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Canine nutrition and oral health

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A graduate of the National Veterinary School of Toulouse in 1988, Philippe Hennet conducted a research project in canine endodontics with the dental faculty at Toulouse in 1987-1989, which led to a veterinary doctoral thesis in 1990. He continued his research as part of a clinical residency at the Dentistry Section of the University of Pennsylvania Veterinary School at Philadelphia in 1990-1992. Philippe now specializes in oral and ENT diseases at his practice in Paris. He has been a dentistry assistant at the National Veterinary School of Alfort since 1993. He has also been the scientific co-organizer of the dentistry course at the European School for Advanced Veterinary Studies (ESAVS) in Luxembourg since 1995. A diplomate of the American Veterinary Dentistry College (AVDC) since 1993, and of the European Veterinary Dentistry College (EVDC) since 1998, he is the author of many publications in English and in French.

Periodontal disease is the most common disease of the oral cavity in dogs. Every dog is affected during its life to some degree. Curiously, compared with other diseases it's often neglected, although it can be treated or even prevented with care. In oral hygiene, the benefit of any therapeutic intervention is of short duration if it isn't prolonged with daily care by the owner.

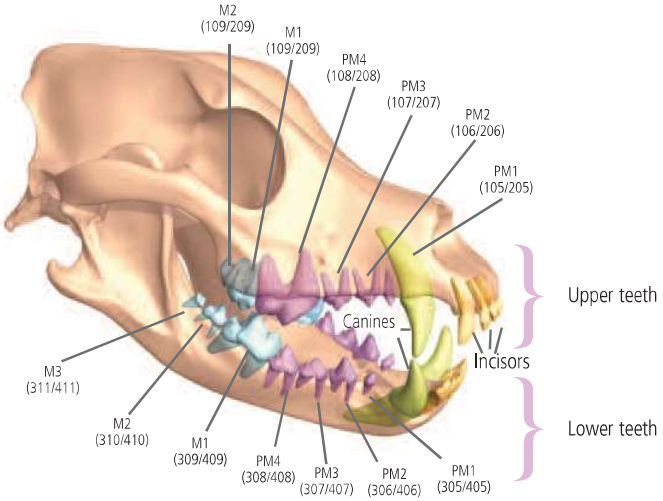
The aim of this care is to fight dental plaque. While brushing is accepted as the most effective means of protection, there are alternatives – both physical and chemical – to help control plaque.

1 - Anatomy and physiology

► Teeth

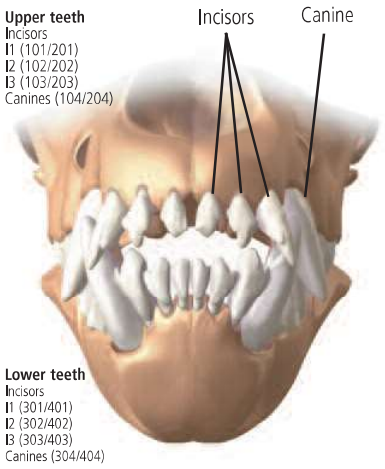
(Figures 1 and 2)

FIGURE 1 - LATERAL VIEW OF THE DENTURE OF THE DOG



The adult dog has 42 teeth. The dental formula by demi-jaw is: I 3/3; C 1/1; PM 4/4; M 2/3.

FIGURE 2 - FRONTAL VIEW OF THE DENTURE OF THE DOG



The incisors, which are much larger in the upper jaw, are (from the middle of the denture): frontal, central and corner incisors.

The first primitive mammals that appeared 250 million years ago during the Mesozoic era already possessed two hemi-mandibles connected ventrally by a symphysis and joined to the squamosal's glenoid cavity by a condyle (temporomandibular articulation). The enamel-covered teeth were divided into cutting incisors, rounded canines and grinding or hacking molars, implanted in the alveolar borders of the maxilla and the mandible. Present-day mammals retain these essential anatomical characteristics, with modifications depending on diet (*Lavergne et al, 1996*).

The carnivores are diphyodonts (having two successive sets of teeth, deciduous and permanent) and heterodonts (having different types of teeth with different functions). The incisors – prehensile cutters that number three per hemi-jaw – only have one root. The conical canines are tearing teeth adapted to the diet of a carnivore.

The premolars have two roots, with the exception of the first premolar, which is regressive and has a crown formed by three cusps in a line. There is alternate occlusion of the crowns of the maxillary and mandibular premolars with the necessity of diastema between the teeth.

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Occlusion of permanent teeth in dogs
Note the regular alternation of maxillary and mandibular premolars: the main cuspid of maxillary premolars is lodged in the middle of the interdental space of the two mandibular premolars. The mandibular canine is lodged in the corner maxillary canine interdental space, thus forming a powerful triad. In mesocephalic and dolichocephalic dogs, and in certain brachycephalic dogs, the incisors have a scissor bite (the cuspid of the mandibular incisors in contact with the cingulum of the maxillary incisors).

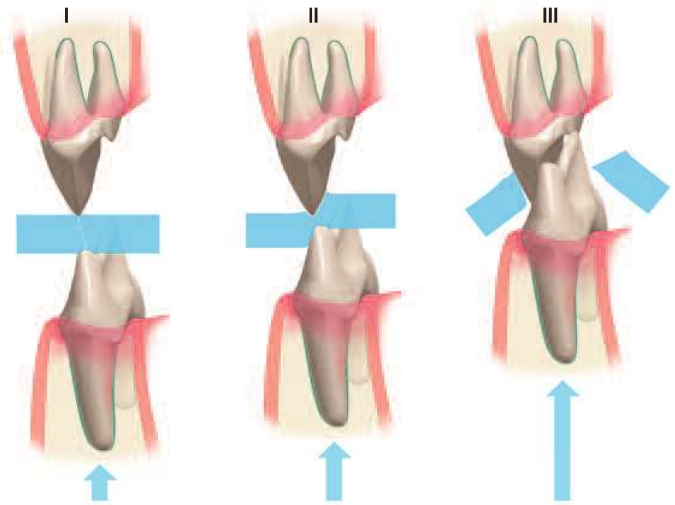
► Jaws

In the carnivore specialization, temporomandibular articulation is located in the extension of the occlusal plane. It consists of a deep transversally-oriented, hemi-cylindrical mandibular fossa, bordered ventrally by a powerful retro-articular process into which an elongated mandibular condyle fits transversally. This mechanism principally permits the raising and lowering of the mandible as well as the lateral movements in dogs that are essential for ripping through prey (*Lafond, 1929*; *Gaspard, 1967*).

► Physiology of manducation

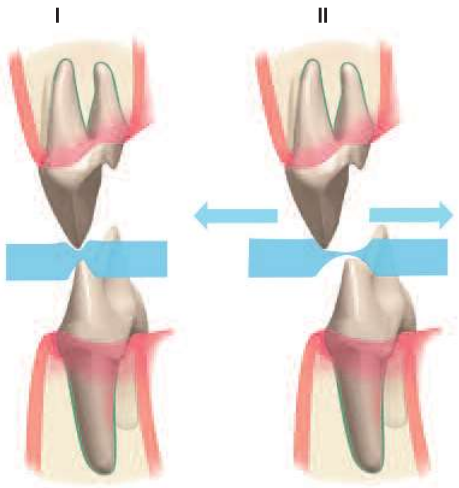
The term manducation designates all the actions involved in eating, including prehension, mastication, insalivation and deglutition *(Verchère et al, 1992)*. Contrary to humans, carnivores do not chew their food. They divide them into scraps that are not completely crushed and scarcely insalivated, but that are quickly swallowed. Manducation principally consists in breaking up large pieces of food. In the wild, the canids capture their prey with their powerful canines. The incisors serve to cut and tear large pieces, which are then introduced deeper into the oral cavity. This action may be supplemented with jerks of the head driven by the muscles in the nape. The piece of food – a muscle mass for instance – is cut by the scissors formed by the cuspids of the mandibular and maxillary carnassials **(Figure 3)**. To enable this, the vestibular surface of the mandibular carnassials must come into contact with the lingual surface of the upper carnassials through an opening of the symphysis and an external torsion of the mandibular body *(Gaspard, 1967)*.

FIGURE 3 - CUTTING EFFORT
(From Gaspard, 1967)



Mandibular biomechanics allow an alignment of the cuspids of the mandibular and maxillary carnassials (I), to exercise a shear force (II) that breaks the food when the mouth is closed (III).

FIGURE 4 - BREAK BY EXTENSION
(From Gaspard, 1967)



Snagged by the cuspids of the carnassials, the food is elongated by a lateral movement that results in its breaking.

Only one mandibular branch works at any one time *(Lafond, 1929)*. When the piece is soft and less voluminous the canid can lock its jaws without bringing its carnassials together. This is also what happens when it works simultaneously with the two hemi-mandibles. Here the piece breaks due to an extension associated with shearing. The deformation is accompanied by lateral movements. Carnivores rip the elastic body and tear the fibrous tissues by laceration, which consists of violently moving the mandibular teeth across the maxillary teeth. The food is violently stretched, which results in it breaking at the point of least resistance **(Figure 4)**.

When faced with a long, rigid body like a bone, the canid immobilizes it between its forepaws by pressing one extremity against the ground and energetically seizing the other extremity in its mouth. It then revolves its head from one side to the other to subject the body to flexion and torsion. The body ultimately breaks at the point of the carnassials. Thus, the body is squeezed then crushed between the first upper molar and the crushing talon cusp of the lower carnassial. These food fragmentation techniques and the major forces developed explain the powerful chewing muscles that allow carnivores to lock their jaws.

2 - Periodontal disease and oral hygiene

Unlike in humans, dental caries is very rare in dogs. A study of 435 dogs presented at a practice specialized in veterinary dentistry reported that only 23 dogs (5.3%) presented with caries *(Hale, 1998)*. The most common oral malady in dogs is periodontal disease, and most of this chapter is devoted to it.

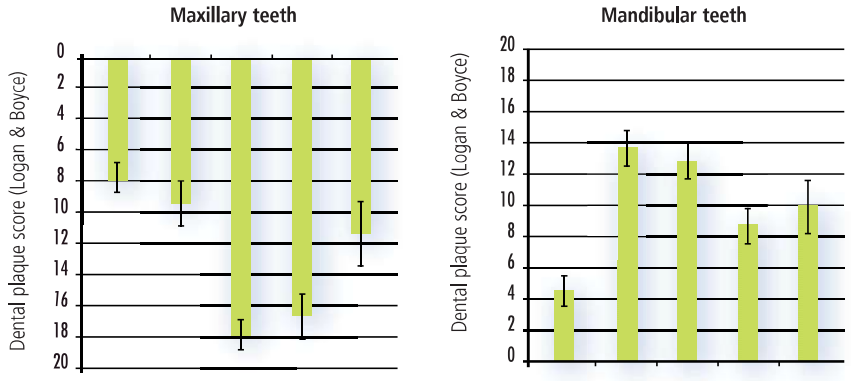
► Periodontal disease

Periodontal disease is the result of a fight at tissue level (periodontium = gingiva, alveolar bone, periodontal ligament and cementum) between bacteria that accumulate on the dental crowns (bacterial dental plaque) and the individual's defense system **(Figure 5)**.

> Epidemiology

Periodontal disease affects every dog in the course of its life, although prevalence varies depending on the breed and the individual. The accumulation of bacterial dental plaque on the dental crowns along the gingiva leads to an inflammatory reaction in this gingiva known as gingivitis. Traditionally, the external surfaces (vestibular) of the teeth are more severely affected than the internal surfaces (palatines or lingual), and the maxillary teeth are more affected than the mandibular teeth *(Isogai et al, 1989; Rosenberg et al, 1966; Harvey et al, 1994)* **(Figure 6)**.

FIGURE 6 - COMPARISON OF DENTAL PLAQUE ON THE TEETH OF SMALL DOGS *(Hennet et al, 2004)*



Four-month study on 18 small dogs (<10 kg), 1-8 years old.
Dental plaque is generally very common on the fourth premolar and the first upper molar.

- ***Influence of the size of the dog***

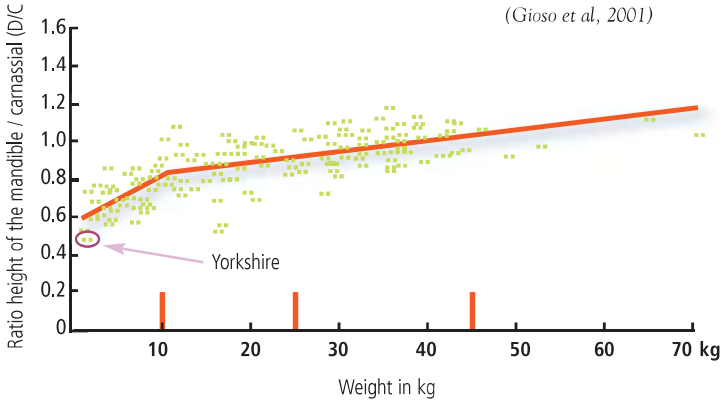
Small dogs (weighing less than 8 kg) suffer earlier and more severely, particularly on the incisors and the internal surfaces of the teeth *(Harvey et al, 1994)*. The smaller the dog, the greater the volume of the teeth in the jaw. As a result, in the event of periodontitis, the gradual destruction of the alveolar bone along the root may threaten the very solidity of the jaw. It has been shown that the ratio [height of the mandible / height of the first molar] in dogs decreases significantly in conjunction with the size of the dog *(Gioso et al, 2001)* **(Figure 7)**.

The loss of a few millimeters of bone in a Yorkshire Terrier has greater consequences than it has for a large dog. The jaw may become so fragile that fractures occur. In Yorkshire Terriers, oral disease represents the primary reason for veterinarian consultation among all age groups *(Veterinary Medical Data Base, 1979-1999)*.

FIGURE 5 - PERIODONTAL DISEASE

FIGURE 7 - RELATIONSHIP BETWEEN THE DOG'S WEIGHT AND THE RATIO "HEIGHT OF THE MANDIBLE (D)/HEIGHT OF THE MANDIBULAR CARNASSIAL (C)"

(Gioso et al, 2001)

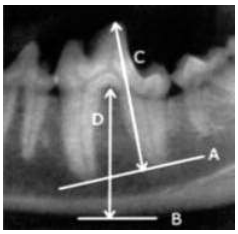


The average D/C ratio of dogs weighing less than 5 kg is 0.64, compared with 1 for dogs weighing more than 30 kg: this means that the height of the mandibular carnassial of a small dog is almost twice that of the height of the jaw itself (Gioso et al, 2001). The record is held by the Yorkshire Terrier, which has a ratio of 0.49.

Dog's weight (kg)	Number of dogs studied	Ratio: height of mandible / height of carnassial (D/C)
< 5.0	33 (14.1%)	0.64 ± 0.019a
5.0-10.0	31 (13.3%)	0.76 ± 0.020b
10.1-20.0	53 (22.7%)	0.87 ± 0.015c
20.1-30.0	45 (19.2%)	0.97 ± 0.016d
> 30.0	72 (30.8%)	1.00 ± 0.013e

Radiograph of the mandibular carnassial of a dog

A = line joining apices of the mandibular carnassial, B = line along mandibular ventral cortex, C = height of the mandibular carnassial, D = height of the mandible

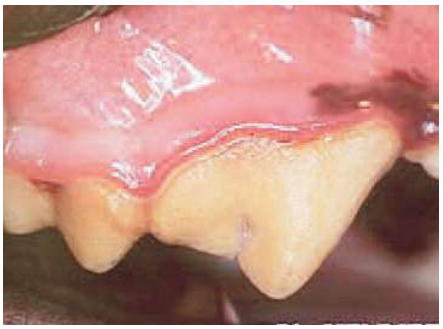


• *Influence of the individual*

The transition from gingivitis to periodontitis is a phenomenon specific to each individual. It depends on limiting the development of infection through oral hygiene and/or the individual's local immune system.

• *Influence of age*

A study has shown that 80% of dogs older than six years of age presented with moderate to severe periodontitis characterized by destruction of bone *(Hamp et al, 1984)*. The supragingival dental plaque is gradually mineralized into calculus by salivary secretions. The calculus may become visible a few weeks after the dental plaque starts to accumulate. In a study of young Beagles, by the age of 26 months, 95% of the dogs presented with a very large accumulation of calculus as well as serious gingival inflammation accompanied by periodontitis *(Rosenberg et al, 1966)*. Periodontal disease is naturally aggravated with age. There is a significant statistical correlation between age and the gingival index (intensity of the inflammation), the calculus index (quantity of calculus), the tooth mobility index and the furcation index (importance of the interradicular bone resorption) *(Harvey et al, 1994)*.



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Gingivitis in dogs. *Accumulation of dental plaque with gradual formation of calculus, responsible for inflammation of the gingiva without destruction of deeper-lying tissue.*

• *Influence of sex*

No sexual predisposition has been shown in the canine species.

> The causes of the disease

Bacterial dental plaque is a natural bacterial film (biofilm) that develops on the surface of the teeth *(Overman, 2000)* **(Figure 8)**.

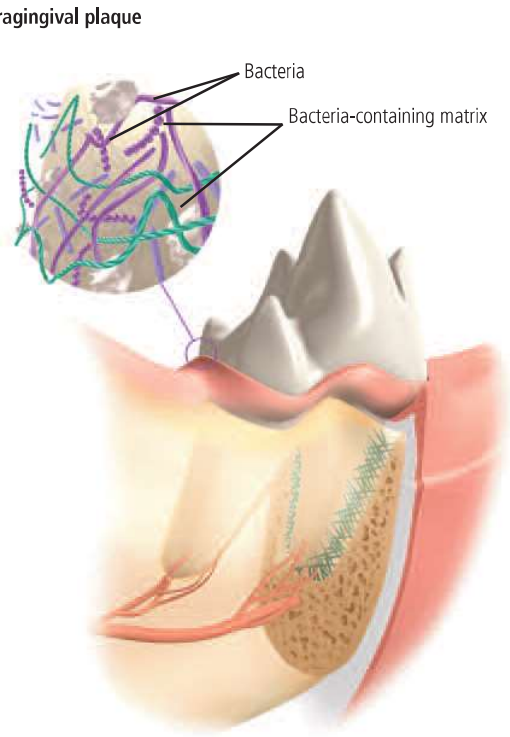
There are more than 350 recorded strains of bacteria in the oral cavity. Periodontal disease is accordingly not caused by a single strain. These bacteria first accumulate in

large numbers on the visible surface of the teeth (supragingival dental plaque), before spreading under the gingiva (subgingival plaque). A milligram of dental plaque contains around 10 million bacteria *(Loesche, 1988)*. In contact with the gingiva, these bacteria naturally provoke an inflammatory reaction, known as gingivitis.

The bacteria that spread under the gingiva may also gradually provoke more deep-lying lesions (destruction of the gingiva, periodontal ligament lesions, lesion of the alveolar bone that supports the tooth). These deep lesions loosen the tooth, which becomes more and more mobile. This characterizes the periodontitis phase. The normal attachment of the periodontium to the tooth is destroyed and migrates to the extremity of the root (= loss of attachment), resulting in the creation of a periodontal pocket. The depth of this pocket depends on the concomitant rate of gingival recession.

Calculus is formed by the gradual mineralization of the dental plaque caused by mineral salts (especially calcium) provided by the saliva for supragingival plaque, or by the gingival fluid in which the gingival crevice is immersed, for subgingival plaque. Calculus is not responsible for periodontal disease, but on a rough surface it is an ideal medium for bacterial dental plaque. In the event of chronic periodontal disease the calculus is indivisible from the bacterial dental plaque. It must be eliminated to enable the eradication of plaque. Limiting the formation of calculus while curbing the formation of bacterial dental plaque is one of the objectives of oral hygiene.

FIGURE 8 - HEALTHY TOOTH AND GUM



The biofilm constituting the dental plaque is made up of numerous bacteria inserted in a glycoprotein matrix that forms a kind of natural glue. The bacteria communicate with each other by chemical signals that trigger the production of proteins and potentially harmful enzymes.

Certain factors (reduced masticatory activity, dental malocclusion, persistence of deciduous teeth, absence of oral hygiene) can advance the accumulation of dental plaque. Other factors that affect the individual's capacity to develop a normal defense reaction include: systemic diseases (diabetes mellitus, kidney failure, liver failure) and innate or acquired immunodeficiency. The individual's capacity to develop an appropriate defense reaction is an innate factor. In general, the dog presents increased dental plaque and calculus accumulation and more serious gingivitis when it is nourished with soft, sticky food compared with firm, fibrous food *(Egelberg, 1965; Kaplan et al, 1978)*.

This apparent advantage in favor of firm, fibrous food applies only when the food is given in the form of large pieces, which encourages the use of the teeth.

► Oral hygiene

While not every individual that presents gingivitis automatically develops periodontitis, gingivitis is the essential preliminary stage in the development of periodontitis. The very principle of oral hygiene is therefore based on the control of supragingival dental plaque. A study of Beagles suffering from light to moderate periodontitis has shown that professional periodontal treatment (scaling, subgingival debridement and polishing), followed by daily brushing, helps reduce the initial loss of attachment and maintains this gain over a three-year period. Additional periodontal treatment every six months over this period does not improve the periodontal condition: neither does this same treatment every six months

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Periodontitis in the dog.
Destruction of the tissue that attaches to the tooth. In the absence of treatment, this will ultimately result in tooth loss.

A

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B

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Aspect of the teeth of the same dog from the right (A) and the left (B). *At right all teeth are presented and the deposits of dental plaque and calculus are very low. At right, the maxillary carnassial is absent, which means that there is no mechanical effect with the mandibular carnassial, resulting in major accumulation of dental plaque and calculus.*

in the absence of daily brushing which helps prevent the deepening of the pockets and the loss of attachment *(Morrison et al, 1979)*.

Oral hygiene can be split into primary hygiene (preventive measures on healthy gingivae before periodontal disease develops) and secondary hygiene (prevention of recurrence, after professional periodontal treatment of a pre-existing periodontal disease). In all cases, primary prevention is always desirable, because it occurs earlier and thefore is more effective. The puppy must be educated from a very early age. **While oral hygiene applies to all dogs and all breeds, the main targets are small and miniature dogs.**

> Brushing

Tooth brushing is the gold standard in terms of controlling supragingival dental plaque.

In humans, an efficacy of the order of 70% inhibition of dental plaque can be asserted, at least for the most accessible vestibular surfaces *(Mankodi et al, 1998; Van der Weijden et al, 1998)*. Studies of Beagles have shown that brushing at least three times a week helps maintain healthy gingivae, while brushing once a week does not *(Tromp et al, 1986a)*. In the presence of gingivitis, only daily brushing will re-establish healthy gingivae *(Tromp et al, 1986b)*. The only clinical study published on tooth brushing in dogs shows that, during a 13-month period, 49 of 51 owners (96%) recall having received brushing instructions and 34 of 51 owners (67%) recall having been shown how to brush teeth; 15 of 51 owners (2%) always brush the dog's teeth several times a week and 12 of 51 owners (24%) do so every day or every second day *(Miller & Harvey, 1994)*.

While being a reference in oral hygiene, brushing is not an easy task for owners to accomplish. Brushing can be complemented with the use of active chemical substances, of which chlorhexidine is still the most effective. In a study of Beagles in which the dogs' teeth and gums were massaged every day with a dental gel containing chlorhexidine and other ingredients, dental plaque on the vestibular surfaces was reduced by 42-49% *(Hennet, 2002)*. Whether these products are applied through brushing or massage, they do necessitate the intervention of the owner and the cooperation of the animal. These limitations have naturally led to the development of other oral hygiene means that do not require the owner's direct intervention. These indirect means comprise collagen-based chewing bones that can or cannot be eaten and specific dental foods.

3 - Role of food in oral hygiene

► Influence of the food's composition

When the composition of a food is changed but not its consistency, no significant influence is observed on the development of periodontal disease. Protein deficiency does not appear to have any consequence *(Ruben et al, 1962)*. A protein-lipid (P-L) diet (50-50% in dry weight) or the addition of carbohydrates (C) (60% C, 20% P, 20% L) does not lead to an aggravation of periodontal disease *(Carlsson & Egelberg, 1965; Egelberg, 1965)*. Osteopenia of alveolar bone induced by secondary hyperparathyroidism with a nutritional cause (Ca/P = 0.1) does not appear to influence the initiation and advancement of periodontal disease *(Svanberg et al, 1973)*.

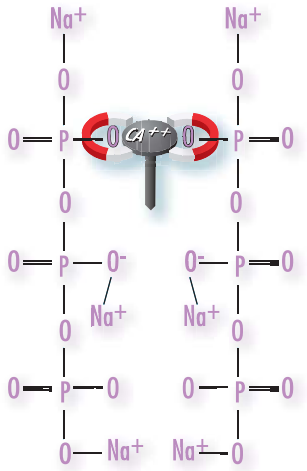
The active agents against dental plaque or calculus can be incorporated into a kibble or a chewing bar. They are then released in the oral environment during mastication. Anti-calculus agents such as polyphosphates were studied first *(Stookey et al, 1993)*. These are phosphate polymers

(pyrophosphate, polyphosphate, hexametaphosphate), some of which present sequestering properties with bivalent cations like calcium **(Figure 9)**.

The chelation of salivary calcium is responsible for inhibiting the formation of calculus. To facilitate the release and the contact with salivary calcium, the polyphosphates must be incorporated in the kibble coating *(Stookey et al, 1993)*.

Other compounds (polyphenols, essential oils, metallic ion salts, etc.) that have exhibited *in vitro* or *in vivo* activity on the formation of dental plaque may also be incorporated. Studies are needed to evaluate their activity in these conditions and to determine the best way of optimizing the release of these substances in the oral cavity (in the external coating or in the kibble proper).

FIGURE 9 - MECHANISM OF SALIVARY CALCIUM CHELATION BY SODIUM POLYPHOSPHATE



The free calcium (Ca^{2+}) in the saliva is trapped by two sodium polyphosphate molecules. It takes the place of two sodium ions (Na^+) and is essential to the formation of calculus.

► Influence of the physical presentation of the food

While it appears logical that a soft food or food in very small pieces would not help the function of the teeth and manducation in canids, interest in the role played by the food is a relatively recent phenomenon.

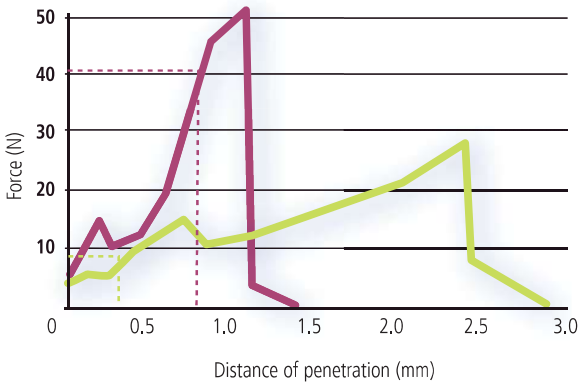
Studies conducted by physiologists have shown that gastrectomized dogs fed with a soft food developed more calculus *(Ivy et al, 1931)*. In a study in which one group of dogs were fed with slices of entire beef, the esophagus, the muscles and a mineral and vitamin supplement, and another group was fed with the same food minced, the dogs in the second group presented with greater accumulation of dental plaque than the dogs in the first group *(Egelberg, 1965)*. Many other studies have confirmed this *(Krasse & Brill, 1960; Kaplan et al, 1978)*. In addition to the absence of mechanical action, a soft food can provoke a reduction in the flow of saliva, a reduction in enzyme secretions and functional atrophy *(Sreebny, 1972)*.

It cannot simply be concluded however that a food in kibble form or a hard food is generally more effective than a soft food. In Egelberg's study (1965) the main factor is the fibrous character of the food rather than its hardness. A multicenter study on 1350 dogs in North America has shown that there is no significant difference between dogs fed exclusively with a dry food and other dogs. On the other hand, dogs that have a number of objects to chew present less calculus, fewer cases of gingivitis and less alveolysis than those that have few or no objects to chew *(Harvey et al, 1996)*.

A dry food is potentially beneficial for dental hygiene if the shape and texture of the kibbles are specially designed for a particular size or breed of dog to contribute to passive tooth brushing mechanism. To scrape the surface of the tooth when the dog eats, the dog must chew so that the tooth penetrates the kibble deeply before the kibble breaks. Size and breed are two parameters that influence the pressure exercised on the kibble at the moment of prehension. Devices have been studied to test the kibble penetration threshold before fragmentation. This enables a comparison between various kibbles **(Figure 10)**.

FIGURE 10 - FORCE NEEDED TO BREAK THE KIBBLE: COMPARISON BETWEEN TWO DIFFRENT TYPES OF KIBBLES FOR SMALL DOGS

(Royal Canin, 2003)



An elastic kibble that resists the pressure on it for longer before breaking enables the tooth to penetrate much deeper and so produces a more pronounced 'cleaning' effect.

► Control of dental hygiene with food

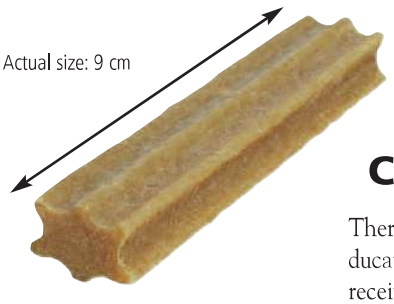
Royal Canin laboratory texturometer.
The texturometer is used to measure the resistance of the kibble to the force of the dog's jaws and teeth. Interchangeable modules mimic the shape and the dimensions of the teeth of dogs of various ages and sizes.

The possibility of controlling dental plaque and the development of periodontal disease by the mechanical action of a chewing bone or specific foods was picked up on in the pet food industry in the early 1990s. Various studies were conducted on dogs with respect to dental plaque, calculus, coloration and gingivitis. Only dental plaque and gingivitis presented a medical interest. Dental coloration, important in humans for aesthetic reasons, is not of interest in dogs.

A significant 19% reduction in dental plaque compared with the control group was obtained after one week of feeding with a kibble specifically targeting oral hygiene (*Jensen et al, 1995*). More recently, significant reductions of 39% in dental plaque and 36% in gingival inflammation were obtained after six months with the same food among dogs weighing 9-25 kg (*Logan et al, 2002*). In another study on the preventive effect of a daily food bone in dogs weighing an average of 23 kg, a significant reduction of dental plaque at 12 and 21 months (but not at 18 months) and gingivitis at 12, 18 and 21 months was observed (*Gorrel & Bierer, 1999*). Unfortunately, the reduction percentages are not given in this study, but an extrapolation based on the graphs show a maximum reduction of dental plaque and gingivitis of 15-20%.

The improvement of oral hygiene by food or dietary complement is accordingly a blossoming field. Besides the action on calculus, dental plaque and gingival inflammation must also be targeted. While the above results are very interesting, they have been obtained on medium-sized dogs, which is not at all the group most seriously affected by periodontal disease. Dogs weighing less than 8 kg are most seriously affected by periodontal disease. Studies must be conducted on specific breeds (Yorkshire Terrier, Poodle, Dachshund, etc) to verify whether the same results can be obtained. The author has conducted a study on 18 small dogs [average 7 kg] belonging to one of two groups depending on their genetic relationship. The test group that was given a dental chewing bar presented significant statistical reductions of 17% in dental plaque and 45% in calculus at the end of four months of study (*Hennet, 2004*).

The methodology of these studies has been questioned, mainly with respect to the evaluation of the dental plaque (*Hennet, 1999; Harvey 2002*). An improvement in the methodology could be considered to achieve results that are not only statistically significant but more importantly, biologically significant.



Example of a dental bar for small dogs that helps limit the accumulation of dental plaque and calculus.
It is recommended that this type of complement be first given after scaling. The resistant yet elastic texture of this type of bar requires the dog to use its teeth to chew before swallowing.

Conclusion

There are various ways of controlling the formation of dental plaque and calculus through manducation, all of which have been studied a great deal. Product shape, texture and appetence have received most attention, as has the possibility of incorporating chemical agents that act on the dental plaque, the calculus or the inflammatory reaction. These innovations have undoubtedly advanced the efforts to prevent periodontal disease.

We're witnessing a new era in veterinary nutrition. After mastering the food at the dietary level, the specific characteristics of the species and the various breeds must be given due consideration. Besides offering a good nutritional balance, the food can also play a role in preventing medical problems. Food with added value in oral hygiene and chewing bars that encourage mastication and have a texture that maximizes the self-cleaning effect contribute to reducing the accumulation of dental deposits and perhaps to preventing gingivitis. While daily brushing remains the best way of preventing periodontal disease, the complementary use of dental foods is recommended.

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Food is a useful tool for the prevention of periodontal disease, as it helps to slow down the development of dental plaque and calculus. The most efficient approach combines a mechanical effect coupled with active ingredients.

Key Points
in the analysis of:

Ingredients that play a role in the prevention of periodontal disease

Kibbles with a dental function have a special form and texture that obliges the dog to chew to obtain a light abrasion of the teeth. However, kibbles are less effective than brushing.

When it comes to oral hygiene, the kibble can support the active agents which are released in the oral cavity during mastication. Upon release, the active agents are incorporated with saliva. Until now, the objective of various solutions has been to limit bacterial proliferation through substances that have a bacteriostatic or even bactericidal effect. The inconvenience of these products is that they disrupt the natural floral equilibrium, because the bacterial action targets all bacteria, even beneficial strains.

New lines of research are focusing on molecules that limit the adhesion of bacteria to the surface of the teeth.

Kibbles with a dental function.

Frequently asked questions about kibbles with a dental function

Q	A
Should kibbles with a dental function be prescribed to a dog that already has calculus?	Prior dental care is essential because a dog that suffers from periodontitis may feel discomfort or pain when eating and refuse to eat the kibbles. The prescription of a specific food with a dental function delays calculus accumulation but it does not remove it.
Which is preferable, a chewing bar or kibbles with a dental function?	Selection is based on the age (kibbles with a dental function are for adult dogs) and the size of the dog, as well as the motivation and the budget of the owner. The ideal solution for dogs is a combination of the two.
Do kibbles with a dental function contain any ingredients against plaque?	**No**, but they can contain nutrients that significantly curb the development of dental plaque.

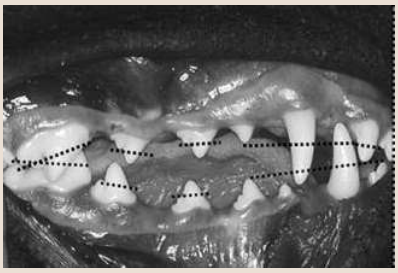
1 • Evaluation of the Logan & Boyce plaque index for a study on the accumulation of dental plaque in the dog

Many index systems have been developed to evaluate the accumulation of plaque on the dental surfaces. The Silness & Loë index *(1964)* focuses on the thickness of the plaque that accumulates on the tooth along the gingival line, while most methods evaluate the spread of the plaque on the dental surface after the action of a colorant; e.g. Quigley & Hein *(1962)*, Turesky et al *(1970)*.

• A modification of the Turesky index was introduced into veterinary dentistry by Logan & Boyce *(1994)*. This index has since been used in several studies evaluating the influence of chewing toys, bones or specific foods on the formation of dental plaque *(Gorrel, 1999; Logan et al, 2002)*. Since this new evaluation method differs significantly from the original Turesky index, the name Logan & Boyce index has been proposed *(Hennet, 1999)*. In the original description of this index, a horizontal division of the surface of the crown in two parts (coronary and gingival) was proposed, without this being precisely described *(Logan & Boyce, 1994)*. Other systems used in human dentistry, like the Navy plaque index, use a horizontal division of the surface of the crown, based on anatomical criteria *(Fischman, 1986, 1988)*. In contrast to the Turesky method, the Logan & Boyce index evaluates the surface and the thickness of the plaque on every half of the dental crown. The intensity of coloration (light, medium or intense) is used to evaluate the thickness of the plaque. The Logan & Boyce index has been validated for use in veterinary dentistry *(Gorrel, 1999)*. But to our knowledge, no study has been published to document the reliability of this index in dogs (intra-observer repeatability and inter-observer reproducibility).

• The aim of this study was to follow the repeatability of the scores provided by an experienced observer (intra-observer repeatability) and to compare the scores provided by an experienced or inexperienced observer (inter-observer reproducibility), utilizing the Logan & Boyce index. The authors were also interested in the influence of a modified Logan & Boyce index, in which the anatomical points are used for a horizontal division of the tooth, and an intensity gradient was used to evaluate the intensity of coloration, so as to improve the repeatability of the measures.

ANATOMICAL POINTS FOR THE HORIZONTAL DIVISION OF THE TEETH



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***Third incisor**: horizontal line to the gingival line at the distal tubercle of the second incisor.*
***Canine**: horizontal line to the gingival line at the level of the cusp of the first premolar.*
***Second and third premolars**: horizontal line to the gingival line at the distal tubercle of the first incisor.*
***Fourth premolar**: horizontal line to the gingival line at the distal talon.*
***First molar**: horizontal line to the gingival line at the oral tubercle of the tooth.*

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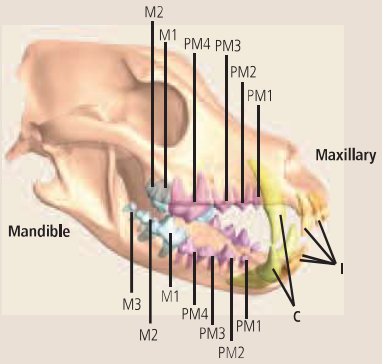
2 • Prevention of periodontal disease: complementing the mechanical action with active principles

A survey conducted in the United States on more than 30,000 dogs presented to their veterinarian shows that calculus and gingivitis are the most common presenting complaints (respective prevalence 20.5% and 19.5%), ahead of otitis externa, dermatoses and infestation by fleas *(Lund, 1999)*. A spectacular advance in the field of veterinary dentistry means we can offer companion animals effective and preservative care. Prevention continues to be the best approach in the fight against the development of this disease, however this is often neglected in comparison with other disease conditions.

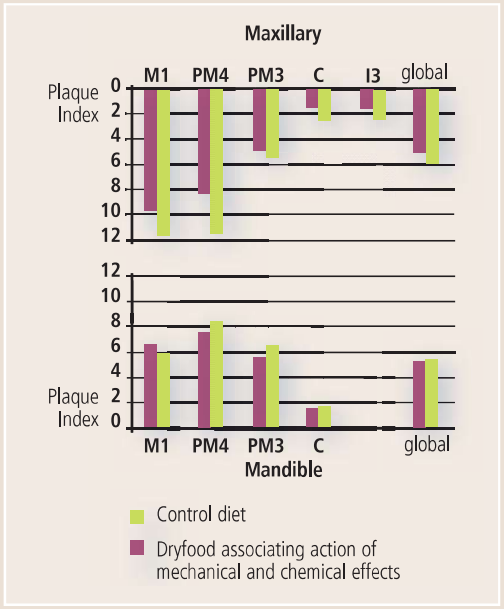
COMPARISON OF PLAQUE AND CALCULUS DEPOSITS 28 DAYS AFTER SCALING

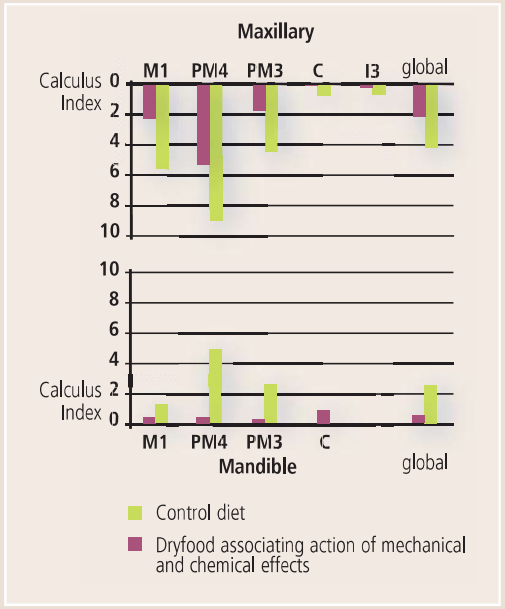
(Sources Royal Canin, 2004)

I3 : incisor 3
C : canine
PM3 : premolar 3
PM4 : premolar 4
M1 : molar 1



After tooth brushing, which is acknowledged as the most effective way of preventing periodontal disease, nutritional supplements and/or specific foods can be very useful.





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3 • Significance of specific phosphates for oral health

The use of polyphosphate salts is significant because they chelate salivary calcium. Chelation varies depending on the type of polyphosphate. To facilitate the release and the contact with salivary calcium, the polyphosphates must be incorporated into the external coating of the kibble.

The various types of phosphate

Phosphates constitute a very large family of more than 150 different molecules (including orthophosphate, pyrophosphate, polyphosphate and metaphosphate). Some phosphates present sequestering properties with bivalent cations such as calcium (e.g. Ca^{2+}). These properties depend on the length of the phosphate chain (the longer the chain, the greater their capacity to chelate bivalent cations) and on the local pH. These types of compounds are used in many human toothpastes *(Sowinski et al, 1998)*.

Phosphates: type of action

The Ca^{2+} cations in saliva have a direct role in the calcification of dental plaque (calculus deposition). The phosphates which are able to chelate polyvalent cations will be able to capture the Ca^{++} cations in the saliva. If polyphosphates are released in the oral cavity they will naturally chelate the salivary calcium in ionic form, thus limiting its integration in the dental calculus matrix. Calcium is then released as normal in the digestive tract and absorbed by the organism in accordance with its needs.

Scientific studies

The anti-calcification effect of hexametaphosphate (HMP) on the dental biofilm has been verified *in vitro* where the formation of calcium hydroxyapatite crystals was shown to be significantly reduced *(White et al, 2002)*.

Beagles fed for one month with kibbles coated with HMP present a significantly reduced calculus deposit (-58%) compared with dogs fed with the same diet when polyphosphates were incorporated into the interior of the kibble *(Cox et al, 2002)*.

The chelating effect varies depending on the type of polyphosphate used, even when the dose is identical. Compared with a control group, the reduction in the calculus deposit after a month among Beagles given kibbles coated with polyphosphates was as follows:

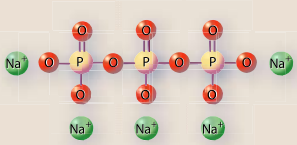
- 36% with hexametaphosphate
- 55% with sodium tripolyphosphate

(Royal Canin Research Centre, 2001-2002)

ACTION OF THE SODIUM TRIPOLYPHOSPHATE

The chelated calcium ions are unavailable for the formation of calculus

MOLECULE OF SODIUM TRIPOLYPHOSPHATE



REACTION BETWEEN SODIUM TRIPOLYPHOSPHATE AND Ca^{2+} CATIONS

Sodium tripolyphosphate + calcium

↕

Calcium tripolyphosphate + sodium

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4 • Significance of zinc salts for oral health

DENTAL PLAQUE

More than 300 strains of bacteria are present in the oral cavity. Streptococci and Actinomyces, which have adherence properties, are the first to colonize the dental biofilm. The primary supragingival plaque will reach the sub-gingival area, where the development of an anaerobic flora is favored. This transition from a commensal flora to a pathogenic bacterial population is responsible for the development of periodontal disease.

Zinc salts have potential beneficial effects in the area of oral health. They can act as oral antiseptics that tend to limit bacterial proliferation in the oral cavity, and can reduce the formation of dental plaque and calculus.

The various zinc salts

There is organic zinc (e.g. zinc citrate) and inorganic zinc (e.g. zinc sulfate, $ZnSO_4^{2-}$).

Scientific studies

Inhibition of calculus formation

In vitro the zinc salts can help limit the deposit of dental calculus by inhibiting the formation of calcium hydroxyapatite complex, and by promoting the formation of more soluble calcareous complexes like tricalcium phosphate.

A study conducted on rats has shown that animals whose teeth are brushed with a toothpaste formulated with zinc salts present significantly less calculus deposit than the control group *(Putt et al, 2002)*. This finding has been confirmed in humans *(Sowinski et al, 2001; Barrea et al, 2001)*.

Inhibition of the production of sulfonated volatile fatty acids

In vitro the zinc salts help control the production of foul-smelling molecules responsible for halitosis *(Weesner, 2003)*.

A study of humans has also shown that zinc salts inhibit the production of foul-smelling volatile fatty acids from 14C-glucose *(Harrap et al, 1984)*.

Inhibition of bacterial growth

The zinc salts present bacteriostatic properties that have been demonstrated *in vitro*, especially a high anti-microbial activity against *Streptococcus mutans* *(Belcastro et al, 1994)*.

This anti-microbial activity has been confirmed in cats. A significant reduction in plaque deposition and the burden of anaerobic pathogenic bacteria involved in periodontal disease have been observed in a group of cats treated with a gel containing zinc salts *(Clarke, 2001)*.

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5 • Significance of specific polyphenols for oral health

Some polyphenol sources can be incorporated into the food to limit the formation of dental biofilm. Green tea, which is rich in active polyphenols (e.g. epigallocatechin gallate or EGCg), is considered to be beneficial in the prevention of periodontal disease.

The various types of polyphenols

More than 8000 types of polyphenol have been identified. Some have a highly complex chemical structure. This decidedly varied group comprises molecules containing a simple phenolic nucleus and highly polymerized compounds (tannins). Naturally present in all living beings, polyphenols play an essential antioxidant role.

Polyphenols: type of action

The bacteriostatic action of certain polyphenols is allied to their antioxidant properties, especially to the presence of the hydroxyl group ($OH^{\cdot}$) in ortho configuration, as well as the presence of the gallate function on the phenolic ring.

Scientific studies

Inhibition of the growth of bacteria in dental plaque

In dogs, the flora of the periodontal pockets is marked by the presence of specific bacteria, such as *Porphyromonas endodontalis*, *gingivalis* and *circumdentaria* (*Isogai et al, 1999*).

• ***In vitro***

Certain phenolic compounds (particularly those of the catechin family) present an anti-bacterial effect against the bacteria in the dental plaque, such as *Porphyromonas gingivalis* and *Prevotella spp.* (*Hirasawa et al, 2002*), *Escherichia coli*, *Streptococcus salivarius* and *Streptococcus mutans* (*Rasheed et al, 1998*).

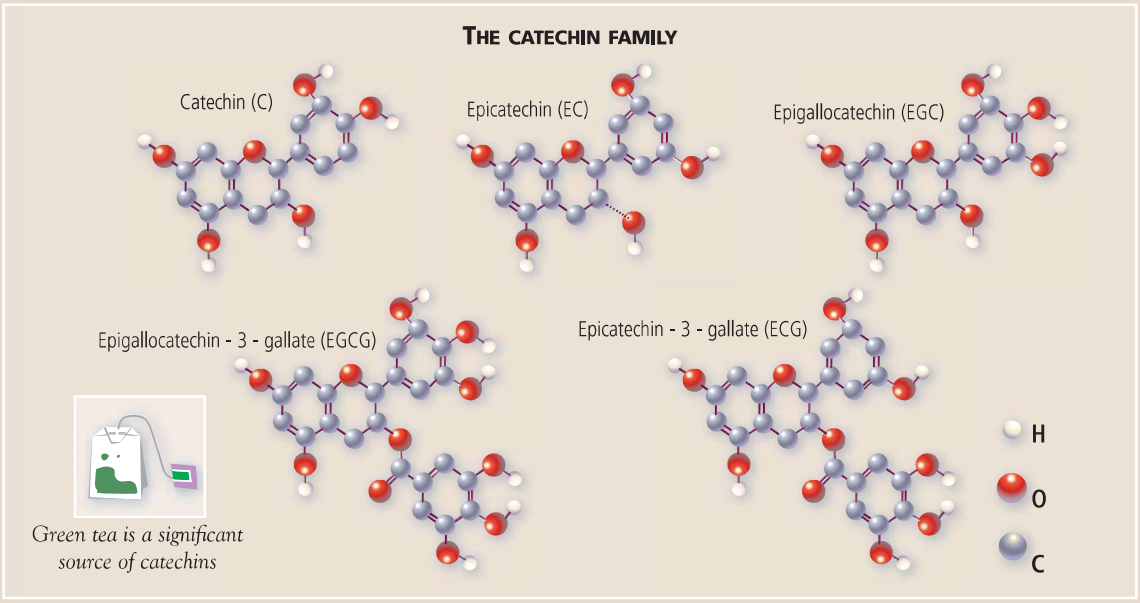
Among the polyphenols present in green tea, epigallocatechin gallate (EGCg) has the strongest bactericidal activity. Its minimal inhibition concentration is between 250 and 500 µg/mL depending on the various strains of *Porphyromonas gingivalis* (*Sakanaka et al, 1996*).

• ***In vivo***

In dogs, a diet formulated with green tea, which is naturally rich in catechins, has helped inhibit the growth of bacteria and after two months, to significantly reduce the *Porphyromonas* percentage in the microbial population of dental plaque (*Isogai et al; 1995, 1992*).

Inhibition of the capacity of bacteria to adhere to the epithelial cells in the mouth

In vitro, the polyphenols contain a gallate function (epigallocatechin gallate or EGCg; gallocatechin gallate or GCg; catechin gallate or Cg), which reduces the capacity of *Porphyromonas gingivalis* to adhere to the surface of epithelial cells (*Sakanaka et al, 1996*).



Green tea is a significant source of catechins

On average, every epithelial cell can capture 300 *P. gingivalis*. At 250 µg/mL of pure polyphenols (which possess a gallate function), the inhibition of the adherence is almost complete, but at 7.8 µg/mL the number of *P. gingivalis* adhering is reduced by 30% *(Sakanaka et al, 1996)*. According to these authors the anti-adhesion capacities of polyphenols will be targeted on the bacteria rather than the epithelial cells.

The adhesion of other bacteria is also limited by polyphenols which possess a gallate function.

At concentrations between 125 and 250 µg/mL the adhesion of *Porphyromonas melaninogenicus* and *Streptococcus sanguis* is reduced by 50%. *Streptococcus sanguis* is one of the first bacteria that leads to the formation of plaque *(Sakanaka et al, 1996)*.

Inhibition of the production of acid metabolites by the bacteria of dental plaque

The bacteria of the plaque (such as *Porphyromonas gingivalis*) generate acids: n-butyric acid, phenylacetic acid or propionic acid. *In vitro*, some polyphenols are capable of inhibiting the production of these acid metabolites generated by the bacteria of the plaque (e.g. *Porphyromonas gingivalis*). This inhibitor effect is due to the presence of the gallate function of certain phenolic compounds, especially EGCg, GCg, and Cg, which are present in green tea *(Sakanaka et al, 2004)*.

ROLES OF POLYPHENOLS

Source: Polyphenols can be extracted from green tea and grapes.

Polyphenols are known among humans for their protective qualities against cardiovascular diseases (hypolipemic effect). In dogs, they are valued for their major antioxidant activity and for their antiseptic role against certain bacteria of dental plaque.

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6 • Significance of specific essential oils for oral health

Some essential oils (e.g. eucalyptus oil) act to reduce bad breath and gingiva inflammation, while curbing bacterial proliferation.

Which essential oils?

Manuka oil, tea oil, eucalyptus oil, lavender oil and rosemary oil.

Oils rich in antioxidant molecules have a bacteriostatic or bacteriocidal action.

Scientific studies

Inhibition of bad breath

Some oils, notably eucalyptus or rosemary oil, help to limit bad breath (halitosis). The significance of eucalyptus oil is due to the fact that it not only masks bad smells, but actively participates in reducing the production of sulfonated volatile fatty acids.

In a study evaluating volative sulfonated compounds (VSCs), cookies containing 0.1 % eucalyptus role significantly reduced bad breath in dogs, compared to a control group *(Waltham Research Centre, 2001)*.

Inhibition of inflammatory activity

In vitro, 1.8-cineol (or eucalyptol), the main eucalyptus monoterpene, inhibits the metabolism of arachidonic acid which produces molecules that cause inflammation (prostaglandins E2 and B4), and cytokines in human monocytes. This mechanism is promissing for limiting the development of nascent gingivitis *(Juergens et al, 2003)*.

Inhibition of bacterial activity

Eucalyptus oil inhibits the growth of certain bacteria involved in periodontal disease such as *Porphyromonas gingivalis*, *Fusobacterium nucleatum*, Streptococcus *mutans* and *Streptococcus sobrinus*. These periodontogenic bacteria are destroyed by 30-minutes of exposure to a solution containing 0.2% of eucalyptus or rosemary oil. The eucalyptus oil inhibits the adhesion of *Streptococcus mutans* *(Takarada et al, 2004)*.

Conclusion

Periodontal disease always develops from the bacterial biofilm that makes up the dental plaque. Any factors that can limit the formation of this plaque are potentially significant. Brushing the teeth with toothpaste adapted for dogs remains the best means of preventing the formation of dental plaque. The kibbles can be complementary to brushing due to their mechanical (crunching-friction) and chemical (anti-plaque/calculus actives) actions.
Further studies are required to determine how to optimize the liberation of these active substances in the oral cavity (in the coating or in the interior of the kibble).

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7 • Short- to medium-term effect of a chewing bar on dental deposits in dogs

Over a short period (28 days)

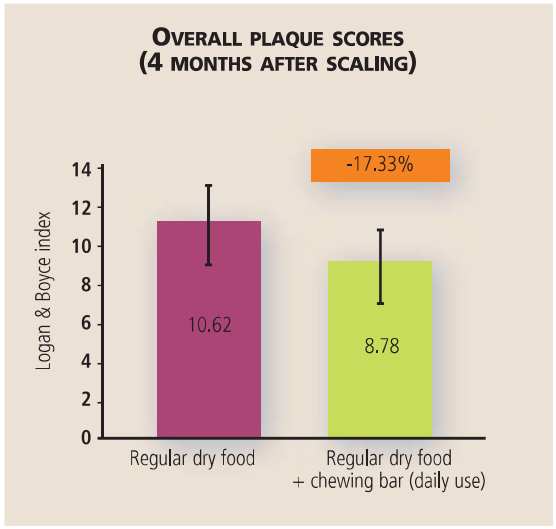
The combination of traditional kibbles and a chewing bar for daily use was associated with a significant reduction in plaque deposition [-27%; p-value < 0.05] and the formation of calculus [-53%; p-value < 0.05], compared with a diet constituted solely of traditional kibbles.

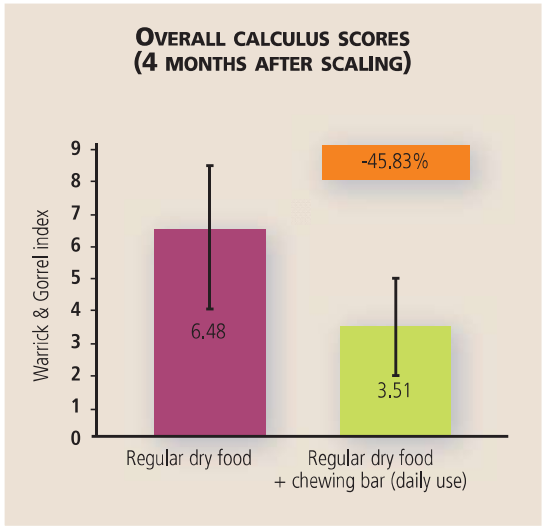
Over a short period (28 days)

The combination of traditional kibbles and a chewing bar for daily use is more effective than commercially available kibbles that are specially designed for oral hygiene, in terms of both plaque [-12%; p-value < 0.084] and calculus deposit reduction [-37%; p-value < 0.077].

Over a longer period (4 months)

The combination of traditional kibbles and a chewing bar for daily use is associated with a significant reduction in plaque deposit [-17%; p-value < 0.05] and the accumulation of calculus [-45%; p-value < 0.05], compared with a food constituted solely of kibbles.





Cavalier King Charles
A specially conceived chewing bar (formula, texture, shape and size) is an effective means of preventing periodontal disease as it limits dental deposits. This product is recommended as soon as the dog's final dentition has erupted.