Nicolas GIRARD
DMV

Eric SERVET
MEng, Royal Canin Research Center in Aimargues, France

Nutrition and oral health in cats

ABBREVIATIONS USED IN THIS CHAPTER

C: canine
DR: dental resorption (type 1 or 2)
FORL: feline odontoclastic resorptive lesion
I: incisor
M: molar
PM: premolar
PRN: plaque reduction nutrient
TMJ: temporo-mandibular joint

Nutrition and oral health in cats

Nicolas GIRARD

DVM

Nicolas Girard graduated from the National Veterinary School of Alfort in 1987. After practicing general veterinary medicine for small animals for approximately twelve years. Nicolas is now a practicing veterinary dentist and ear, nose and throat specialist in the southwest of France.

Nicolas is in charge of the dentistry consultation at the National Veterinary School of Alfort. He is also responsible for the scientific committee of the Veterinarian Dentistry Study and Research Group Office (GEROS), a component of the French Association of Veterinarians for Companion Animals (AFVAC). Nicolas is also a member of the European Veterinary Dental Society (EVDS).

Eric SERVET

MEng, Royal Canin Research Center in Aimargues, France

Eric Servet graduated in engineering from ENITIAA in Nantes, specializing in dietary ingredients and technologies. In 1999-2001 he worked on the pilot development and formulation of commercial dairy products. He subsequently spent a year in the United States at Royal Canin USA, working in product stability and palatability. Since 2002 he has been a research engineer at the Royal Canin Research and Development Center in Aimargues, France. His main fields of feline and canine research are dental hygiene, joint cartilage nutrition, and obesity.

The teeth have an essential influence on the cat's general health. They have a role to play in many different functions, such as hunting, grasping and breaking food, self-defense and competition. There are few precise epidemiological studies describing the oral health of cats. Data on cats are mostly extrapolated from dogs, although the oral-dental pathology of cats in all their diversity has special particularities that veterinarians need to know.

Periodontal diseases are common in cats but are often underrated by veterinarians and treated superficially. Recent advancements in feline veterinarian dentistry have provided new tools for their evaluation and diagnosis, as well as more effective prevention tools. All this information must be at the center of the care agreement between the clinic and the owner and aimed at minimizing pain and associated infections.

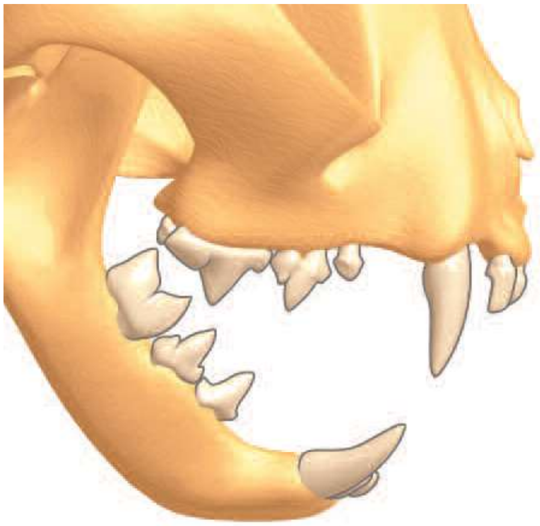
1 - Dietary behavior in cats

► Anatomical and pathological specificities

Cats are genuine carnivores and their dentition is the same as the major Felidae **(Figure 1)**. They have four types of teeth [incisors (I), canines (C), premolars (PM) and molars (M)] but unlike dogs and other carnivores, cats do not have any chewing teeth – upper molars **(Figures 1 and 2)**.

In the various sequences of dietary behavior, the role of teeth is to capture and dismember small prey, using groups of differentiated teeth.
- The shape of the incisors enables them to cut, hollow out and hack.
- The canines are profiled to pierce and grasp prey.
- The premolars serve to transport the food and to break it into small pieces.

FIGURE 1 - PROFILE VIEW OF THE DENTITION OF AN ADULT CAT



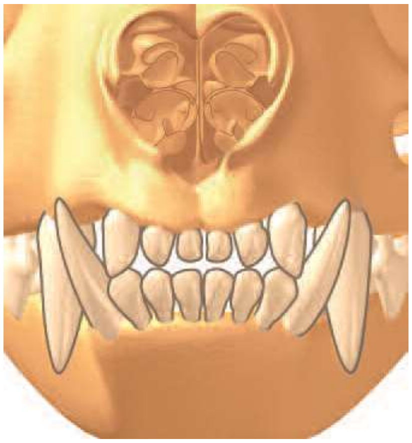
The four largest cutting teeth at the back of the upper and lower jaws are called carnassials (PM4 upper and M1 lower).

Dental formula of an adult cat (per quadrant):
I 3/3; C 1/1; PM 3/2; M 1/1
Collectively, there are 30 teeth in the oral cavity of the adult cat.

The oral cavity of cats can be opened wide to enable the canines to grasp the prey, while facilitating the powerful action of the carnassials. Once the prey has been broken up into pieces, it is swallowed *(Wiggs & Lobprise, 1997)*.

The movements of the jaws are limited sagittally (no transversal masticatory movement). This extreme specialization of the jaws and the temporomandibular joints in cats guarantees great efficiency with respect to the forces exercised when prey is grasped and broken down *(Orsini & Hennet, 1992)*. In domesticated cats, the canines apply around 23 kg of pressure, the carnassials around 28 kg *(Buckland, 1975)*. Joint integrity is maintained by powerful lateral ligaments covered by an effective jaw musculature. Typically, while the carnassials break the food up, the temporomandibular joints twist and rotate it, doubling the effect. The fibrous symphysis connecting the two branches of the mandible enables the distinct movements of the right and left jaw according to the needs and the side used by the cat *(Harvey & Emily, 1993)*.

FIGURE 2 - FRONT VIEW OF DENTAL OCCLUSION IN THE CAT



When the oral cavity is closed, the incisors of the lower jaw rest directly behind the incisors of the upper jaw, and the lower canine is between the upper canine and the third upper incisor.

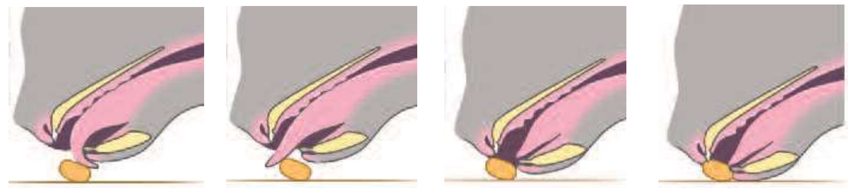
► Varied oral prehension techniques

In nature, the diet of a wild cat comprises mostly of small rodents, rabbits, birds and some lizards. After catching its prey, step-by-step the cat cuts and swallows it in small pieces.

While domestication has changed their behavior to a degree, domesticated cats still have the ability to return to their wild life, as they retain the hunting instinct, separate from the feeding function. Only 13% of tracked prey is actually caught *(Kays & DeWan, 2004)*. A study shows that, even properly fed housecats with outdoor access will continue to hunt and eat prey, although the proportion of such prey in the total ration is clearly lower than in that of cats that permanently live outdoors (66 g/day vs. 294 g/day) *(Liberg, 1984)*.

Figure 3 - Video analysis of the oral prehension method of Persian cats.
Analysis conducted in association with Royal Canin, École Nationale des Arts et Métiers d'Angers (ENSAM) and Ecole des Mines d'Alès (EMA).

FIGURE 4 - DIFFERENT ORAL PREHENSION METHODS OBSERVED IN CATS



Supra-lingual mode
First point of contact with the kibble is the upper side of the tongue.

Sub-lingual mode
First point of contact with the kibble is the lower side of the tongue.

Labial mode
First point of contact with the kibble is the lips.

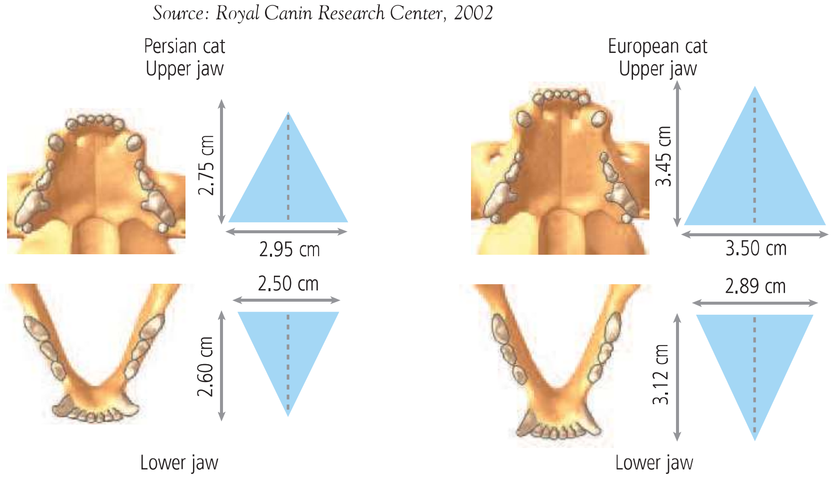
"Shovel" mode
First point of contact with the kibble is the incisors.

The palatability of commercial food has been studied in detail to continually improve product quality. Dry kibbles in various shapes, sizes, textures and densities are given to cats to evaluate their reaction. Analyzing videos of the feeding behavior of different breeds of domesticated cats **(Figure 3)** has enabled the characterization of how cats grasp their food in general, while also identifying several kibble prehension methods **(Figure 4)**:
- *supra-lingual mode*: using the upper side of the tongue
- *labial mode*: using the lips and jaws
- *"shovel" mode:* using the incisors
- *sub-lingual mode*: using the lower side of the tongue

The kibble prehension method varies with the breed. A certain degree of adaptability in terms of prehension and mastication behavior is observed depending on the kibble shape and size *(unpublished internal Royal Canin studies, 2002)*.

Observing brachycephalic breeds (e.g. Persians), it is clear that they have difficulty grasping standard-sized, round kibbles, particularly with the incisors. Persians use the tongue to trap a standard kibble in 80% of cases (60% lower tongue **(Figure 5)** and 20% upper tongue). They use their lips just 20% of time, while the "shovel" method is not observed.

FIGURE 5 - COMPARATIVE JAW CONFORMATION BETWEEN A BRACHYCEPHALIC CAT (PERSIAN) AND A MESOCEPHALIC CAT
Source: Royal Canin Research Center, 2002



Impressions show the teeth of a Persian are implanted closer together in the jaw. A particular prehension method is observed in this breed (sub-lingual mode).

- Dolichocephalic cats (e.g. Siamese) like to use their incisors **(Figure 6)**. The "shovel" method is observed in 30% of cases, which is more efficient when the kibble bowl is full. Prehension tends to progress towards the upper tongue method as the bowl empties (to ensure the tongue grasps the kibble). Siamese cats use the upper tongue method in 70% of cases.

- Mesocephalic cats (e.g. Maine Coon) make almost equal use of upper tongue and lips at the start of the meal (in 57% and 42% of cases respectively) **(Figure 7)**. The upper tongue method may become more prevalent during the course of the meal or if the kibbles are smaller (83% tongue vs. 17% lips).

The influence of anatomical particularities related to breed also affects others aspects of feeding behavior. After grasping a standard kibble, Persians chew in only around 10% of cases, whereas the chewing percentage is 90% among Maine Coons and Siamese cats (*unpublished internal Royal Canin studies, 2002*).

Hence, prehension methods differ significantly from one breed to the other, and especially from one maxillofacial biometric to another.

Source: Centre de Recherche Royal Canin, 2002

Figure 6 - Traditional food prehension method used by the Siamese cat.
The sequential analysis of 4800 prehension sessions shows that the Siamese uses its incisors in 30% of cases. The jaws open at a very wide angle.

► Feeding rhythm in domesticated cats

Domesticated cats habitually divide up much of their daily food. When different types of dry food are offered, the frequency and average duration of meals varies according to the breed and the food (*internal Royal Canin studies, 2006*).

On average, a cat fed ad libitum will feed a dozen or so times a day. Each session lasts about two minutes, with the cat consuming around 6 g of food. In one 24-hour period, the cat therefore devotes an average of 20 minutes to eating and digesting 50-60 g of kibbles **(Table 1)**. Nocturnal consumption accounts for 30% of all food ingested. At night, meals are generally larger and take longer. A strong correlation between breed and feeding rhythm **(Figure 8)** and the quantities ingested at each meal has been shown.

The influence of maxillofacial biometric variations on the feeding method of the domesticated cat is accordingly self-evident. The significant differences observed between facial morphologies provide more proof of different prehension methods, feeding rhythms and quantities of food ingested. The low adaptability of jaw movements (see above) requires them to adapt the natural sequences of prehension and ingestion to suit the food.

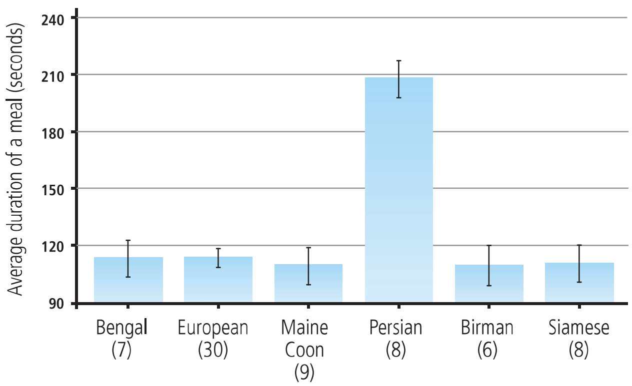
Source: Centre de Recherche Royal Canin, 2002

Figure 7 - Traditional food prehension method used by the Maine Coon cat
The sequential analysis of 7200 prehension sessions shows that the Maine Coon uses the lower tongue and labial method almost equally.

TABLE 1 – FOOD CONSUMPTION INDEXES IN CATS FED DRY FOOD AD LIBITUM
(Data from 16 cats fed ad libitum one of four foods consecutively – internal Royal Canin studies, 2006)

	Food 1	Food 2	Food 3	Food 4	Average
Number of meals/24 h	9.5	8.4	10.0	10.1	**9.5**
Size of meal (g)	6.7	6.7	5.6	5.3	**6.1**
Total consumption/24 h (g)	57.1	53.1	53.7	52.8	**54.2**
Average duration of meal (min' sec")	1'48"	2'16"	2'16"	2'09"	**2'07"**
Total consumption time/24 h (min' sec")	16'39"	18'35"	22'28"	21'46"	**19'53"**
Speed of consumption (g/min)	4.1	3.3	2.9	2.7	**3.2**

FIGURE 8 - INFLUENCE OF BREED ON THE AVERAGE DURATION OF MEALS IN CATS FED WITH A DRY FOOD



When cats are fed a standard dry food they feed around a dozen times in a 24-hour period. The average duration of each meal is 2 minutes ('), all breeds included. This average is however twice as long among Persians: 3'27", compared with 1'49" among all other breeds (unpublished Royal Canin data, 2005).

Domesticated cats have however retained the principle features of their wild feeding behavior. This feeding behavior continues to be studied frequently to evaluate the impact of commercial food on the oral health of cats as precisely as possible.

2 - Common oral diseases

► Prevalence of feline oral diseases in wild and domesticated populations

Whether wild or domesticated, a cat's diet is dictated by its environment. In this respect, commercial food preparation is often considered to be an aggravating factor in the event of oral diseases. The analysis of the oral diseases of a population of wild cats provides an opportunity to study the potential link between a well-defined diet and the various diseases identified.

Four cats were introduced on Marion Island in the Indian Ocean in 1949 and the cat population grew rapidly. The diet of these cats is mostly seabirds (96%) associated with the ingestion of some pebbles. The postmortem analysis of a collection of 300 skulls from this cat population enabled the study of oral health. Despite the average age of the group being estimated at 2-3 years, the prevalence of periodontal disease in a moderate to severe form, was 48%. Taking account of missing teeth (probably due to periodontal disease), periodontal disease was prevalent in 61.8% of cats and 14.8% of the teeth observed. The prevalence of dental trauma and feline odontoclastic resorptive lesions (FORLs) was also high, statistically associated with the prevalence of periodontal disease. On the other hand, only 9% of cats in this study presented calculus, and then typically on the upper carnassials.

The highly specific diet of this wild cat population undoubtedly explains the high frequency of periodontal lesions and the low prevalence of dental calculus observed in such a young colony. When the cat tears apart the carcasses of seabirds, the sharp bone sections are probably responsible for gum trauma, which is assumed to favor the development of more severe periodontal inflammation *(Verstraete et al, 1996)*.

In an Australian study, the analysis of oral diseases based on clinical and radiographic criteria in 29 wild cats and 20 domesticated cats *(Clarke & Cameron, 1998)* established that the prevalence of periodontal disease was not significantly different in cats fed with commercial foods and cats whose diet was mainly made up of small prey. A hunting-based diet does not provide natural protection from oral diseases for wild cats.

Veterinarian examination of 15,226 domesticated cats *(Lund et al, 1998)* showed that oral diseases are the most common of all diseases observed. Calculus is present in 24% of cats and 13% of them suffer from some form of gingivitis.

A more detailed analysis conducted by veterinarians specialized in dentistry confirms a strong prevalence of oral diseases. 73% of a population of 753 cats studied presented gingivitis; 67% presented dental calculus; 28% of them had missing teeth; 25% FORLs; 19% severe periodontitis; 12% stomatitis and 11% tooth fractures *(Verhaerte & Van Wetter, 2004)*.

Periodontal disease is found in 32% of individuals presented to veterinarians specialized in dentistry. Out of a population of 152 cats, gingivitis and missing teeth were observed in 59% of cases, FORLs in 57% of cases, teeth fractures in 23% of cases and stomatitis in 2.6% of cases. The prevalence of dental calculus was estimated at 90% *(Crossley, 1991)*.

The postmortem analysis of 81 cats whose death was unrelated to an established oral disease, based on pathological and clinical examination, reported a high prevalence of periodontal disease. 52% of cats older than 4 years of age presented a form of periodontal inflammation. More than 40% of animals aged over 9 years presented a severe form of the disease. Less than 3% of animals aged over 15 years presented any form of lesion due to periodontal disease *(Gengler et al, 1995)*.

To summarize the studies above, the high prevalence of periodontal disease in cats cannot be ignored. There are no major differences between wild and domesticated populations and no apparent influence of commercial food. The presence of oral diseases is therefore not something that characterizes domesticated cats alone and is not necessarily associated with the feeding of commercial foods.

This information is unfortunately always underestimated. It does however shed light on the fact that the high prevalence of oral inflammation in cats is the most common cause of infectious disease in the species. The clinical impact turns out to be much greater than it appeared at first sight. It is especially clear in groups of wildcats whose health is generally related to interspecies competition and conditions the very survival of individuals. In the case of domesticated cats, the pain caused by oral disease is typically underestimated. Once they have been treated, these cats do show major behavioral modifications. Some owners describe this return to health as a “rebirth”.

► Periodontal disease

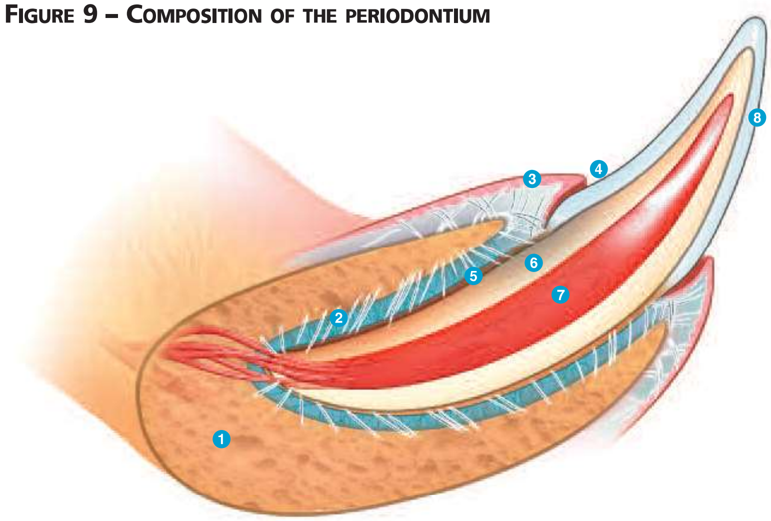
Periodontal disease is the most common disease in cats. It is an inflammatory oral disease associated with the development of dental plaque. Periodontal disease is not a disease as such as much as a collection of periodontal inflammations with varied clinical characteristics chronic or aggressive, local or generalized. All stages are possible: from early-stage periodontal disease to moderate or severe forms. The way periodontal disease develops depends on the mechanical constraints that oppose the development of dental plaque, but also the local immune response of each individual.

The incidence of periodontal disease on the general health of cats is widely underestimated. It is the source of chronic pain that owners are often unaware of and chronic bacterial diseases whose effects on the kidneys, lungs and heart are just starting to be better understood. Periodontal disease is the most common disease reported in cats, with a prevalence estimated at 30-70% of individuals according to studies and the evaluation criteria.

In wild cat populations, oral inflammation could threaten the health and even the survival of individuals.

FIGURE 9 – COMPOSITION OF THE PERIODONTIUM

1. Jaw bone
2. Periodontal ligament
3. Gum
4. Sulcus
5. Cement (covers the root)
6. Dentine
7. Pulp
8. Enamel (covers the crown)



> Description and function of the periodontium

The periodontium is the tissue that supports the teeth in the oral cavity. It connects the teeth, the bone structure of the jaws and the oral mucosa. Its development is associated with the eruption of the tooth and it disappears with its exfoliation. The periodontal tissue guarantees the integrity of dental structures and effectively protects the underlying anatomical structures from aggressions in the oral environment.

The periodontium is composed of the gum, the periodontal ligament, cement and the alveolar bone **(Figure 9)**.

The alveolar bone is a differentiated part of the jawbone. It is responsible for positioning the roots of the teeth in depressions known as dental alveoli.
The periodontal ligament is composed of collagen fibers, which connects the surface of the tooth root (cement) to the alveolar bone. Like a hydraulic shock absorber the periodontal ligament absorbs the pressures placed on the alveolar bone during prehension and the tearing of food. These specialized fibers improve the resistance to pressure of underlying bone tissue and generate a pain signal when the limit of its mechanical resistance is reached.
The cement covers the root of the tooth. It has a similar structure to bone, but without lacunas and channels.
The gum covers the underlying alveolar bone and tightly hugs the base of the crown of the tooth. The gum is composed of a squamous, keratinized epithelium, which is different from the loose, vascularized and non-keratinized alveolar mucosa. It is made up of two parts.

- *The free gum* is located at the level of the crown. It defines a space against the crown known as the gingival crevice, whose physiological depth is less than 0.5 mm in cats. The weak point of the tooth/gum junction is always the gingival crevice. The delimited space is fairly closed and is predisposed to accumulating dental plaque and various food debris. As its histological nature makes it more sensitive to the inflammatory process, the gingival crevice forms a gateway for periodontal disease. As a consequence, all attention must be focused on periodontal disease treatment and prevention programs.

- *The gum attached* to the tooth and the alveolar bone is an essential barrier against bacterial aggression. The seam of the gum is stuck against the bulge of the base of the crown and enhances this protective action.

Healthy gum.

Some 100 billion bacteria are discharged in the saliva every day. The oral cavity is therefore never sterile. There is always a minimal residual inflammation of the mucosa and the oral epithelium. A "healthy" periodontium is therefore defined clinically. The criteria for evaluating a healthy periodontium in cats are the absence of visual evidence of inflammation and the depth of the gingival crevice less than 0.5 mm.

© N. Girard

Figure 10 - Supragingival dental plaque on healthy teeth and gums. *The phenomena of bacterial coaggregation and coadhesion facilitate the installation of 90% of the biomass of the dental plaque within 24 hours (the dental plaque is revealed using eosin-type vital staining).*

> Pathogenesis of periodontal disease

The development of dental plaque in contact with all the surfaces of the tooth is a natural process resulting from the interaction between tooth and saliva. The anatomical sites predisposed to the deposition of dental plaque are the limit of the crown and the seams of the gum as well as the contacts between the teeth.

The adhesion and proliferation of bacteria on the surface of the enamel is not possible as such. The gradual colonization of the tooth surfaces by the bacteria is a succession of steps that steadily facilitate the adhesion and multiplication of bacteria:
- physical adhesion of an organic film to the surface of the teeth.
- secondary colonization by specific or pioneer bacteria.
- bacterial proliferation from the colonized organic film.

The adhesion of pioneer bacteria to the tooth surface is possible only after the development of an organic film (acquired pellicle) essentially formed from salivary components (glycoprotein, polypeptides, carbohydrate). Within a few hours of its development, specific bacteria *(Streptococcus sanguis, Actynomyces viscosus)* arrive to colonize the acquired pellicle, gradually saturating the entire surface (>6 million/sq. mm) and forming a biofilm, **dental plaque (Figure 10)**. New bacterial appositions, which stimulate the phenomena of coaggregation and coadhesion, establish 90% of the dental plaque's biomass within 24 hours.

Initially, dental plaque is essentially composed of aerobic Gram+ bacteria but this population develops rapidly. With the increase in the bacterial population comes the fall in oxygen in the air, from 12-14% in the mouth to 1-2% at the base of the gingival crevice. These new environmental conditions, which are associated with various sources of nutrients (diet, bacterial degradation, epithelial degradation), lead to the development of an anaerobic bacterial flora.

As the inflammatory process advances, so the proportion of Gram– bacteria *(Porphyromonas sp, Prevotella sp, Peptostreptococcus sp)*, *Fusobacterium* and spirillians increases. The pathogenic role of these aggressive bacteria is much more pronounced and is exercised through various enzymes, toxins and degradation products *(Haake et al, 2002)*.

To summarize, the dental plaque is a biofilm that forms on the tooth surface. It is composed of a community of bacterial species embedded inside an extracellular matrix of polymers produced by the hosts and the bacteria themselves *(Marsh, 2004)*. Modification of its composition is closely associated with the development of periodontal inflammation. Its interrelation with the cat's immune defense mechanisms conditions to some extent the scale of the periodontal inflammation.

Calculus is only a mineralized, fossilized form of dental plaque, consequential to the catalytic activity of some bacteria. It is deposited both above and under the gum **(Figure 11)**. While calculus does not contain any pathogenic bacteria, its porous character favors the new accumulation of dental plaque. So while it does not cause the inflammation of the periodontium it is an aggravating factor.

© N. Girard

Figure 11 - Deposit of dental calculus in the cat. *Accumulation of calculus on 100% of the upper PM4 associated with gum recession and exposure of the furcation.*

© N. Girard

Figure 12 - Generalized gingivitis.
Pronounced gum edema from the canine to the carnassial; spontaneous bleeding around PM3.

The accumulation of dental plaque in the gingival crevice leads to inflammation of the gum seams **(Figure 12)**. At this point, professional care together with the removal of the dental plaque will ensure full remission of the lesions. Without treatment, the dental plaque continues to accumulate and inflammation advances. The environmental conditions in the oral cavity become more favorable to an anaerobic bacterial population containing more and more Gram negative bacteria. **Gingivitis**, the reversible inflammatory stage, may stabilize or develop into periodontitis.

The advancement of the inflammatory process inexorably leads to the collapse of the connecting tissues on the surface of the tooth. Dental plaque then colonizes the tooth root further down. The epithelium of the junction, which constitutes the lower limit of the gingival crevice, migrates to an apical region to heal in the "non-inflammatory" zone, creating a periodontal pocket. **Periodontitis (Figure 13)** is the irreversible stage of periodontal disease. The lesions are final and the main objective of treatment is to halt their advancement. The main cause of the development of periodontal disease is the disruption of the balance between the pathogenic bacterial flora of the dental plaque and the host's immune response.

> Description of periodontal disease in cats

First and foremost, it should be noted that few publications deal with periodontal disease in cats, contrary to a large quantity of publications on the disease in dogs. We would also observe that the expression of periodontal disease in cats is generally described on the model of the dog or human, without taking account of any feline particularities.

- A clinical radiographic and histological study has helped outline the development of periodontal disease in 15 cats *(Reichart et al, 1984)*. A loss of attachment appeared in 25% of premolars and molars, essentially localized to the buccal surface. A pronounced to severe gingivitis was shown in 56% of premolars and molars (buccal surface) and 25% of canines and incisors (buccal surface). After radiographic analysis, alveolar bone loss appeared to be significant in 77% of premolars and molars. Bone loss was also observed on the buccal surface of 82% and on the oral surface of 75% of incisors and canines. The general distribution of observed lesions in cats (gingivitis, alveolar bone loss, inflammatory FORL) was more pronounced in the premolars and molars.

Bearing in mind the high percentage of bone loss shown in the canines and incisors, however, together with the high percentage of missing incisors, it would appear that these teeth are highly susceptible to periodontal disease *(Reichart et al, 1984)*.

A form of periodontitis was shown using dental radiography in 69% of cats presented to the specialist veterinary dentistry department of the University of California, Davis. The results of this

FIGURE 13 - SEVERE LOCAL PERIODONTITIS OF THE UPPER LEFT PM4

© N. Girard

13A - Severe gingivitis on the mesial and vestibular surface.

© N. Girard

13B - Severe gum recession on the mesial and palatine surface.

© N. Girard

13C - Severe horizontal alveolysis.

FIGURE 14 - GENERALIZED HORIZONTAL BONE LOSS DURING PERIODONTAL DISEASE IN THE CAT WITH RESPECT TO THE RIGHT LOWER CARNASSIAL

© N. Girard

Severe periodontitis.

© N. Girard

Generalized severe horizontal bone loss.

study confirm that generalized horizontal bone loss **(Figure 14)** is the most common form of bone loss in cats (38%). In total, the height of the alveolar bone was normal in just 28% of cases *(Lommer & Verstraete, 2001)*.

© N. Girard

Figure 15 - Severe gum recession around a canine tooth in the cat.
Pronounced gum recession and alveolar bone loss around the upper and lower canines.

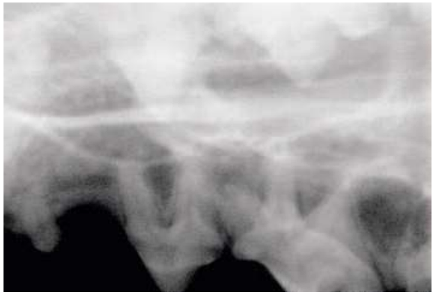
A clinical and radiographic study based on the oral examination of 109 healthy cats fed with dry food confirms these results. The presence of moderate to severe gingivitis associated with the presence of bleeding during periodontal probing was 13%. The average loss of periodontal attachment observed was 0.49 mm (c=1.28) with higher average values in the canines: 1.2 mm in the upper canine and 0.8 mm in the lower canine. Loss of attachment greater or equal to 2 mm was observed in 3.4% of examinations of the vestibular surface, 3% of the distal surface, 2.3% of the mesial surface and 2.2% of the lingual part. Gum recession **(Figure 15)** was observed in 10% of teeth. Absent teeth were most often upper premolars and incisors (21.1% and 11.4% respectively). Furcation **(Figure 16)** was observed in 18% of multi-root teeth and on average in two teeth of every cat examined. The radiographical analysis revealed a high prevalence of bone loss with respect to the dental arches: 21% of upper teeth and 42% of lower teeth. Horizontal and/or vertical bone loss was revealed in 52% and 14% of lower teeth respectively. The simplified analysis of premolars and molars underlines the importance of the inflammatory process: bone loss was observed in 66.5% of teeth *(Girard et al, 2008)*.

Periodontal disease in cats is characterized by a low proportion of periodontal pockets **(Figure 17)**, the strong prevalence of osteolysis in its horizontal form, a high proportion of gum recession and the early appearance of furcation.

FIGURE 16 - FURCATION AROUND THE UPPER PM3 IN THE CAT

© N. Girard

Profuse bleeding following periodontal probing of the furcation.



© N. Girard

Vertical bone loss.

Figure 17 - Periodontal pocket in the cat

Pronounced recession and severe gingivitis. *Insertion of the periodontal probe.* *Evaluation of the depth of the periodontal pocket: 13 mm.* *Severe horizontal alveolar bone loss.*

> Predisposing factors

Many factors have an influence on the development of periodontal disease:
- excessive accumulation of dental plaque in the junction between the tooth and gum (absence of oral hygiene, low fiber diet)
- inflammation promoted by a probable insufficiency of the local immune system or in the presence of systemic diseases such as diabetes mellitus, thyroid, liver or kidney insufficiency
- a familial and/or genetic effect is often evoked but never proven
- facial conformation, malocclusion, occlusion trauma.

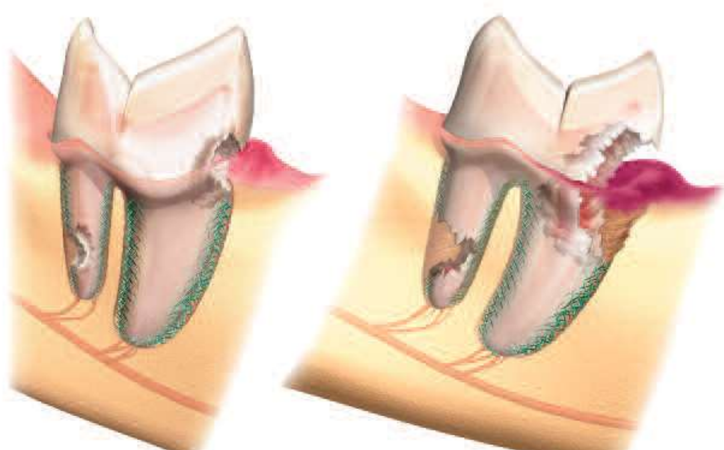
► Tooth resorptions

> Definition

Tooth resorptions are lesions by which the gradual loss of tooth substance is observed **(Figure 18)**. In cats, they are commonly known as feline odontoclastic resorptive lesions (FORLs), as the process of tooth resorption is controlled by multinuclear odontoclastic cells (odontoclasts) *(Gautier et al, 2001)*. These lesions affect the interior and/or exterior of the tooth and their clinical diagnosis is often delicate. Tooth resorptions are also observed in humans and dogs. They are generally due to periodontal inflammation or mechanical constraints with respect to the periodontal ligament (orthodontic treatment, tooth trauma).

Figure 18 - Feline odontoclastic resorptive lesion

Feline odontoclastic resorptive lesions are initiated in the radicular cement and then develop through the dentine and/or the crown. The alveolar bone and the adjacent periodontal ligament are also included locally in the tooth resorption process. The tooth canal is only affected at the end of the process, signaling an internal tooth resorptive lesion.



> Prevalence

A high prevalence of FORL has been shown in various cat populations and especially in domestic cats. According to the populations studied and/or the methodology used, the results were between 28% and 67% *(Coles, 1990; Van Messum et al, 1992)*. Such a variation is connected with the choice of population studied (specialist dental department, general dental department, healthy population) or the diagnostic methods used (clinical examination +/- radiological examination). Two studies of healthy cat populations reporting both a clinical and radiological examination revealed an average prevalence of 30% *(Ingham et al, 2002a; Girard et al, 2008)*.

> Pathogenesis

FORLs in cats are mostly external tooth lesions. The resorbed tooth tissue is gradually replaced by newly formed cement or bone tissue. FORLs are initiated in the radicular cement and then develop through the dentine and/or the crown. The alveolar bone and the adjacent periodontal ligament are also included locally in the tooth resorption process.

The tooth canal is only affected at the end of the process, signaling an internal tooth resorptive lesion. Inflammation of the tooth pulp is rare except at the end, when a degenerative state is described. The enamel of the crown may resorb itself in time, but more commonly it fractures due to the absence of underlying support, leading to the clinical appearance of a tooth cavity *(Okuda & Harvey, 1992)*.

FORLs mainly appear in the buccal part of the crown. Sixty-nine percent of the FORLs revealed are associated with an inflammatory phenomenon and 30% display signs of repair (*Reichart et al, 1984*).

> Etiologies of FORLs

External FORLs may have one or more origins. In human dentistry, the disease may be associated with:
- a chronic inflammatory process adjacent to a cyst, benign or malignant tumor,
or
- be the consequence of dental trauma (mechanical/occlusal) or orthodontic tooth displacement.
Lesions are qualified differently depending on whether an inflammatory process is present. Surface FORLs, dentoalveolar ankylosis and replacement lesions are considered to be the consequence of tooth traumas and qualified as non-inflammatory. On the other hand, apical FORLs and periradicular periodontitis are the consequence of lesions of the tooth pulp and are qualified as inflammatory lesions (radicular inflammatory tooth resorptions).

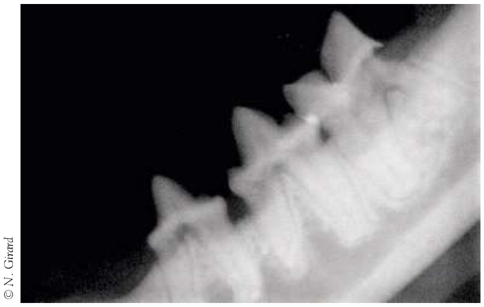
FORLs of the neck of the tooth are often confused with radicular inflammatory tooth resorptions. They are considered to be inflammatory because they are associated with inflammatory damage to the epithelial attachment (in the event of periodontal disease for example) *(Andreasen, 1985; Trope et al, 2002)*.

The precise etiology of FORLs remains unknown and is still the subject of discussion and research. The suspected role of masticatory mechanical constraints and chronic inflammation due to periodontal disease is underlined in various histological *(Gorrel & Larsson, 2002; Roux et al, 2002)* and radiographic *(DuPont & DeBowes, 2002)* studies as well as one clinical study *(Girard et al, 2008)*. Excessive vitamin D intake through the diet *(Reiter et al, 2005)* is proposed as a cofactor, although this continues to be debated. The precise role of specific histological dental structures in cats (vasodentine, osteodentine) has not been fully explained. Any interactions in the calcium regulation process associated with resorptions have been proposed *(Okuda & Harvey, 1992)*.

Figure 19 - type 1 FORL of the lower M1

© N. Girard

Severe gingivitis in the distal part.



© N. Girard

Inter-oral radiography: type 1 FORL.

Current veterinary recommendations propose the differentiation of FORLs based on the results of the radiographic evaluation:

- **type 1 FORL:** observation of a physiological periodontal ligament space (*lamina dura*) and radio density of the affected root similar to that of healthy adjacent roots **(Figure 19)**

- **type 2 FORL:** disappearance of the lamina dura in the radiographic examination and radio density of the affected root similar to that of the adjacent alveolar bone (bone remodeling) **(Figure 20)**.

The combined study of the location of FORLs depending on their radiographic type shows significant differences (*Girard et al, 2008*). Among house cats, the greater prevalence of type 1 lesions is observed in the lower carnassial and type 2 lesions in PM3. Among purebred cats a significant difference is observed for incisors (Type 2 FORL) and the lower carnassial (Type 1 FORL). The distribution of FORLs in the mouth is not uniform according to the type of lesion observed radiographically. This information corroborates the hypothesis that different etiologies cause feline resorptive lesions.

The analysis of FORLs in a population of cats treated at the dentistry department of the University of California, Davis, reveal a significant association between FORL and the presence of severe localized vertical alveolar bone loss (*Lommer & Verstraete, 2001*).

Figure 20 - Type 2 FORL of the lower left PM3

© N. Girard

Early gingivitis.

© N. Girard

Type 2 FORL.

The high prevalence of FORLs in the wild cat population on Marion Island (see above) fed almost exclusively with seabirds reduces the role some authors feel commercial food plays in the appearance of these tooth lesions. The author rather sees a consequence of feline oral inflammatory pathologies like periodontal disease and feline stomatitis *(Verstraete et al, 1996)*.

An in-depth statistical analysis of the distribution of FORLs and 14 clinical and radiographic criteria associated with periodontal disease underlines a strong association *(Girard et al, 2008)*. The global prevalence of FORLs may be significantly correlated to 6 of these periodontal parameters as well as age. Type 1 and 2 resorptions appear as two different phenomena without any association criteria. Type 1 FORL is significantly associated with 8 of the periodontal variables and so is strongly associated with periodontal disease. Type 2 FORL is correlated with just 2 periodontal parameters so the correlation to periodontal disease is low.

Age appears to be a factor strongly associated with the presence of type 2 FORL and weakly associated with type 1 FORL. All of these observations suggest that type 1 FORL is less sensitive to age with regard to its supposed link to the development of periodontal disease.

► Stomatitis

The term feline stomatitis covers all the oral diseases characterized by a pronounced inflammation of the oral mucosa **(Figure 21)**. Their prevalence appears to be low, although few statistical studies have been published on the subject (2.6% according to *Crossley, 1991*; 12% according to *Verhaert & Van Wetter, 2004*). Studies of large human populations show a prevalence of 5-15% of aggressive forms of periodontal inflammation, supposedly associated with ethnic predisposition *(Wolf et al, 2005)*.

The analysis of tooth diseases in a population of 109 cats reveals 5.5% cases of stomatitis (3.7% buccal stomatitis, 1.8% caudal stomatitis) and 12.8% aggressive periodontitis *(Girard et al, 2008)*. All these aggressive inflammatory diseases affected purebred cats, none of them housecats. The real impact of breed is still undergoing evaluation with respect to the probable familial effect.

The different types of stomatitis are known and dreaded, because they are generally a real therapeutic challenge. They are so painful that they disrupt the appetite and even the very survival of affected animals. The veterinarians' feeling of helplessness is amplified by the many uncertainties related to the etiology of these diseases.

The clinical management of feline stomatitis demands great diagnostic and therapeutic rigor. Recent studies confirm the role of the Calicivirus in the development of caudal stomatitis *(Addie et al, 2003)*. The most descriptive clinical examination is needed to advance the etiological analysis of feline stomatitis. Few published studies use an appropriate terminology to correctly evaluate a given type of medication, complementary examination or viral etiology. More precise information on the therapeutic benefits of selected substances, the role of selected viruses (FCV, HV1, FIV, FeLV) and the best histopathological (especially immunohistological) knowledge in this disease is expected to be found in the years to come.

Figure 21 - Stomatitis lesions in a cat*. Jugal buccal stomatitis.*

Figure 22 - Illustration of the efficacy of tooth brushing in a cat.

© N. Girard

© N. Girard

A case of aggressive ulceroproliferative periodontitis in an eight-month-old Sphinx cat (photograph and radiograph).

© N. Girard

© N. Girard

Post-surgery re-examination after 18 months during which time professional care was administered under general anesthetic three times a year and tooth brushing twice a day.

► Conclusion

Feline oral diseases are varied and in the majority of cases they include an inflammatory component. While the prevalence of periodontal disease is not really different from its occurrence in other species, the cat does suffer from relatively aggressive forms: inflammatory extension with respect to the oral mucosa (stomatitis) and FORLs that may render the clinical diagnosis more delicate when associated with chronic periodontitis. The local immune system is often perceived as one of the key factors of aggressive oral inflammation.

3 - Prevention of oral diseases

The conventional treatment of inflammation of the periodontium has three stages:
- initial therapy: explain the appropriate hygiene measures
- control the risk factors: diabetes mellitus, thyroid disease, FeLV, FIV.
- eliminate plaque and calculus by scaling and surfacing the roots and/or subgingival debridement under the gum

The success of treatment is then based on the maintenance phase. It is necessary to help the owner maintain optimal oral hygiene in the cat and to check the results every 6 months *(Houle & Grenier, 2003)*.

► General consequences of oral diseases

Responding to periodontal inflammation appears to be one of the main goals in terms of the cat's long-term general health. Pain and infection are always connected with the development of inflammatory diseases of the oral cavity in cats. In dogs, prospective studies on the systemic consequences of periodontal disease have revealed a significant connection between the development of the disease and the scale of inflammatory histological lesions in the kidneys, liver and the mitral and tricuspid heart *(DeBowes et al, 1996; Pavlica & Petelin, 2003)*. These studies suggest blood dissemination of inflammatory substances produced as a result of periodontal disease (cytokines, IL-1, IL-6, IL-8, TNFα) *(Pavlica, 2002)*. The remote action of pathogenic periodontal bacteria through a chronic bacteremia is strongly suggested but as yet unproven *(Tou et al, 2005; Boutoille & Gauthier, 2006)*.

In cats, there is a lack of results to specify the general impact of periodontal disease, although the pathogenesis is "relatively" similar in dogs and cats. The low life expectancy of wild cats on Marion Island (4-5 years) does however suggest the negative effect of the development of this disease. It may prevent the individual from being competitive in its group and so reduce its chances of survival *(Verstraete et al, 1996)*.

► Controlling dental plaque

The main challenge in combating periodontal inflammation is disorganizing the biofilm that makes up the dental plaque *(Barbieri, 2000)*. Dental plaque forms within hours and matures after 48 hours *(Perry & Schmidt, 2004)*. Efficient daily action is therefore essential.

Pathogenic bacteria develop in a bacterial community and are embedded in a glycoprotein mesh organized around the channels and lacunas, which limits the host's defense capacities and the efficiency of many drugs. On the other hand, a properly targeted mechanical action can disrupt the physical balance of dental plaque. In dogs, the absence of mechanical control on the development of dental plaque is closely associated with the appearance of gingivitis in 7-21 days *(Tromp et al, 1986a)*. Daily checks will however resolve the gingivitis, confirming its reversible character *(Tromp et al, 1986b)*.

Dental plaque only has negative effects. By some it is considered to protect against desiccation and forms a defensive shield against colonization by much more pathogenic exogenic bacteria. The current aim is to control dental plaque as best as possible, without expecting to eliminate it completely *(Marsh, 2004)*.

► Brushing

Tooth brushing appears to be key to preventing and treating gingivitis and periodontal diseases *(Brandtzaeg, 1964)* **(Figure 22)**. A one-week study on cats showed a 95% reduction in calculus accumulation on teeth brushed once a day or twice a week *(Richardson, 1965)*.

A two-year study *(Ingham et al, 2002b)* on the other hand highlighted the low efficacy of brushing in cats, probably closely linked to the great technical difficulty of doing this on a daily basis. In the study, brushing reduced gingivitis on the buccal surface of teeth but did not show any significant difference.

More recently, a six-month field study involving 88 cat owners compared the efficacy of tooth brushing together with a specialized diet. At the end of the study, the observance of tooth brushing was just 40% *(Theyse, 2003)*.

Figure 23 - Measure of a kibble's resistance to pressure
The texturometer is a good way to measure the resistance of the kibble to the forces exerted on it by the cat's jaws and teeth. Interchangeable modules mimic the shape and dimensions of cat teeth based on age and breed.

► Mechanical role of food

Producers of cat kibbles have studied the dietary behavior of domesticated cats extensively. The size, shape and texture of kibbles are regularly tested with the aim of adapting them to the different facial conformations of different breeds of cat and encourage them to use their teeth in a physiological way. Commercial food producers have especially studied the texture of kibbles to improve the control of dental plaque **(Figure 23)**.

> Influence of the texture of the food

Texture, especially fibrous character, appears to be the most important physical aspect with respect to reducing the development of dental plaque. Numerous studies describe the negative impact of a wet food on the development of periodontal disease in dogs *(Egelberg, 1965; Harvey et al, 1996)*.
While there have been fewer studies on cats, all available results confirm the essential impact of food texture on dental plaque.

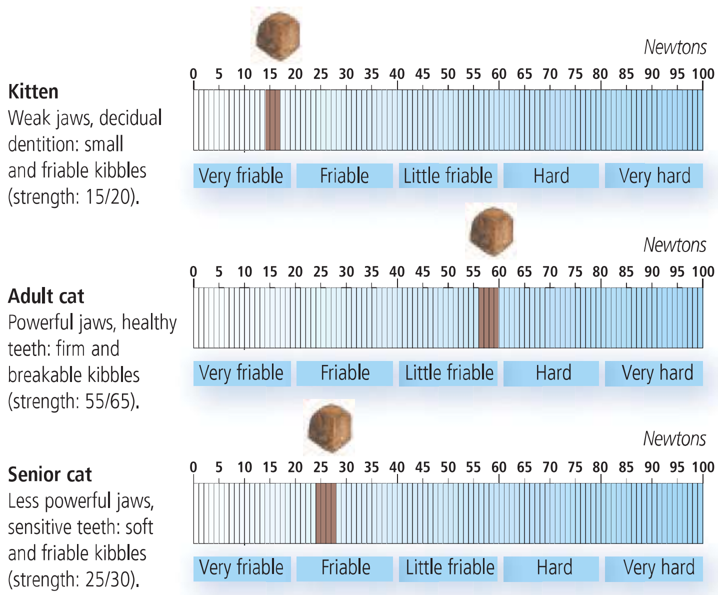
- In kittens, wet foods are implicated in promoting the appearance of calculus, gingivitis, tooth recession and bad breath *(Studer & Stapley, 1973)*.
- A significant reduction in dental plaque is observed after two weeks of study between two groups of cats fed with a dry food rather than a wet one *(Boyce, 1992)*.
- In tigers, a fiber supplement in the diet twice a week has been shown to help reduce the development of dental plaque and associated periodontal inflammation *(Haberstroh, 1984)*.
- The daily distribution of a chewing stick to 15 cats, supplementary to a dry food, helps obtain a significant reduction in dental plaque (-20%) and calculus (-39%) on premolars, molars and canines. Associated gingivitis was not as pronounced with the stick, although these data provide no statistical value *(Gorrel et al, 1998)*.
- In a similar study, 24 cats were fed with a dry food plus a chewing treat once a day for four weeks. The reduction in calculus was significant (-64%) compared with the group of cats fed exclusively with dry food. A significant difference was also observed with respect to the reduction in dental plaque (-15%) and the average gingival index (-11%) *(Ingham et al, 2002a)*.

> Influence of size and shape of the food

The impact of the shape and texture of a kibble distributed ad libitum in cats have been studied together. A significant reduction of 41% in the accumulation of plaque was observed in cats fed with bigger, rectangular kibbles of a texture with a higher penetration index (+ 25%) compared

Figure 24 – Influence of ergonomics and kibble texture on mechanical tooth brushing

Indicative value (Newton) measured at the Royal Canin Research Center (2002)



Due to its particular texture, the kibble encourages deeper penetration by the tooth, improving the efficacy of mechanical brushing.

with small triangular kibbles **(Figure 24)**. This reduction in dental plaque is explained by the more complete mechanical action of large kibbles. When brushing is encouraged and the kibble texture enables the tooth to penetrate deeper before it fractures, the dental friction time is longer and the efficacy of brushing is improved *(Servet et al, 2003)*.

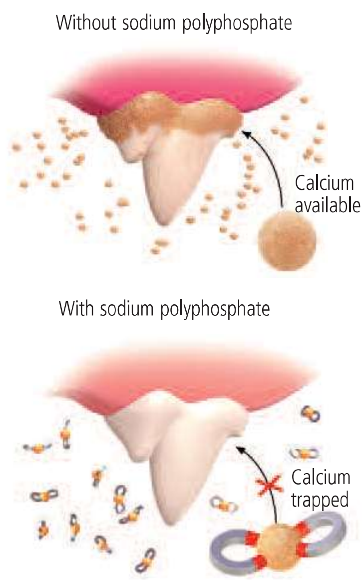
► Role of the composition of the food

The food may also contain certain ingredients that act against dental plaque and calculus, and so help prevent periodontal disease, when they are released in the oral cavity during mastication.

> Benefit of polyphosphate salts

The efficacy of some polyphosphate salts **(Figure 25)** in curbing the development of calculus is well known and clinically validated. The Ca^{2+} cations in the saliva are responsible for calcifying the dental plaque and transforming it into calculus. If polyphosphates with the capacity to chelate the versatile cations (e.g. Ca^{2+}, Mg^{2+}) are released in the oral cavity they naturally trap the calcium in the saliva in an ionic form, limiting its integration in the dental calculus matrix. The calcium is then released normally in the digestive tract so that it can be absorbed in accordance with the individual's needs. A significant reduction in the accumulation of calculus (-32%) has been observed in cats fed with a food coated with a calcium chelator, compared with a control group fed with the same kibbles without polyphosphate salts *(Servet et al, 2003; 2006)* **(Figure 26)**.

Figure 25 - Action of sodium polyphosphate salts with calcium in saliva



The chelated calcium ions are unavailable for the formation of calculus.

> Benefit of essential oils

The use of essential oils (thymol, eucalyptol, menthol, methyl salicylate) has also undergone long-term clinical evaluation in human dentistry. A reduction of dental plaque (-20-35%) as well as a significant reduction in associated gingivitis (-25-35%) has been obtained by using mouth-rinse solutions containing essential oils *(Perry & Schmidt, 2002)*. The benefit of this type of substance has gradually led to its incorporation in commercial foods. However, no study has yet been published on its specific efficacy.

> Other agents active against dental plaque

Current oral health research focuses on the development of new active components to combat the development of dental plaque.

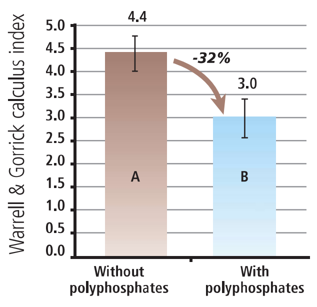
In cats, an ingredient identified in research for human cosmetics (plaque reduction nutrient or PRN) has been shown to inhibit the development of dental plaque in a standardized comparative study. Its inclusion in a dry reference food (already possessing beneficial mechanical properties due to its special texture) led to a significant reduction in the accumulation of dental plaque (*Servet et al, 2006*). After one month, a 12% reduction in dental plaque **(Figure 27)** was observed on all teeth tested (upper C, P3 and P4; upper P3, P4 and M1). A more detailed analysis of the gum line showed a reduction in plaque of 22% on all teeth tested **(Figure 28)** and 36% when the following teeth were excluded: upper premolars P3-P4 and lower M1. This validates the chemical effect on all the cat's dentition. This study also highlights the greater efficacy with respect to the food's target teeth: upper P4, P3 and lower M1.

New plaque reduction nutrients will probably be developed with the discovery of substances that act not only on bacteria cell integrity but also on the physical interface between dental plaque and the tooth, to facilitate its detachment.

Combining the impact of size/texture and the composition of daily food, it is now possible to promise a significant reduction in the deposition of dental plaque in cats in the region of 30% and of calculus in the region of 50%. Given the cat's very particular chewing mechanism, the action due to the food's physical properties is more pronounced on the carnassials. The addition of PRNs also produces this effect in the rostral part of the oral cavity (canines and incisors).

FIGURE 26 - REDUCTION IN CALCULUS ACCUMULATION

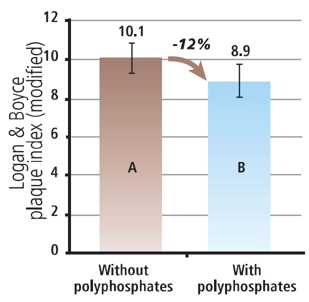
(Royal Canin, 2005)



Global calculus deposit index before and after two months of a dry food enriched with polyphosphates.

FIGURE 27 - REDUCTION IN PLAQUE ACCUMULATION

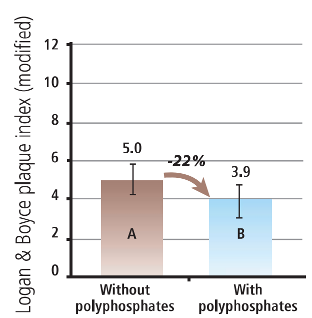
(Royal Canin, 2005)



Global dental plaque accumulation index before and after one month of a dry food enriched with PRN.

FIGURE 28 - REDUCTION IN PLAQUE ACCUMULATION

(Royal Canin, 2005)



Dental plaque gingival index before and after one month of a dry food enriched with PRN.

Conclusion

The prevalence of oral inflammation in cats is widely underestimated. The clinical impact proves to be more important than it appears. In fact it is the number one cause of infectious disease in the species. Contrary to what many people think, periodontal disease is not the same in cats and dogs. It is expressed differently. The most recent studies to evaluate the secondary systemic effects of periodontal inflammations cast new light on the benefit with respect to oral diseases. The aim is not simply to combat bad breath, it is much more ambitious. It is to improve the cat's medical health and life expectancy.

Appropriate treatment reduces the chronic pain and infections associated with oral diseases. Owners are often amazed by the positive effects on their cat when the appropriate care is given. Toothache often produces major behavioral change. After treatment, the cats are generally more active, they eat better and their general condition by and large improves.

Full attention needs to be focused on preventing the development of dental plaque. The potential role of the food as an effective support for oral hygiene is now accepted. It is especially beneficial in cats, bearing in mind the difficulty of daily tooth brushing and their low interest in objects for chewing. The efficacy of this approach will no doubt be improved by working on the physical presentation of the food and searching for new PRNs.

Fallacies regarding oral diseases in cats

F	A
"Cats rarely suffer from oral lesions."	Pain is difficult to evaluate in cats by simply observing their day-to-day behavior. Dental care often leads to an improvement in the animal's health a posteriori. Any oral lesion (periodontitis, tooth resorption, stomatitis) must therefore always be considered potentially painful.
"Dental caries is common in cats."	Caries is NEVER observed in cats. The absence of caries is thought to be due to several factors: the conical shape of the teeth, the peculiarities of the diet and the composition of the dental plaque.
"Regular scaling prevents the emergence of periodontal disease in cats."	Calculus as such does not cause inflammation of the periodontium, but rather the daily accumulation of dental plaque and the bacterial populations it is composed of. There are therefore few benefits of removing calculus. Scaling helps suppress the dental plaque in a specialized dental procedure, but it does not unfortunately address the problem of permanent plaque development on the surface of the teeth. To prevent chronic periodontitis, regular scaling must always be combined with other oral hygiene techniques.
"The regular distribution of antibiotics eliminates dental plaque."	Unfortunately not. The bacteria in dental plaque are trapped in a protective complex that strengthens their cooperation. At best, antibiotics will be effective on a very superficial part of the bacterial population. Furthermore, their regular use contributes to the emergence of new strains in the plaque that have developed resistance to antibiotics.
"You have to start looking after a cat's teeth when it gets older."	The prevention of oral disease is always more effective when lesions are diagnosed early. Most cats less than 3 years of age already have tooth lesions that justify specific care. An inspection of the cat's mouth should accordingly be part of every vaccination visit.
"It's not possible to brush a cat's teeth."	While it is clearly difficult to get owners to brush their cat's teeth, the procedure is not impossible. Patience and motivation are often keys to surprising prophylactic results.
"Feeding a cat kibbles helps prevent the development of chronic periodontitis."	Simply giving your cat dry food kibbles will not be enough to reduce dental plaque. Kibble shape, size and texture need to be studied extensively to produce mechanical friction on the tooth surface enough to slow down plaque deposits and calculus formation. It now appears to be very important to combine this mechanical effect with the organic effect produced by nutritional factors that can act by diffusion on the composition of the oral flora.

References

Addie DD, Radford A, Yam PS, et al. Cessation of feline calicivirus shedding coincident with resolution of chronic gingivostomatitis in a cat. J Small Anim Pract *2003; 44: 172-176.*

Andreasen JO. External root resorption: its implication in dental traumatology, paedodontics, periodontics, orthodontics and endodontics. Int Endodon J *1985; 18: 109-118.*

Barbieri B. Biofilm et maladies parodontales. Inf Dent *2000; 40: 3451-3457.*

Boutoille F, Dorizon A, Navarro A, et al. Echocardiographic alterations and periodontal disease in dogs: a clinical study. In Proceedings:15th European Congress of Veterinary Dentistry 2006, Cambridge (UK): 63-65.

Boyce EN. Feline experimental models for control of periodontal disease. Vet Clin North Am Small Anim Pract *1992; 22: 1309-1321.*

Brandtzaeg P. The significance of oral hygiene in the prevention of dental diseases. Odont T *1964; 72: 460.*

Buckland-Wright JC. Structure and function of cat skull bones in relation to the transmission of biting forces. PhD thesis, university of London, 1975.

Clarke DE, Cameron A. Relationship between diet, dental calculus and periodontal disease in domestic and feral cats in Australia. Aust Vet *1998; 76: 690-693.*

Coles S. The prevalence of buccal cervical root resorptions in Australian cats. J Vet Dent *1990; 7: 14-16.*

Crossley DA. Survey of feline problems encountered in a small animal practice in New England. Brit Vet Dent Ass J*, 1991; 2: 3-6.*

DeBowes LJ, Mosier D, Logan E, et al. Association of periodontal disease and histologic lesions in multiple organs from 45 dogs. J Vet Dent *1996; 13: 57-60.*

DuPont GA, DeBowes LJ. Comparison of periodontitis and root replacement in cat teeth with resorptive lesions. J Vet Dent *2002; 19: 71-75.*

Egelberg J. Local effect of diet on plaque formation and development of gingivitis in dogs. I. Effect of hard and soft diets. Odont Revy *1965; 16:31-41.*

Gauthier O, Boudigues S, Pilet P, et al. Scanning electron microscopic description of cellular activity and mineral changes in feline odontoclastic resorptive lesions. J Vet Dent *2001; 18: 171-176.*

Gengler W, Dubielzig R, Ramer J. Physical examination and radiographic analysis to detect dental and mandibular bone resorption in cats: a study of 81 cases from necropsy. J Vet Dent. *1995; 12: 97-100.*

Girard N, Servet E, Biourge V, et al. Feline Dental Resorptions in a colony of 109 cats. J Vet Dent *2008; in press.*

Girard N, et coll. Periodontal status in a colony of 100 cats. J Vet Dent *2008: in press.*

Gorrel C, Larsson A. Feline odontoclastic resorptive lesions: unveiling the early lesion. J Small Anim Pract *2002; 43: 482-488.*

Gorrel C, Inskeep G, Inskeep T. Benefit of a dental hygiene chew on the periodontal health of cats. J Vet Dent *1998; 15: 135-138.*

Haake SA, Newman NG, Nisengard RJ, et al. Periodontal microbiology. In: Caranza's Clinical periodontology. 9th ed. Newman Takei Carranza: Saunders 2002.

Haberstroh LI, Ullrey DE, Sikarski JG, et al. - Diet and oral health in captive amur tigers (Panthera tigris altaica). J Zoo Anim Med *1984; 15: 142-146.*

Harvey C, Emily PP. Function, formation, and anatomy of oral structures in carnivores. In: Small animal dentistry. St Louis: Mosby, 1993.

Harvey CE, Orsini P, McLahan C, et al. Mapping of the radiographic central point of feline dental resorptive lesions. J Vet Dent *2004; 21: 15-21.*

Harvey C, Shofer FS, Laster L. Correlation of diet, other chewing activities and periodontal disease in North American client owned-dog. J Vet Dent *1996; 13: 101-105.*

Houle MA, Grenier D. Maladies parodontales: connaissances actuelles. Current concepts in periodontal diseases. In: Médecine et maladies infectieuses. Elsevier ed, 2003; 33: 331-340.

Ingham KE, Gorrel C, Blackburn JM, et al. Prevalence of odontoclastic resorptive lesions in a population of clinically healthy cats. J Small Anim Pract *2001; 42: 439-443.*

Ingham KE, Gorrel C, Bierer BS. Effect of a dental chew on dental substrates and gingivitis in cats. J Vet Dent *2002 (a); 19; 201-204.*

Ingham KE, Gorrel C, Blackburn JM, et al. The effect of tooth brushing on periodontal disease in cats. J Nutr *2002 (b); 132:1740S-1741S.*

Kays RW, DeWan AA. Ecological impact of inside/outside house cats around a suburban, nature preserve. Animal Conservation *2004; 7: 273-283.*

Liberg O. Food habits and prey impact by feral and house-based domestic cats in a rural area in Southern Sweden. J Mamm *1984; 65: 424-432.*

Lommer M, Verstraete FJ. Prevalence of resorptive lesions and periapical radiographic lucencies in cats: 265 cases (1995-1998). J Am Vet Med Assoc *2000; 217: 1866-1869.*

Lommer MJ, Verstraete FJ. Radiographic pattern of periodontitis in cats: 147 cases (1998-1999). J Am Vet Med Assoc *2001; 218: 230-234.*

Lund EM, Bohacek LK, Dahlke JL, et al. Prevalence and risk factors for odontoclastic resorptive lesions in cats. J Am Vet Assoc *1998; 212: 392-395.*

Marsh PD. Dental plaque as a microbial biofilm. Caries Res *2004; 38: 204-211.*

Orsini P, Hennet P. Anatomy of the mouth and teeth of the cat. Vet Clin North Am Small Anim Pract *1992; 22: 1265-1277.*

Okuda A, Harvey C. Ethiopathogenesis of feline dental resorptive lesions. Vet Clin North Am Small Anim Pract *1992; 22: 1385-1404.*

Pavlica Z. Periodontal disease and its systemic effects in the risk population for dogs. Clinical and nutritional management of senior dogs and cats. In: Proceedings. *28th World Small Animal Veterinary Association Congress 2002: 19-24.*

Pavlica Z, Petelin M. Systemic effects on chronically infected wound in oral cavity of dogs. In: Proceedings. 12th Congress of European Veterinary Dental Society (EVDS) 2003: 29-32.

Perry DA, Schmidt MO. Phase 1 Periodontal therapy. In: Caranza's Clinical periodontology. 9th ed. Newman Takei Carranza: Saunders 2002.

Reichart PA, Durr UM, Triadan H, et al. Periodontal disease in the domestic cat: a histopathologic study. J Periodontal Res *1984; 19: 67-75.*

Reiter AM, Lewis JR, Okuda A. Update on the etiology of tooth resorption in domestic cats. Vet Clin Small Anim *2005; 35: 913-942.*

Richardson RL. Effect of administering antibiotics, removing the major salivary glands, and tooth brushing on dental calculi formation in the cat. Arch Oral Biol *1965; 10: 245-253.*

Roux P, Berger M, Stoffel M, et al. Observations of the periodontal ligament and cementum in cats with dental resorptive lesions. J Vet Dent *2005; 22: 74-85.*

Servet E, Hendricks W, Clarke D. Kibbles can be a useful means in the prevention of feline periodontal disease. Waltham Focus *2003; 13: 32-35.*

Servet E, Hendriks W, Clarke D. Dietary intervention can improve oral health in cats. J Vet Dent *2008 (in press).*

Studer E, Stapley B. The role of dry food in maintaining healthy teeth and gums in the cat. Vet Med Small Anim Clin *1973; 68: 1124-1126.*

Theyse LFH. Hill's prescription diet feline t/d: results of a field study, in Proceedings. Hill's oral symposium (19th-21st March 2003): 60-63.

Tou AP, Adin DB, Castelman WL. Mitral valve endocarditis after prophylaxis in a dog. J Vet Intern Med *2005; 19: 268-270.*

Tromp JAH, Jansen J, Pilot T. Gingival health and frequency of the tooth brushing in the beagle dog model. J Clin Periodontol *1986 (a);13: 164-168.*

Tromp JAH, van Rijn LJ, Jansen J. Experimental gingivitis and frequency of tooth brushing in the beagle dog model. J Clin Periodontol *1986 (b); 13:190-194.*

Trope M, Chivian N, Sigurdsson A. Traumatic injury. In: Cohen S, Burns RC, eds. Pathways of the pulp. 8th ed. St Louis: Mosby, 2002; 623-632.

Van Messum R, Harvey CE, Hennet P. Feline dental resorptive lesions, prevalence patterns. Vet Clin N Amer.1992; 1405-1416.

Verhaert L, Van Wetter C. Survey of oral disease in cats in Flanders. Vlaams Diergeneeskundig Tijdschrift *2004; 73: 331-341.*

Verstraete FJM, van Aarde RJ, Nieuwoudt BA, et al. The dental pathology of feral cats on Marion Island, part 2: Periodontitis, external odontoclastic resorption lesions and mandibular thickening. J Comp Path *1996; 115: 283-297.*

Wiggs RB, Lobprise HB. Oral anatomy and physiology. In: Veterinary Dentistry, principles and practice. Blackwell Publishing, Lippincott-Raven, 1997: 55-86.

Wolf H, Rateitschak EM, Rateitschak KH, et al. Periodontology. In: Rateitschak EM, et al. Color Atlas of Dental Medicine. 3rd ed: Thieme Medical Publishers, 2005; 95-98.

Focus on:

Nutrients acting on oral health in cats

Servet E., Hendriks W., Clarke D., Biourge V. - Royal Canin Research Center, Aimargues, France - Massey University, New Zealand

Introduction

It has been shown that diets consisting of dry, hard foods result in less accumulation of plaque and tartar compared to canned or other soft foods. This is due to the abrasive nature of the dry food which can scrape or brush the accumulated materials off the tooth surface. In addition, the shape of the kibble has an important role in efficacy of brushing the tooth (when the owner cannot perform tooth brushing of the cat on a regular basis). A previous study *(Servet et al, 2003)* has reported that in cats, a rectangular kibble is more effective in preventing plaque than a triangular kibble.

The purpose of this study was to determine if chelated polyphosphates (sodium polyphosphate- SPP), a unique plaque reducing nutrient (PRN) and a larger kibble size would result in a significant reduction in calculus and plaque formation. SPP is a cation sequestrant that forms soluble complexes with calcium within dental plaque, thereby preventing the accumulation of calculus. A larger kibble of a rectangular shape should require additional prehension, biting and chewing to impact calculus and plaque formation.

Materials and methods

Animals

A total of 30 healthy mixed breed cats were used in the study. To be included in this study, cats had to have normal dentition, scissor-configuration occlusion, dental plaque accumulation and no or mild gingivitis. Cats were housed in groups of 10 and provided their respective diet *ad libitum*. Fresh water was also provided *ad libitum*.

Diets

Cats were exclusively fed dry extruded diets throughout the study. No snacks, calculus or plaque control treats, chews or chew toys were allowed. Three different dietary regimens were compared:

- Diet A: A dry-expanded diet with triangular kibble shape and no oral care purpose, as a negative control diet
- Diet B: A dry-expanded diet with rectangular kibble shape formulated for oral care purpose, including SPP and PRN
- Diet C: A dry-expanded diet with triangular kibble shape and oral care provided by SPP.

All diets were formulated to meet the nutritional levels established by the AAFCO Cat Food Nutrient Profiles for adult maintenance.

Study design

All 30 cats were fed Diet A for 14 days in a pre-study phase **(Table 1).** At the end of the pre-study phase, all cats were anesthetized and a dental prophylaxis performed to remove all supra and subgingival calculus and plaque. Each cat was deemed to begin the study with a “clean tooth model”. All cats remained on Diet A and after a further seven days, plaque indexes were evaluated according to the Logan & Boyce procedure *(Logan & Boyce, 1994)*. Cats were then randomly assigned by gender and plaque forming ability to one of 3 diets. Plaque indexes were evaluated at 7 days. At 28 days, plaque and calculus indexes were evaluated by the *Logan & Boyce* (plaque) and *Warrick & Gorrel* (calculus) procedures *(Warrick & Gorrel, 1995)*. Calculus formation was evaluated a second time at day 56 **(Table 2)**. One scorer was used to score all cats in a blinded procedure to the different feeding regimens and the scoring order of the cats.

The scored teeth were the canines (C), pre-molar 3 and 4 (PM3 and PM 4) for the upper jaw (maxilla) and C, PM3, PM 4, and molar 1 (M1) for the lower jaw (mandible).

Gingivitis was evaluated according to the method of *Loe & Silness*. Teeth scored were incisor 3 (I3), C, PM3, PM4, M1 for the maxilla and C, PM2, PM3, PM4, M1 for the mandible.

TABLE 1 - STUDY DESIGN

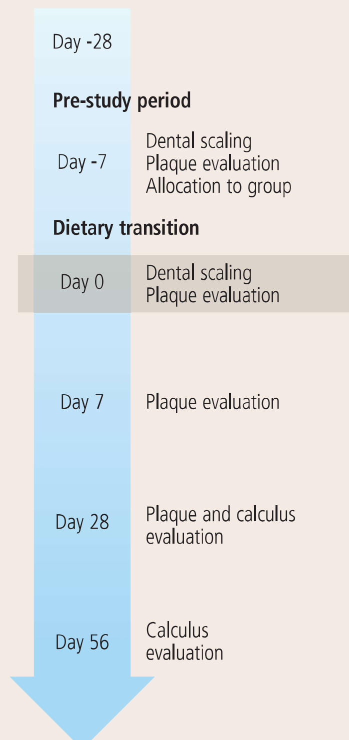


TABLE 2 – CRITERIA FOR CALCULUS DETERMINATION	
Coverage	0 - no observable calculus 1 - scattered calculus covering less than 24% of the buccal tooth surface 2 - calculus covering between 25-49% of the buccal tooth surface 3 - calculus covering between 50-74% of the buccal tooth surface 4 - calculus covering more than 75% of the buccal tooth surface
Thickness	L = light = 1 (for calculations) M = moderate = 2 (for calculations) H = heavy = 3 (for calculations)

Data Analysis

Dental plaque and calculus scores were expressed as a whole mouth score for each cat and were calculated from the mean value of the scores for each target tooth. Data were expressed as mean ± standard error of the mean (sem). Repeated-measures ANOVA tests were used to derive F-tests for significant differences between treatments. F-values with p-values less than 0.05 were considered significant. Analyses were performed using the General Linear Model procedures in Statgraphics V5 statistical software.

Results

Plaque score at day 7 **(Figure 1)** was significantly lower for Diet B compared to Diet A and Diet B compared with Diet C (28.3% and 28.1%, respectively). In addition, gingival plaque score at Day 7 **(Figure 2)** was significantly lower for Diet B compared with Diet A and Diet C (27.3% and 30.5%, respectively). Diet B was associated with a 30.3% lower plaque score at day 28 compared to Diet A, and 30.1% lower plaque score at day 28 compared to Diet C **(Figure 3)**. Likewise, Diet B was associated with a significant reduction in gingival plaque scores at day 28 **(Figure 4)** compared to both Diet A and Diet C (31.7% and 29.2%, respectively).

Calculus score at day 28 **(Figure 5)** was significantly lower for Diet B compared to Diet A and Diet B compared with Diet C (47.4% and 23.8%, respectively). In addition, there was a significant reduction (30.9%) in calculus score for Diet C compared with Diet A. The calculus score **(Figure 6)** for Diet B was significantly lower than Diet A or Diet C at 56 days (44.6% and 18.9%, respectively). The calculus score for Diet C was significantly lower (31.7%) than Diet A at 56 days.

FIGURE 1 - PLAQUE SCORE DAY 7

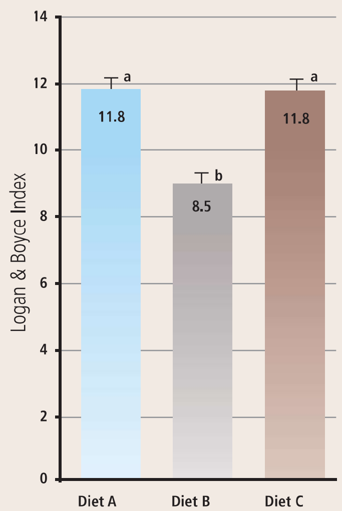


FIGURE 2 - GINGIVAL PLAQUE SCORE DAY 7

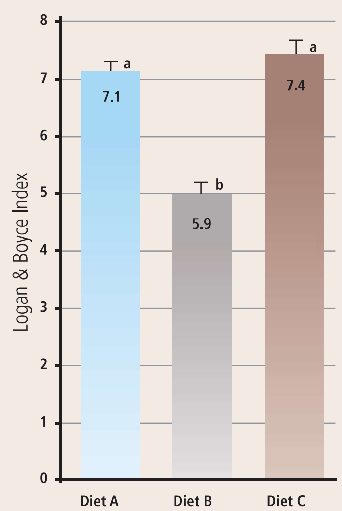
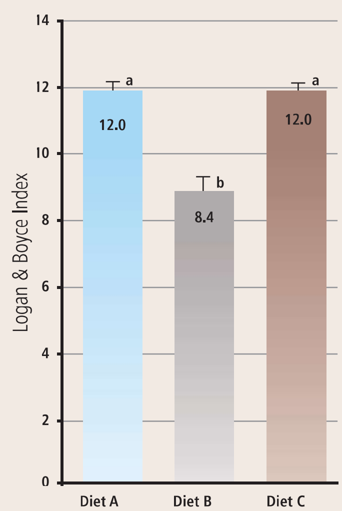


FIGURE 3 - PLAQUE SCORE DAY 28



Discussion

The results of this study demonstrated that plaque and calculus accumulation can be significantly reduced in cats when they are fed a diet that has been specifically formulated with a larger rectangular kibble coated with sodium polyphosphate and a specific plaque reducing nutrient. Plaque was reduced by approximately 30% and calculus was reduced by approximately 45%.

Coating the kibble with sodium polyphosphate alone (Diet C) resulted in significantly less calculus build up compared to the control diet (Diet A), but no significant reduction in plaque was observed. These results confirm that sodium polyphosphate has a significant impact only on calculus, and the results are in agreement with other available feline calculus data *(Stookey, 1995; Johnson & Cox, 2002)*.

Sodium polyphosphate, coated on the external surface of the kibble is released into the oral cavity where it chelates salivary calcium so that it is unavailable for plaque calcification into calculus. When swallowed, the calcium polyphosphate complexes are not stable in the acid environment of the stomach and are rapidly converted to orthophosphates and used as a dietary phosphate source.

The larger, rectangular kibble coated with sodium polyphosphate resulted in significantly less calculus accumulation compared to the smaller triangular kibble coated with sodium polyphosphate (Diet C). Previous studies have shown that diet texture, kibble shape, size and design all impact calculus formation in cats (Servet et al, 2003). Indeed, it has been shown that dry kibble in a rectangular shape as opposed to a triangular shape aids in scraping away plaque when the cat bites and chews the kibble (Servet et al, 2003). This lower plaque deposition rate is attributed to the specially designed kibbles that convey an enhanced mechanical action, attributed to increased friction, induced both a higher crunching rate and by optimized crushing with greater teeth penetration into the kibbles. This process mimics tooth brushing. The significant impact on plaque deposition was attributed to the addition of the unique plaque reducing nutrient, coupled with the size, shape and texture of the kibble, which enhanced the mechanical action and simulated a brushing effect.

Conclusion

A 30% reduction in plaque and 45% reduction in calculus accumulation can be achieved when cats are fed a diet that has been specifically formulated with a larger rectangular kibble coated with sodium polyphosphate and a specific plaque reducing nutrient.

FIGURE 4 - GINGIVAL PLAQUE SCORE DAY 28

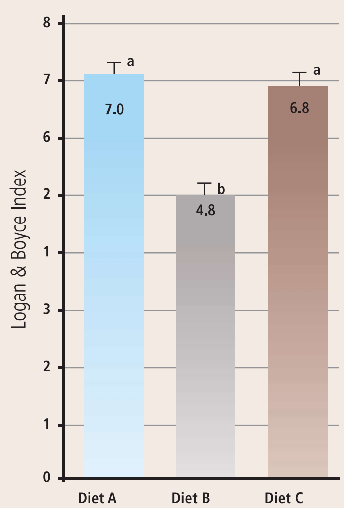


FIGURE 5 - CALCULUS SCORE DAY 28

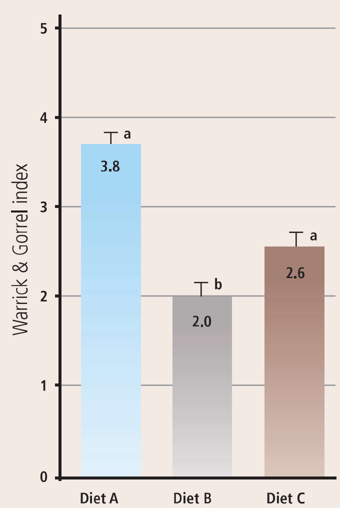
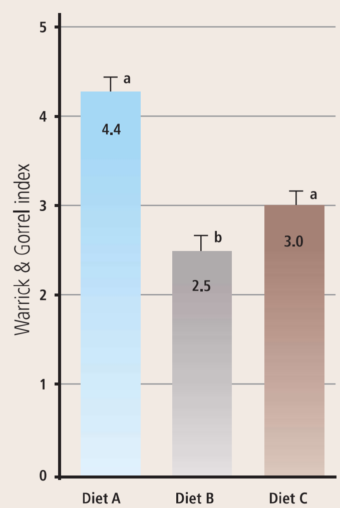


FIGURE 6 - CALCULUS SCORE DAY 56



70% of cats aged over 3 years old present oral lesions (Harvey, 2004).

Key points
to remember:

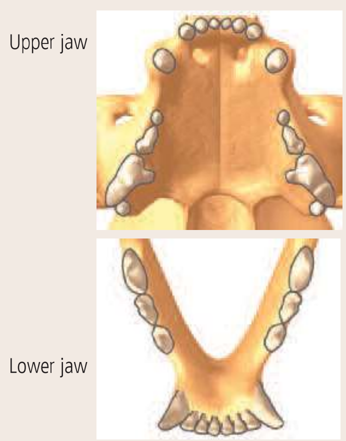
Periodontal disease in cats

Dental health can have repercussions for the cat's general health. It is important that the teeth and oral cavity are regularly examined during a veterinary check-up.

Periodontal disease is the most common disease, affecting 70% of cats aged 20-27 months to various degrees *(Ingham et al, 2002)*. It develops in three phases:

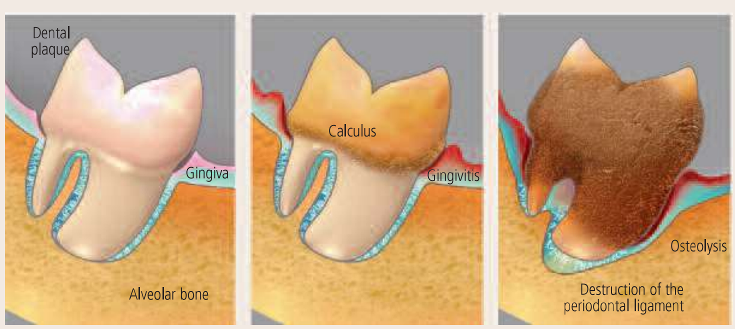
- **phase 1:** deposition of dental plaque, constituting an organic film of salivary polysaccharides and glycoproteins, colonized by aerobic bacteria;
- **phase 2:** development of gingivitis and mineralization of the dental plaque into calculus. The aerobic bacteria are replaced by anaerobic bacteria and bad breath is caused by the formation of volatile sulfur compounds;
- **phase 3:** destruction of the periodontal ligament (periodontitis). The bacteria reach the base of the root and attack the bone in which the tooth is embedded. Gum recession and osteolysis facilitate the tooth's loosening.

Dental follow up



Date	Age	Comments

O: absent tooth
X: extracted tooth
B: broken tooth
GR: unembedded tooth
FORL: feline odontoclastic resorption lesion
M: loose tooth



Nutritional responses

Tooth brushing is the best means of preventing the development of periodontal disease. When it is not possible because the owner is not available or the cat is uncooperative, the food can play a beneficial preventive role based on its mechanical and/or chemical effects. The expected benefits are observed only when the cat eats nothing else on a daily basis.

Mechanical effect

Dry foods can have a light abrasive effect on the teeth when they are chewed correctly before swallowing. This permits the destruction of the bacterial mesh that constitutes dental plaque. It is important not to crush or mash the kibbles, as this will negate these benefits.

The mechanical effect is based on matching the appropriate kibble size, shape and texture to the age and size of the individual animal. The aim is maximum penetration of the kibble by the tooth before the kibble crumbles, so as to obtain relative "brushing".

The fact that the cat chews also stimulates the production of saliva, which has a beneficial antibacterial role.

Effect on bacterial flora

Some nutrients can inhibit the deposition of dental plaque by curbing the adhesion of bacteria and/or acting as a bactericide *(Servet et al, 2006)*. The aim is to reduce the proliferation of the anaerobic bacterial population and the production of volatile sulfur compounds responsible for halitosis.

While no specific studies have been published on cats, several studies have demonstrated the efficacy of some nutrients in limiting bad breath. Of the nutrients studied, organic zinc salts (e.g. zinc citrate) and inorganic zinc salts (e.g. zinc sulfate: $ZnSO_4^{2-}$) present beneficial bacteriostatic properties *(Weesner, 2003; Waller, 1997)*.

There are also bacteriostatic and bactericidal oils. Eucalyptus oil for example helps actively reduce the production of sulfur fatty acids *(Pan et al, 2000)*. Lastly, some bacteria are highly sensitive to the action of tea polyphenols *(Isogai et al, 1995)*, the antioxidant properties of which are well known.

Chemical effect

Sodium polyphosphates have a chelator effect on the calcium in saliva and so help limit the calcification of dental plaque.

Conclusion

Adding up the impact of size/texture and composition of daily food, it is now also possible to promise a significant reduction in the deposition of dental plaque in cats.

© Yves Lanceau/RC/Maine Coon

References

Harvey CE. The oral cavity. In: Chandler EA, Gaskell CJ, Gaskell RM; Feline medicine and therapeutics *2004; Blackwell Publishing & BSAVA: 379-395.*

Ingham KE, Gorrel C, Blackburn JM, et al. The effect of tooth brushing on periodontal disease in cats. J Nutr *2002; 132: 1740S-1741S.*

Isogai E, Isogai H, Kimura K, et al. Effect of Japanese green tea extract on canine periodontal diseases. Microbial Ecology in Health & Diseases *1995; 8: 57-61.*

Pan P, Barnett ML, Coelho J, et al. Determination of the in situ bactericidal activity of an essential oil mouth rinse using a vital stain method. J Clin Periodontol *2000; 27: 256-261.*

Servet E, Hendriks W, Clarke D, et al. Dietary intervention can improve oral health in cats. J Vet Dent *2008 (in press).*

Waler SM. The effect of some metal ions on volatile sulphur-containing compounds originating from the oral cavity. Acta Ondontol Scand *1997; 55: 261-4.*

Weesner BW Jr. Curing Halitosis: the sweet smell of success. J Tenn Dent Assoc *2003; 83: 20.*