia is very likely congenital (Schweda et al. 2014).
5 CLINICAL SIGNS

Clinical signs of dental disease are typically non-specific (Verstraete and Osofsky 2005). Typical signs associated with dental disease may include: emaciation, general loss of condition, decreased food intake, dysphagia or anorexia; change in faecal size, quantity and appearance; excessive grooming; salivation, drooling, epiphora; dyspnea; obesity; exophthalmos, facial masses or swellings; purulent nasal discharge; inability to close the mouth, restricted and painful mandibular movements; reduced activity; poor fur condition (Lennox 2008, Mans and Jekl 2016). Dehydration is also a common clinical sign, especially in advanced dental disease (Legendre 2016). Production of smaller faecal pellets may appear because of reduced food intake. Faecal pellet output may stop completely if the animal is anorectic (Verstraete and Osofsky 2005).

Clinical signs might not appear until severe changes in the dentition and complications due to those changes have occurred (Mans and Jekl 2016).

Enamel spikes and spurs in the cheek teeth can result in mucosal trauma and oral pain. The respective clinical signs include reduced food intake, excess salivation (ptyalism) and reluctance to chew, which in turn results in further tooth elongation. Animals affected with elongation of the maxillary teeth may be dull and depressed. Drooling caused by dental problems is common in rabbits and chinchillas, but not so much in guinea pigs. Saliva can wet the fur at the chin, neck and forequarters (Reiter 2008).

Secondary conditions can follow dental disease: systemic disease (emaciation, loss of condition), dermatitis, ocular disease (dacryocystitis, conjunctivitis, corneal ulcerations), gastric impaction and bloat, periapical abscesses (Lennox 2008).

Chinchillas also paw their mouth because of pain in the teeth. Chinchillas often only demonstrate clinical signs of the dental disease in advanced cases, so the disease might have progressed quite far before being noticed. Weight loss in chinchillas often goes unnoticed by the owner because of the dense fur (Cappello 2008a).

When tooth apices extend into periapical tissues and involve the zygomatic process of the maxilla and the floor of the orbit, the typical clinical signs are epiphora, exophthalmos and conjunctivitis. Ptyalism commonly follows. Epiphora can be caused by increased tear production which in this case is a reflex response to mucosal or bone pain. Other reason for
epiphora, even though less common, is an obstruction that may be due to compression of the (naso)lacrimal duct (Reiter 2008).

Rabbits with periapical abscess formation typically have purulent nasal or ocular discharge. Osteomyelitis can also develop (Reiter 2008).

Rabbits are more capable of hiding the effects of dental disease and they can tolerate significant dental abnormalities for longer periods of time than guinea pigs or chinchillas. A slight alteration of the occlusal plane in guinea pig is painful enough to discourage chewing and even a slight overgrowth of the clinical crowns can interfere with tongue mobility and swallowing, which makes guinea pigs more susceptible to anorexia than rabbits (Cappello 2008a).
6 DIAGNOSIS

6.1 Clinical examination

Complete thorough history, diet, feeding habits and possible symptoms should be enquired from the owner. The clinician must inspect the whole animal (Cappello 2016a), as well as perform a thorough dental examination of pet rabbits and rodents from two years of age (Cappello 2008a). Patency of the nasolacrimal duct should be part of the dental examination of the rabbits (Cappello 2016a). Proper diagnosis of dental disease tends to require oral endoscopy and radiographs of the skull (Cappello 2008a).

Palpation of the skull is important to detect any abnormalities (Legendre 2016). Palpate the head for asymmetry in muscles, eye globes and swelling in hard and soft tissues. Apical elongation will lead to deformity of the cortices and palpable protrusions in the mandible; rostral cheek tooth elongation may be palpated in the preorbital fossa as a hard, bulging area (Mans and Jekl 2016). Check for submandibular, maxillofacial and retrobulbar abscess formation (Verstraete 2003).

The skin should be checked for alopecia in the head (lips, chin, medial canthus of the eyes), ventral neck and forearms, as well as matted fur and anything else that might be an indication for dental problems (Mans and Jekl 2016).

Other examinations that might be useful in diagnostic are haematology and biochemistry to evaluate overall patient condition. In patients presenting abscesses, bacterial culture and sensitivity are recommended (Legendre 2016).

6.2 Intraoral examination

Examination of the oral cavity for dental problems should include endoscopy. Imaging such as radiography and computed tomography (CT) is often required. General anaesthesia is essential for diagnosis and treatment of dental disease (Lennox 2008). Up to 50% of intraoral lesions may be missed during intraoral examination performed in conscious patient. Stomatoscopy increases the chance of detecting the pathological lesions (Mans and Jekl 2016). Examination of the oral cavity in general anaesthesia should encompass all aspects of
each tooth, the tongue and buccal and lingual mucosa (Lennox 2008). Routine examination of the oral cavity can be performed with an otoscope, a lighted nasal speculum or a video otoscope (Verstraete 2003).

Thorough intraoral examination requires anaesthesia and different instruments can be applied. The tabletop mouth gag for rabbits and rodents is a specially designed platform. The patient is placed in sternal recumbency and incisors are fitted around two horizontal bars which work as a mouth gag, holding the mouth open for examination (Cappello 2016b). Speculums known as pouch-dilators can be added between incisors and the lips to improve visualization of the oral cavity. Good lighting and magnification are required for the best view (Verstraete and Osofsky 2005). Anatomic forceps with smooth tips can be used to manage the tongue. A spatula is good for deflecting the tongue and protecting soft tissues during treatment (Cappello 2016b). A dental probe is needed to assess the mobility of the cheek teeth and checking for gingival pockets (Verstraete and Osofsky 2005). Cotton tip applicators or suction are needed to remove saliva and debris from the mouth (Mans and Jekl 2016).

Below are the main elements to be observed and practical hints for the dental examination:

- Evaluate incisor teeth in anatomic positioning, occlusion, wear and coloration (Mans and Jekl 2016). Incisors should be inspected from the front and lateral aspects (Cappello 2016a).
- Before evaluating the cheek teeth, remove all the food material and debris (if there is any) from the interproximal spaces (Mans and Jekl 2016).
- Retract the tongue gently taking care that it does not get lacerated by the incisors (Verstraete and Osofsky 2005).
- Verify that all the clinical crowns of the cheek teeth are present; missing tooth can be congenital or secondary to tooth resorption (Mans and Jekl 2016).
- Assess tooth mobility and increased probing depth by using a periodontal probe (Verstraete and Osofsky 2005).
- Examine all the teeth for elongation, mobility, malocclusion, fracture, spurs and spikes, tooth resorption, caries and other pathologies that might occur (Mans and Jekl 2016).

Deviation of cheek teeth from the occlusal plane can also be verified during oral examination. Two typical deviations in the cheek teeth are wave mouth (the occlusal plane is undulating), and step mouth (step-like differences in tooth length) (Lennox 2008). In wave mouth the
height difference in adjacent cheek teeth is usually up to few millimetres. In step mouth the height difference in adjacent cheek teeth is marked (Cappello 2016a). Sharp spurs or spikes on lingual or buccal aspects of the cheek teeth may be found (Lennox 2008). Loose or fractured teeth, pus, widened interproximal spaces might also occur. Excessive coronal elongation is commonly followed by dental fracture, first mandibular cheek tooth fracture is very common in rabbits. Fractures usually lead to periapical infections and abscesses (Cappello 2016a). Damage to the tongue and adjacent soft tissues must be checked (Lennox 2008). Ulceration of the mucosa can be easily overlooked (Mans and Donnelly 2013). Caries lesions should also be checked, especially in chinchillas. Depigmentation of the teeth should be noticed (Mans and Jekl 2016).

It is important to remember that even very early malocclusion and subsequent alteration of the sloped occlusal planes are enough to evoke reduced food intake, anorexia and consequent cachexia in guinea pigs. Rabbits and chinchillas can develop abnormalities in the occlusal plane that occur in the rostrocaudal direction with the production of step mouth and wave mouth. Excessive elongation of the reserve crowns leads to both maxillary and mandibular apical deformities of the cheek teeth, presenting as a typical firm swelling that can be palpated in the ventrolateral aspect of the mandible. In chinchillas these swellings are more pronounced and more lateral than rabbits (Cappello 2008a).

In guinea pigs, elongation of one or both mandibular premolars, is the most common early stage of malocclusion. A more advanced form of malocclusion in guinea pigs is the bridge-like overgrowth of mandibular cheek teeth, which is a common finding in oral examination. Malocclusion of the whole mandibular arcade is seen in intermediate stages (Cappello 2016a).

Rabbits have maximal jaw opening of 20° to 25° and a long narrow oral cavity, which makes examination of the mouth relatively difficult (Donnelly and Vella 2016).

Periodontal disease, caries and tooth resorption are common in chinchillas but are frequently missed at intraoral examination even under general anaesthesia. Using an endoscope for oral examination increases the chance to detect dental lesions (Mans and Donnelly 2013).

Cleaning the retained food material from the teeth and assessing each tooth for mobility is essential for diagnosing periodontal disease (Mans and Jekl 2016). Guinea pigs have very rarely primary malocclusion of the incisors, so it is very important to check the cheek teeth (Cappello 2008a). Macrodontia can be readily seen in the incisors of
guinea pigs at oral examination but macrodontia in cheek teeth can usually be diagnosed only by CT (Schweda et al. 2014).

6.3 Endoscopy

Endoscopic examination assesses the oral mucosa and soft tissues. The normal length of the clinical crowns is assessed. The endoscope allows for the occlusal plane to be assessed in great detail, as well as the pattern of occlusion (Cappello 2016a).

Jekl and Knotek (2007) used a laryngoscope for preliminary examination of the oral cavity. If any pathologies or lesions were found, they stopped the examination and anesthetised the patient for a better examination with an endoscope (Jekl and Knotek 2007).

Examining the oral cavity with endoscopy provides magnification and focal illumination which allows for better visualisation of lesions, especially pitting and fissures and soft tissue and mucosal ulcers (Taylor 1999). Cappello (2016a) states that the telescopes most commonly used in exotic mammals are 2.7 mm with 30-degree view. The 1.9 mm semiflexible and 1.7 mm flexible miniscopes are also regarded as useful (Cappello 2016a). A camera attached to the endoscope provides enlarged view and recording of the examination (Taylor 1999). Mans and Jekl (2016) preferred an endoscope with a diameter of 4 mm that is safe to use without protective sheath.

6.4 Diagnostic imaging

Radiographs are an essential part of a comprehensive oral examination and they are also a diagnostic tool for malocclusion, periapical lesions and bone disease. Radiographic interpretation can be difficult because of the small size of the skull and the superimposition of dental quadrants in radiographs (Verstraete and Osofsky 2005). It is important to remember that the clinical crown that is visible above the gingival margin is only a small portion of the tooth. Most of the dental structures are invisible on clinical inspection, even in a sedated animal. That is why radiographs are an essential part of evaluating the supporting bone and periapical structures and other parts of the skull, for making a diagnosis (and possibly a prognosis) for dental disease (Cappello 2016a).
6.4.1 Radiography

Radiographs of the skull should be taken from both sides, laterally and obliquely in 45° angle as well as dorsoventral and ventrodorsal views (Verstraete 2003). Cappello (2016a) states in his paper that normally a 10 to 20-degree rotation is sufficient, depending on any specific need to a different oblique view. Rostrocaudal view is diagnostic for temporomandibular joint, mandibular symphysis, tympanic bullae and occlusal plane of the cheek teeth (Mans and Jekl 2016). Laterolateral, latero oblique and dorsoventral images are essential, other views are recommended additionally to assess specific areas of interest. Perfect superimposition of bilateral anatomic structures confirms the correct positioning and diagnostic quality of laterolateral view. With laterolateral projection, the occlusal plane in chinchillas and rabbits can be assessed. In guinea pig the occlusal plane is angled so it cannot be evaluated with laterolateral projection (Cappello 2016a).

Intraoral technique is usually preferred in veterinary medicine because of its short object-to-film distance and therefore minimal image size distortion, better positioning of the patient and the use of proper angles to obtain dedicated oblique views. Intraoral technique is reported in small mammals, but practical execution is somewhat difficult because of the small size of the oral cavity in small mammals (Cappello 2016a). Some cases intraoral technique is used to evaluate maxillary and mandibular incisors. Gracis (2008) has suggested that periapical film (22x35 mm, 24x40 mm, 31x41 mm) or bite-wing (27x54 mm) dental film could be useful for incisor exposures.

Intraoral film plates can be used also extra-orally, however film plates are not usually big enough for the entire head, so therefore they might be too impractical (Cappello 2016a).

6.4.1.1 Reference lines in radiography

Boehmer and Crossley have established reference lines for objective radiographic evaluation in rabbits, guinea pigs and chinchillas. These reference lines were created to help to monitor pathological changes in teeth and occlusal planes. Radiographs are best taken from laterolateral and dorsoventral projections. (Boehmer and Crossley 2009) Use of reference lines should only be applied to optimal projections to be reliable (Cappello 2016a).
6.4.1.1.1 Rabbit

In lateral view (Fig. 4), the white line represents the reference line above which no dental structures should not extend (dorsally) in clinically healthy animals. This line is drawn from the tip of the nasal bone to the tip of the occipital protuberance. The yellow line represents the occlusal plane in clinically healthy rabbits. This line is drawn from the rostral end of the hard palate just behind the second incisors to the tympanic bullae at approximately one third of its height. This line should be parallel to the upper white line. The red lines represent the mandibular and maxillary dental arcades, which should be approximately the same length. The ventral mandibular cortex should not be penetrated by the tooth apices, and the cortex should have a near even thickness over the first three mandibular cheek teeth (blue line). The green lines which are drawn on the palatine and mandibular bone plates should slightly converge rostrally in normal rabbits. The degree of convergence varies with skull types in different breeds (Boehmer and Crossley 2009).
Figure 5. Reference lines of the rabbit in the dorsoventral view (Boehmer and Crossley 2009)

In dorsoventral exposures, the white lines are drawn from the lateral sides of both maxillary incisors. A line is drawn from the lateral side of the maxillary incisor to the medial edge of the mandibular ramus, from both sides. Another pair of lines are drawn from lateral border of the tympanic bulla to the tip of the contralateral incisor. These lines represent the space within which all parts of the cheek teeth should be contained. Exceptions are maxillary second and third cheek teeth, as their apices can be normally curved slightly beyond the lines. Blue lines represent the mandibular medial cortex which should be almost straight, even and smooth (Boehmer and Crossley 2009).
6.4.1.1.2 Guinea pig reference lines

In lateral exposure (Fig. 6) the white line is drawn from the rostral end of the nasal bone to the dorsal notch of the tympanic bulla, at approximately three quarters of the height of the bulla. In young guinea pigs the orange line drawn in the dorsal skull, forms almost a straight line. In older animals the orange line is divided in two, forming a slight angle in the point where the lines meet. The green lines are drawn to the palatal and mandibular cortices. Rostrally these lines converge clearly when mouth is closed. This convergence become less obvious when intraoral tooth elongation progresses. The yellow line drawn from the point of the rostral surface of the mandibular incisor, where the green line ends, to the notch of tympanic bulla. These yellow reference lines run straight along the mandibular cheek teeth occlusal line. Occlusal surface is not that clear in laterolateral view in guinea pigs because of the strong angle in the occlusal plane. The blue line is drawn in the ventral mandibular cortex and it should not be penetrated by the apices of mandibular cheek teeth. The red lines in the mandibular and maxillary arcades should be the same length. If there appears any discrepancy between arcade lengths, that is a significant dental problem indicator (Boehmer and Crossley 2009).
Figure 7. Reference lines of the guinea pig in dorsoventral view (Boehmer and Crossley 2009)

On the dorsoventral view (Fig. 7), the white reference line runs from the mesial border of the maxillary incisor to the most caudolateral part of the ipsilateral mandible on the level of the temporal zygomatic process. If no significant tooth elongation appears, only the apical bulla of the maxillary first cheek teeth extends beyond this line. The blue lines are medial cortical borders of the mandible (Boehmer and Crossley 2009).
6.4.1.1.3 Chinchilla reference lines

The white line is drawn from the dorsal margin of the maxillary incisors to the notch of the tympanic bulla. Healthy chinchillas radiolucent soft tissue at the apices of the cheek teeth should be on this line, there should not be any calcified tooth structures extending dorsally from the line. Retrograde displacement is very common in pet chinchillas so animals without any abnormalities in this part is uncommon. The yellow line is drawn from the tip of the upper incisors to through the tympanic bulla, approximately three quarters of its height. This line should run almost parallel to the palatinal bone. The occlusal surfaces of both mandibular and maxillary incisors should be on this line, when they are in normal length and occlusion. The yellow line should also coincide with normal occlusal plane of the cheek teeth. Occlusal plane should be horizontal and quite even in chinchillas. The green line is drawn to the rostral surface of the mandibular cheek teeth and it helps to estimate with the horizontal yellow line, if the teeth are elongated significantly. The blue line is drawn caudally from the most ventral part of the mandibular incisors, corresponding with the ventral mandibular cortex below the first three cheek teeth apices. This blue line should run near parallel to the occlusal line. There shouldn’t be any thinning or distortions caused by the intruded apices in the ventral mandible, it should be smooth and even (Boehmer and Crossley 2009).
Figure 8. Reference lines of the chinchilla in dorsoventral view (Boehmer and Crossley 2009)

In the dorsoventral view (Fig. 8), the white lines are drawn from the medial tip of each maxillary incisor to caudal extremity of the ipsilateral mandibular ramus. In clinically healthy animals they mark the lateral limit of the cheek teeth. The green line is drawn transversely through the points where white lines cross the rostral edge of the maxillary zygomatic processes. The green line indicates in clinically healthy cheek teeth the most rostral extent of the apices (Boehmer and Crossley 2009).

6.4.2 Computed tomography (CT)

CT is a radiologic technique that can be used to obtain multiple, cross-sectional parallel image slices of the patient’s tissues. CT scanners also allow for a great number of visual options and virtual tridimensional (3D) images. With CT imaging the structures that are not of interest can be deleted to obtain better visualisation of the structures of interest. CT helps evaluate
patients with dental disease for a better diagnosis and more accurate prognosis (Cappello and Cauduro 2008).

The entire dentition can be visualized under CT; teeth, periodontal tissues, alveolar bone, soft and hard tissues. Such advantage makes CT a superior diagnostic tool (Schweda et al. 2014). CT imaging provides better assessment about areas with bone loss or osteomyelitis while isolating single portions of the skull without bony structure or soft tissue superimposition (Cappello and Cauduro 2008). 3D-CT scans can add greatly to the diagnosis and prognosis of the dental disease and treatment plan (Cappello 2008b).

Many studies state that sedation or anaesthesia are necessary for proper positioning for CT but at the Veterinary Teaching Hospital at the University of Helsinki, a tubular transparent acrylic plastic box nicknamed “mousetrap” is used. The patient to be examined is tightly packed with towels. Towels prevent the head from oscillating as it takes only a few seconds to scan the patients. It often allows to take another series of images using a specific window for the lungs, which benefits pre-anaesthetic evaluation (Candido, personal communication).

Anesthetized animals are positioned usually in ventral recumbency with the head elevated in a horizontal position (Cappello and Cauduro 2008).

Micro-CT has a small viewing field but provides higher resolution for small mammals than traditional CT (Souza et al. 2006).

Cone-beam CT (CBCT) has lower ionizing radiation dose levels as compared to conventional CT and scan times are typically 5-40 seconds depending on unit and protocol settings. A CBCT can generate thinner slices than conventional CT, as well as 3D images (Riggs et al. 2016). A study conducted by Riggs et al. (2016) found that CBCT imaging was superior to conventional CT when imaging the dentition. Conventional CT is still better if soft tissues need to be evaluated. With CBCT imaging the periodontal ligament can be seen with such detail that it may allow for earlier detection of periodontal disease in rabbits. Consequently, earlier treatment may slow the progression of the disease (Riggs et al. 2016).
6.4.3 Magnetic resonance imaging (MRI)

MRI imaging can provide very good visualization of the soft tissues. A disadvantage of MRI is the longer scanning time than that of CT. In low-field MRI, the scanning time can range from 20 to 40 minutes, as compared to CT which can be performed usually under minute. In rabbits and rodents, the most relevant benefit of MRI could be in diagnosing abscesses, their size and content. CT is still the best choice in diagnosing dental disease, but MRI could give important information for planning a surgical approach to remove an abscess. CT and MRI are best used as complementary tests, whenever available. Due to practical and financial limitations, this may not always be possible (Cappello 2016a).
7 TREATMENT

7.1 General

The goal of dental disease treatment is to restore the patient’s dental health while returning anatomy to normal or as normal as possible (Cappello 2008b). Medical treatment is usually an important part of dental treatment, such as antibiotics to control local infection and analgesia for pain (Cappello 2008a).

Prognosis for the treatment of malocclusion in the cheek teeth is fair to good, unless the patient is presented with poor general health (Cappello 2008a). Prognosis should be discussed with the owner because repeated dental treatments are usually required throughout life (Mans and Jekl 2016).

Therapeutics for incisor and cheek teeth malocclusion are occlusal adjustment of the involved teeth and extraction of the teeth that are severely affected by endodontic and/or periodontal disease, as well as possible abscess debridement. Patients should be well examined before undergoing anaesthesia for dental treatment. There might be concurrent issues like pneumonia, renal or cardiac problems, etc. Gastrointestinal stasis is common in animals with dental problems. One should also consider how often the animal should be treated with the dental problem and how much anaesthesia is required in the future. In severe cases euthanasia is a humane choice of action (Verstraete and Osofsky 2005). Normal dental anatomy must be known when doing dental treatment (Cappello 2008a).

7.2 Instruments and equipment for intraoral treatment

Dr. Crossley has designed a special elevator for rabbit incisors. Luxators designed by Dr. Crossley have at the one end of the instrument a luxator for mandibular incisors and at the other end for maxillary incisors, each end has a different curvature. Alternatively, 18-gauge needles which are properly contoured and flattened can also be used. Crossley have designed luxators for the cheek teeth too. There are special forceps for rabbit cheek teeth extraction (Cappello 2016b).
Cappello (2016b) recommends a dental unit and a straight hand piece for treatment of rabbit teeth. Different types of burr are available in the market with protective sheaths to add on the burr to help to protect the soft tissues. There are still rasps and cutters for rabbit cheek teeth in the market, but their use is discouraged because of the damage they can do to the periodontal ligament, germinal tissue, surrounding soft tissues and possibility of dental fracture (Cappello 2016b).

### 7.3 Species-specific traits

In guinea pigs, elongation of the teeth causes stretching of the masticatory muscles associated with pain and inflammation, that is why they may not improve immediately after dental treatment (Cappello 2008a). It may take several days for the masticatory muscles to adapt. During this time nutritional support and pain management are indicated if needed (Verstraete and Osofsky 2005). Sometimes because of the stretching of masticatory muscles, guinea pigs may have difficulty closing and moving their jaw after coronal reduction, cheek teeth do not achieve proper grind or wear and repeated coronal elongation may occur (Legendre 2016).

Rodents do not adapt as well as rabbits to the extraction of the incisors because they tend to use their incisors for chewing to a larger extent than rabbits (Cappello 2008a).

Reduction of the clinical crown in chinchillas may be very difficult or even impossible due to the elongation of the gingival margin concurrent with the elongation of the clinical crown (Cappello 2008a). If there is severe gingival hyperplasia in a chinchilla, resection of the gingiva can be performed with monopolar surgery (Mans and Donnelly 2013).

Because of the normal curvature in the guinea pig and to a lesser degree in chinchillas, extraction of the cheek teeth is basically impossible unless the tooth is loose (secondary to periodontal infection) (Cappello 2008a).

Rabbits are more prone to periapical infections and osteomyelitis than chinchillas and guinea pigs (Cappello 2008a). In rabbits with PSADD, it is recommended that the spurs from affected teeth are removed (Harcourt-Brown 2006).
7.4 Incisors

Never use clippers or any other manual instruments for reducing incisor length. Using manual instruments may lead to fractures, root damage and abscessation (Verstraete 2003). Therapeutic options for incisor malocclusion are tooth reduction for every three to six weeks (or whenever necessary), as well as dietary adjustment or even extraction of the involved teeth (Verstraete and Osofsky 2005).

Dental handpieces and cutting discs are employed to reduce incisor length, along with saline or water irrigation to cool the teeth and prevent thermal injury (Verstraete 2003, Mans and Jekl 2016). If the patient is not intubated, one must be careful with liquids to avoid aspiration (Lennox 2008).

Coronal reduction of the incisors is used in cases where diagnosis has been done at an early stage, malocclusion is minimal and proper occlusion of both the incisors and the cheek teeth is achievable (Cappello 2016b). Incisor adjustment is always done after completing cheek teeth adjustments. This is because, if after cheek teeth shortening the incisors are too long the cheek teeth do not occlude properly (Böhmer 2015).

If pulp exposure occurs, a partial pulpectomy and direct pulp capping are indicated (Verstraete and Osofsky 2005). If pulp is exposed, the patient should be anaesthetised (if not already) and the tooth should be prepared for partial pulpectomy with an aseptic technique. A small portion of the pulp should be removed, and the remaining cavity filled with calcium hydroxide cement. The cement protects the pulp and stimulates the dentine deposition. Because this cement is not that hard (hard cements should never be used) it is worn away with wearing of the tooth (Crossley 2003).

7.4.1 Extraction of the incisors

7.4.1.1 Intraoral (Rabbit)

Extraction of the incisors might be necessary to effectively treat a severe malocclusion. Rabbits adapt quite well to life without incisors. In most cases, the extraction of all the incisors might be necessary, both upper and lower primary incisors and peg teeth (Cappello 2016b).
Haemostatic clamps or small needle holders can be used as extraction forceps (Cappello 2008a). First gingiva should be scrubbed with 2% povidone solution or dilute (0,1%) chlorhexidine solution (Lennox 2008, Cappello 2016b). After scrubbing, a scalpel (#11 or #15) is inserted to the gingival sulcus to separate the gingival attachment around the entire tooth (Lennox 2008). Then with help of the luxator (18G needle or Crossley luxator) progressively loosen and severe periodontal ligament (Lennox 2008, Cappello 2016b). Move gradually in an apical direction. Concentrate and alternate between lingual and buccal aspect of the tooth when luxating (Verstraete and Osofsky 2005). Awareness of the natural shape and orientation of the reserve crown is important to avoid excessive leverage and tooth fracture (Lennox 2008). Expansion of the alveolar bone should be as limited as possible (Verstraete and Osofsky 2005). Once the tooth is loose, extract it by following its natural curvature (Lennox 2008). Pull with forceps if needed but don’t use rotational movements (Verstraete and Osofsky 2005). The entire tooth and pulp must be checked after extraction to confirm the extraction of the whole tooth. Tissue remaining in the alveolus should be destroyed by curetting the alveolar walls with needle or luxator to prevent regrowth (Lennox 2008). Alternatively, before pulling the teeth out, it can be gently intruded into the alveolus. This dislodges the apical germinal tissue and prevent the tooth to regrow and formation of mineralised dental tissue in vacated alveolus. Cautious must be used with leverage, torque and premature longitudinal traction, because it may cause premature tooth fracture. If the pulp remains vital and there is a retained tooth tip, it may cause the tooth to regrow (Verstraete and Osofsky 2005). Bleeding is usually very minimal after extraction and sterile cotton swabs can be used to control it if necessary. When extracting the maxillary incisors local anaesthesia can be added by blocking the rostral infraorbital nerve. When removing maxillary primary incisors, caution must be used not to damage the secondary incisors. In maxillary incisors the periodontal ligament is very strong on the mesial aspect. Maxillary incisors loosen significantly after severing that ligament. Secondary incisors, “peg teeth” are loosened with a thin 22-gauge contoured hypodermic needle. When secondary incisor is completely luxated, it can be pulled out very carefully and try not to crush the tooth. In peg teeth the alveoli are curetted with a needle to remove any remaining pulp tissue (Cappello 2016b). The tooth socket should be flushed with saline, iodine or chlorhexidine. Gingiva should be closed over the alveolus with 3-0 or smaller absorbable suture (Lennox 2008). Simple interrupted sutures or a purse-string suture pattern can be used. Suture material should be fixed at a minimum of six points through the gingiva before tightening it, if using a purse-string pattern (Cappello 2016b). No closure is recommended if
the tissue is infected (Lennox 2008), in that case the gingiva is left to heal by second intention (Cappello 2016b).

7.4.1.2 Extraoral (mandibular incisors)

In cases where mandibular incisors are fractured or completely abnormal in shape and structure or show signs of resorption due to infection and inflammation or there is remaining dental tissue in the alveolus after an incomplete tooth extraction, an osteotomy is indicated when performing extraction. Preoperative radiographs are necessary for identifying abnormalities and planning for operation (Böhmer 2015). Böhmer (2015) recommends intraoral images or isolated views of the mandible in guinea pigs and chinchillas.

The skin is incised over the tooth to be extracted, followed by blunt dissection through the soft tissue to expose the bone surface (Easson 2016). When performing an extraoral extraction, the bone over the periapical tissues of the affected tooth must be removed (Jekl 2011). Removal of the teeth or their remains osteotomy leads to minimal risk of complications and optimal postoperative healing period. In cases where the jaw has become already partially osteolytic due to infection, there might be already access to the tooth socket. If the jaw is intact, the alveolus can be opened with a small suitable burr in the deepest possible area (Böhmer 2015). The aim is to remove the bone cortex and expose the root apex, until the surrounding periodontal ligament is visible in all four sides. Cooling with saline is necessary to prevent the overheating of bone and flushing the debris away from the site (Easson 2016). If needed the osteotomy area can be enlarged with fine Luer rongeur forceps and the dental tissue can be removed without complications (Böhmer 2015). Hypodermic needles can be used to sever the periodontal ligament (Easson 2016). If there is focus of infection in the intra-alveolar space, it can be flushed and cleaned through the osteotomy site as long as needed (Böhmer 2015). In case of abscessation, marsupialization can be considered. Wound closure can be done with absorbable monofilament suture. Removal of entire tooth can be verified with postoperative radiographs (Easson 2016). Osteotomy is always recommended when extracting purulent mandibular incisors.

In case of maxillary incisor abscessation, osteotomy is rarely indicated. As the maxillary alveoli open downwards, exudates tend to drain well through the empty tooth socket. If more of the
surrounding bone is infected, then an extraoral dorsolateral (or intraoral lateroventral) osteotomy of the alveolus might be necessary (Böhmer 2015).

7.5 Cheek teeth

Treatment for cheek teeth malocclusion and elongation consists in reduction of the coronal height and restoration of the coronal occlusal surfaces (Mans and Donnelly 2013). The natural zigzag pattern of normal occlusal plane is usually impossible to restore (Lennox 2008). A dental unit in which the rotation speed can be controlled is most useful for dental treatment. It may facilitate fine movements of the burr and help prevent overheating the teeth (Candido, personal communication). Soft tissue protectors, such as spatulas or those inbuilt on the handpiece, are recommended to reduce the risk of iatrogenic damage (Lennox 2008, Mans and Donnelly 2013). Coronal reduction of the incisor teeth is often necessary with dental treatment of the cheek teeth. Before shortening the clinical crown, complete inspection and evaluation must be performed. Cutting instruments must never be used, because they pose a high risk for iatrogenic damage, particularly fractures in the clinical or reserve crown (Cappello 2008a). All loose and infected teeth must be removed (Lennox 2008).

Moistened cotton swabs can be used to remove accumulating tooth dust. Saline should be used to prevent thermal injury, caution must be exercised to avoid aspiration if the patient is not intubated (Lennox 2008). Alternatively, to avoid aspiration, one may pack oropharynx. By using a light touch, less cooling fluid is needed (Verstraete and Osofsky 2005).

Coronal reduction should be performed only for restoration of occlusion to normal or as near normal as possible. Intraoral examination must be compared to the radiographs to detect the teeth that are elongated within the gingival margin or alveolus. In cases with step mouth some teeth are longer and others shorter than normal. When the tooth is shorter than normal, it cannot be used as a landmark for occlusal plane restoration. If coronal reduction involves the fourth or fifth mandibular cheek teeth, special attention must be paid because of the lower alveolar vein that lies just under the pharyngeal commissure, at a very close proximity. Injury of this vein could cause significant intraoral haemorrhage (Cappello 2016b). If tooth height reduction is done correctly there should be no pulp exposure (Verstreate and Osofsky 2005). A functional chewing surface is not readily restored with crown length reduction. Normal chewing activity restores the functional chewing surface within 1-2 weeks. If there is
stretching in the masticatory muscles (mostly in guinea pigs), it will take several days to adapt before sufficient contraction develops to permit normal chewing (Crossley 2003).

It is important to pay attention to potential of spurs on the buccal edge of maxillary teeth. Moving the mucosa with a spatula may reveal hidden spurs (Legendre 2016).

If there is severe elongation, a gradual coronal reduction is recommended to avoid excessive damage and pain leading to anorexia. This approach also gives time for the gingiva to recede physiologically. The second treatment should be performed three or four weeks later, with supportive feeding in the meantime if needed (Legendre 2016). Post-treatment imaging is useful to evaluate proper coronal reduction (Cappello 2016b).

### 7.5.1 Chinchilla and caries

No treatment guidelines for treating dental caries in chinchillas have been established. It is still recommended that diseased tooth substance should be removed with burr to a level where healthy tooth is visible. Normal occlusal surface should be restored at the same treatment (Mans and Jekl 2016).

In rabbits, caries is usually found in elongated teeth, so the easiest treatment is to remove the affected part of the teeth at same time while correcting rest of the dentition and shortening the elongated teeth (Crossley 2003).

### 7.5.2 Periodontal disease

Local treatment for periodontal disease consists of the removal of all retained food and debris (Mans and Donnelly 2013). If periodontal infection or gingival pockets are present, Mans and Jekl (2016) prefers to flush them with 3% hydrogen peroxide. Hydrogen peroxide is used as a disinfectant and its typical foaming action leads to superior retention with minimal risk of aspiration. Hydrogen peroxide also has antimicrobial properties especially against anaerobic bacteria, which helps reduce periodontal infection and plaque formation (Mans and Donnelly 2013). One option mentioned by Mans and Jekl (2016) is to remove as much plaque as possible with mechanical scaler and then flush with diluted chlorhexidine (0,125%). When the oral cavity is flushed with diluted chlorhexidine, the oropharynx should be packed with gauze
(Mans and Jekl 2016). Sustained-release antibiotic in sufficiently deep gingival pockets, placed subgingivally, provides high antimicrobial drug concentration for prolonged periods. The most commonly used local antibiotic is doxycycline (Mans and Donnelly 2013). Crossley (2003) has used doxycycline periocutic gel to fill in any pockets left after treatment (and possible tooth extraction). The gel releases high effective levels of doxycycline locally over several days and the gel also provides physical protection from two to four weeks, allowing the tissues to heal (Crossley 2003).

7.5.3 Extraction of cheek teeth

Indications for the extraction of the cheek teeth vary. Extraction is required whenever the tooth is loose, if the tooth is fractured, if there is periapical infection and if there is marked deformity or malocclusion which cannot be easily corrected with burring (Lennox 2008, Cappello 2016b). In some cases, cheek teeth extraction is necessary to gain access to the alveolar bulla to treat empyema or a retrobulbar abscess. Cheek teeth have a primary role in crushing the food so retaining as many of them as possible is usually the goal of the treatment (Cappello 2016b).

Cheek teeth can be extracted intraorally, by an extraoral surgical approach, or with buccotomy. Intraoral non-surgical technique is less traumatic but requires great skill (Verstraete 2003). Cheek teeth extraction is difficult because of the limited access in the small oral cavity and the close proximity of the teeth. Iatrogenic damage to the bone plate may be possible because it is very thin and might already have developed lysis due to dental disease. The bone plate is overlying the alveoli and separates it from the nasal cavity, the orbit and the mandibular cortex (Verstraete and Osofsky 2005).

7.5.3.1 Intraoral surgical technique

Intraoral surgical technique is technically difficult and requires anaesthetic and nursing care support (Verstraete and Osofsky 2005). Extraction begins with loosening the tooth from every aspect (mesial, distal, buccal and lingual) with a luxator (i.e. Crossley luxator). Difficulty of extracting the cheek tooth depends on its condition and how loose the tooth already is. When the tooth is mobile it can be pulled out. Small extraction forceps with angled tips
(approximately 100°) are handy for extraction which can be difficult because of the small size, short clinical crown and long reserve crown of the cheek teeth. When cheek tooth is extracted the extraction of the opposing tooth might not be necessary because the opposing teeth growth can be controlled with regular coronal reductions. Exception is maxillary first and sixth cheek teeth because of the occlusal plane of every other cheek tooth matches two of the opposing teeth. The gingiva can be sutured if it is achievable. Generally gingival suture should be tried if the defect is large and if periapical infection is not present. Challenges for making sutures are small size of the patient and narrow opening of the oral cavity. The procedure requires good lighting, magnification and proper instruments. Good instruments for intraoral sutures are a small and long needle holder, fine-tipped scissors and suture material where the needle is appropriately curved (Cappello 2016b).

7.5.3.2 Combined intraoral and extraoral extraction

In these types of cases where reserve crown of the cheek teeth is fractured or when ankylosis of the reserve crown is present, intraoral extraction might not be possible (Cappello 2016b). In this type of cases Cappello (2016b) recommends a combined intraoral and extraoral approach. In this approach extraction of the clinical crown and part of the reserve crown can be done intraorally. Remaining reserve crown is removed extraorally (Cappello 2016b). In extraoral approach the skin is incised over the affected area and the bone is exposed. The periosteum is elevated, and a hole is drilled in the affected bone. The affected tooth and surrounding tissue are removed, and alveolar debridement is performed. Marsupialization is usually performed for the wound. If maxillary premolars or molars need to be extracted, the rostral part of the zygomatic arc need to be removed first (ostectomy) (Mans and Jekl 2016).

7.6 Submandibular abscessation

It is extremely unlikely that facial abscesses resolve by medical treatment alone (Cappello 2006a). Abscesses are usually large, deep and multi-lobed so aggressive treatment is usually indicated (Legendre 2016). Complete excision, including the capsule is usually the most efficient treatment (Cappello 2006a). The approach includes thorough debridement of the abscess and extraction of the affected teeth, when indicated (Verstraete and Osofsky 2005).
If the affected teeth are not removed, it is likely that soft tissue abscessation and osteomyelitis associated with periapical lesions or combined periodontal-endodontal lesions will not resolve (Verstraete and Osofsky 2005). Debridement of the infected or necrotic bone should be done when indicated (Cappello 2006a). In marsupialization of the soft tissues, sutures are placed between the wall of the capsule and the skin, creating a tract consisting of the capsule wall; this way the closed cavity becomes an open pouch. The abscess cavity can be packed with antibiotic impregnated polymethyl-methylacrylate beads (Verstraete and Osofsky 2005). In case of retrobulbar abscess, enucleation needs to be considered (Mans and Jekl 2016).

7.7 Medical treatment

7.7.1 General

Animals with dental disease and oral pain might have reduced water intake so fluid therapy is usually needed in the clinic and the owner must monitor hydration at home also. Recommended maintenance dose is 50-100 ml/kg/day. Nutrition after dental procedure must be monitored and the animal should be given timothy hay-based syringe feed if necessary (Verstraete and Osofsky 2005).

Animals with dental disease and having dental treatment should get opioids at the clinic (burprenorphine) and NSAID medication at home. One must be cautious with opioids, because pre µ-agonist may induce ileus (Verstraete and Osofsky 2005).

7.7.2 Systemic antibiotic therapy

Systemic antibiotic therapy should be considered with advance periodontal disease, to reduce the severity of periodontal infection and slow the progression of the disease (Mans and Donnelly 2013). Pathogenic bacteria in periodontal disease in rodents and lagomorphs are usually mixed populations of aerobic and anaerobic bacteria. Antimicrobial drugs should be chosen based on culture and sensitivity tests and efficacy for anaerobic bacteria. Antimicrobials should also reach high concentrations in bone when used to treat periodontal infection (Mans and Jekl 2016).
Perioperative and postoperative antibiotic treatment is indicated for patients that require extraction due to the traumatic nature of the procedure and pre-existing dental disease (Verstraete and Osofsky 2005). Antimicrobial protocols vary, depending on the author. The next sections compile some of the protocols used by different authors.

7.7.2.1 Medication for rabbits

Harcourt-Brown (2009b) proposes useful antibiotics for jaw abscesses and osteomyelitis in rabbits to be parenteral penicillin 40 mg/kg once daily, cefalexin 20 mg/kg once daily or amoxicillin 7 mg/kg once daily (Harcourt-Brown 2009b). Fisher and Graham (2018) proposes dosage for procaine penicillin to be 40 000 U/kg for intramuscular injection once daily or 42 000 – 84 000 IU/kg for subcutaneous injection once daily for 5-7 days. For cephalexin 15 mg/kg twice daily (Fisher and Graham 2018). These medications when given parenterally are unlikely to interfere with gut microflora (Harcourt-Brown 2009b). Parenteral oxytetracycline can be given 25 mg/kg once daily as subcutaneous injection (Harcourt-Brown 2009b, Fisher and Graham 2018). Safe oral medications are enrofloxacin 10 mg/kg twice daily, marbofloxacin 10 mg/kg once daily, trimethoprim/sulfadiazine 40 mg/kg twice daily and doxycycline 2-5 mg/kg twice daily (Harcourt-Brown 2009b). Other proposed dosage for marbofloxacin is 5 mg/kg once daily for ten days and for trimethoprim/sulfadiazine 30 mg/kg twice daily (Fisher and Graham 2018). Metronidazole can also be given 40 mg/kg twice daily for three days (Harcourt-Brown 2009b, Fisher and Graham 2018) or 20 mg/kg twice daily for three to five days (Fisher and Graham). Parenteral antibiotics are more effective than these oral antibiotics (Harcourt-Brown 2009b). It’s beneficial to notice that exudate and debris inactivate potentiated sulphonamides (Harcourt-Brown 2009b).

7.7.2.2 Medication for guinea pigs

The following doses are for oral administration. Souza et al. (2006) used for enrofloxacin 5 mg/kg q12h and metronidazole 30 mg/kg q12h for guinea pigs. Another dosage to be found for enrofloxacin is 10 mg/kg twice daily. Guinea pigs can get azithromycin 15-30 mg/kg once daily (Mayer and Mans 2018). Chloramphenicol 30-50 mg/kg two to three times a day,
trimethoprim/sulfadiazine 15-30 mg/kg twice daily and doxycycline 5 mg/kg twice daily (Morrissey and Carpenter 2012, Mayer and Mans 2018).

Oral antimicrobial treatment can cause enteritis and antibiotic-associated clostridial enterotoxemia. Guinea pigs are very susceptible for clostridial enterotoxemia with the following antibiotics: penicillins (including ampicillin and amoxicillin), cefazolin, clindamycin, erythromycin, lincomycin, dihydrostreptomycin, bacitracin, chlortetracycline, oxytetracycline, tetracycline and tylosin. Guinea pigs are also highly susceptible to the ototoxic effects of chloramphenicol and aminoglycosides, when doses are above the recommendations (Mayer and Mans 2018)

7.7.2.3 Medications for chinchillas

Mans and Jekl (2016) propose the use of penicillin G benthazine (long acting) procaine combination with a dosage of 50 000 U/kg every three to five days subcutaneously and report it as safe and effective in chinchillas. Penicillin G reaches high levels in bones and has great efficacy against anaerobic bacteria (Mans and Jekl 2016). Duration of the treatment depends on the severity of disease (Mans and Donnelly 2013). Other safe choices against anaerobic bacteria are chloramphenicol 30-50 mg/kg twice daily (can be ototoxic for chinchilla if given dosages above recommendations) and azithromycin 15-30 mg/kg once daily (Mans and Donnelly 2013, Mayer and Mans 2018). Some sources recommend metronidazole against anaerobic bacteria, but this may result in reduced food consumption in chinchillas due to objectionable taste (Mans and Donnelly 2013, Mayer and Mans 2018). Mans and Jekl (2016) use routinely in the practice a combination of doxycycline 5 mg/kg twice daily and metronidazole 30 mg/kg once daily orally for 10 to 14 days. Duration of the treatment varies depending of the severity of disease and individual response to the medication (Mans and Jekl 2016). Fluoroquinolones (e.g. enrofloxacin) or trimethoprim-sulfadiazine should not be used unless it is indicated by culture and sensitivity results, in combination with an antibiotic that is effective against anaerobic bacteria (Mans and Donnelly 2013). Chinchillas are also susceptible for antibiotic-associated clostridial enterotoxemia with the following oral antibiotics: penicillin, ampicillin, amoxicillin, bacitracin, cefalosporins, clindamycin, erythromycin and lincomycin (Mayer and Mans 2018).
7.8 Supportive treatment

Many pets are in need of supportive treatment before and after the dental treatment. Decreased appetite is often a sign of pain, so adequate analgesia is essential to help the pet recover from dental treatment (Wenger 2012, Mans and Jekl 2016). Nonsteroidal anti-inflammatory drugs (NSAID) commonly used in rabbits and rodents are meloxicam and carprofen (Wenger 2012).

Rabbit, guinea pig and chinchilla are hindgut fermenters. Fermentation serves as a significant source of volatile fatty acids. Inappropriate diet and/or anorexia allows dysbiosis which makes fermentation less efficient (DeCubellis 2016). This will result in a negative energy balance in which fat is broken down and used as an energy source instead. Free fatty acids from the fat are transported to the liver causing hepatic lipidosis, subsequent ketosis and eventually (if state is not corrected) liver failure (Harcourt-Brown 2011, Huynh et al. 2016). Dysbiosis can cause gastrointestinal stasis/ileus and increased gas production which can cause gastric dilatation (DeCubellis 2016). Hypomotility can cause dehydration of gastric and intestinal content and maldistribution of fluids (Huynh et al. 2016). If required, they should receive nutritional support, possibly in the form of a syringe-fed critical care formula for herbivores.

Sometimes parenteral fluid treatment is also needed (Mans and Jekl 2016). Rabbits require daily water intake of 10-12% of bodyweight (Huynh et al. 2016). For assessing that the nutritional support and hydration status are adequate, a non-invasive and inexpensive method is to monitor urine pH and ketones (Mans and Jekl 2016). Checking the weight regularly is also a good way to keep the owner better informed of the nutritional status of the animal.
8 DIET AND PREVENTION

8.1 General

Herbivorous diet has high crude fibre and low energy content which leads to high intake of the food and thorough chewing leading to proper wear of the elodont cheek teeth (Mans and Jekl 2016). In captivity they are often offered grain and pellets and possibly limited access to hay and natural vegetation. Pellets also alter the chewing pattern and reduce the chewing time. Pellets may also have more optimal nutritional content (potentially high calcium and vitamin D) versus what they eat in the wild, which allows the maximal mineralisation of the teeth increasing the resistance to wear (Crossley 2003, Reiter 2008). Guinea pigs and chinchillas originate from South American mountain area where the vegetation in nature is tougher, more fibrous, and rich in silicate phytolith. They must eat large quantities of this highly abrasive and low energy food to fill their energy requirements, thus increasing the tooth wear (Reiter 2008).

Meredith et al. (2015) conducted a study with rabbits where results supported the hypothesis that diet is a factor in the development of dental disease in pet rabbits. Studies have also shown that the rate of eruption matches the rate of attrition which indicates that there might be a physiological feedback mechanism. Although in response to reduced wear and attrition the tooth growth slows down within its physiological range but does not cease which leads to increase in tooth length (Meredith et al. 2015). Böhmer and Böhmer (2017) conducted a study in shape variation of the craniomandibular system and concluded that in some breeds the increased skull height after domestication increases stress for the dentition and therefore it is essential to feed a more natural nutrition for trying to sustain healthy dentition.

8.2 Rabbits with PSADD

Studies suggest that husbandry has a link for syndrome of acquired dental disease in pet rabbits. Rabbits that are kept outside with unlimited access to food and exercise seem to be less prone to development of PSADD. Rabbits that have advanced dental disease seem to have higher plasma parathyroid hormone levels and lower serum calcium levels, suggesting an underlying metabolic bone disease (Harcourt-Brown and Baker 2001). Diet should be modified
so that it includes sufficient calcium especially when the teeth are still growing to try to improve dental structure and enamel quality. Diet should be comprised of a fibrous diet of hay, grass, vegetables and a small amount of concentrated food. If PSADD is caught at an early stages and rabbit is nursed and treated sufficiently, the condition often improves at a later stage (Harcourt-Brown 2006).

With early diagnosis and treatment (coronal reduction etc) before severe changes in the teeth and with a proper nutrition and nursing the advancement of dental disease can be slowed or stopped (Harcourt-Brown 2006).

### 8.3 Chinchillas and caries

Although no treatment guidelines have been established for caries, you should avoid giving chinchillas sugary treats and try to offer fibre rich food. Sugary treats and reduced abraction due to low fibre diet may lead to bacterial plaque formation and reduced salivation, which is thought to predispose to caries (Mans and Donnelly 2013).

Client education is essential for prevention and reduction of the progression of dental disease. Owners should provide their pets hay diet, grass and fibrous vegetable to encourage increased chewing and appropriate attrition of the teeth. Returning to a normal diet may not be possible in severe cases, so in those cases a diet with soaked good quality pellets and syringe feeding might be necessary (Verstraete and Osofsky 2005).
Dental problems in pet rabbits, guinea pigs and chinchillas are very common. Although some of the dental problems may have a genetic origin, it is important to educate pet owners to feed their pets a proper diet. It is also important to keep an eye on the animal’s welfare and take them to the veterinarian for regular check-ups. Regular weight checks at home are an easy way to notice if anything is wrong, when the pet does not present any other signs or symptoms that the owner could notice.

A proper diet can help keep the animals healthy and prevent the development of dental problems. Regular veterinary check-ups allow the early detection of possible dental problems. Veterinarians should be educated and aware that a diligent health check for pet rabbits or rodents must include a thorough dental examination. If findings in intraoral examination raises questions about dental health, it may be advisable to anaesthetize the animal for a more detailed examination. A lot of the findings can be missed in a conscious animal, thus delaying the treatment.

For more accurate diagnosis, diagnostic imaging is practically mandatory. Radiographic imaging can reveal hidden problems, but most accurate prognosis can be given with computed tomography. In recent years the diagnostic imaging has become more available for small mammal diagnostic and to a wider range of clients.

Clippers should never be used in dental treatment for their risk of causing more trauma to the teeth. Proper instruments are cutting discs and burrs providing careful, gradual and precise shortening of the height of the clinical crowns and spikes. Care should be taken to avoid excessive heating of the teeth, by cooling them down with cold saline if necessary. Causing pulpal exposure should also be avoided. The aim of the treatment is to gain functional occlusion as close to normal as possible. In more advanced cases, extraction of one or more teeth may be necessary. Intraoral extraction of the cheek teeth requires good skills and technique. If done properly this is preferable as it is less traumatic than the extraoral approach. Incisor extractions are primarily done in rabbits, for they are more prone to incisor malocclusions than guinea pig and chinchillas.

Treatment of dental disease can be challenging and often requires dedication from the owner. Some of the dental problems are progressive, so careful consideration of the animal’s welfare
must be addressed. Ethical consideration should be done both in the beginning and during the treatment, avoiding unnecessary pain and suffering. Prognostic evaluation should include patient overall condition and health status, as well as owner’s commitment to the treatment. If the owner is not interested or is incapable of investing time and money for regular check-up and treatments which are often required, it might be more humane to euthanize the animal. If the prognosis is very poor or when aggressive treatments are foreseen, euthanasia may be advisable. Contemplating the prognosis and possible treatment outcomes with the owner can be a delicate situation. The owner must be properly informed of all the possible complications and the different outcomes of the treatment. The nature of the disease and what is required from them regarding the treatment at home, must also be properly informed. Therefore, it is very important to make an accurate diagnosis of dental problems and lead excellent communication with the owner.

Knowledge of dental disease has increased in the last ten years. Although much information is now available, many aspects can still benefit from more studies on etiology, diagnostics and treatment of the dental diseases in pet rabbits and rodents. For example, macrodontia in guinea pigs is surprisingly common finding, but there are no thorough studies in this subject. This is one of the subjects that would benefit from further studies for understanding the etiology and better treatment of the condition.

Owner education is very important for prevention of the dental disease in rabbits and rodents. It would be beneficial to do co-operation with pet stores and breeders, that they know how to inform the new owner of proper diet and species-specific needs. This could prevent problems with dental health from developing in many cases.
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