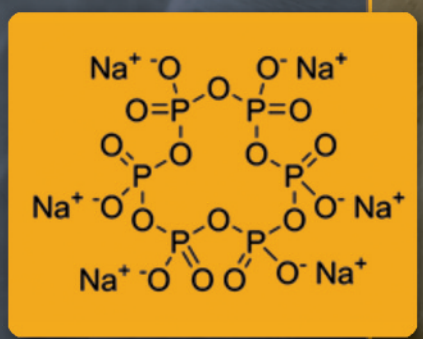

Clinical Effectiveness of Sodium Hexametaphosphate in the Important Role of Canine Calculus Reduction

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Canine dental disease is the most common malady in dogs. Most pet owners consider "dog breath" an expected part of dog ownership and not a treatable or preventable illness. In a landmark study of over 30,000 dogs in numerous companion animal practices, the number-one and -two abnormalities reported on veterinarian-conducted physical examinations were dental calculus and gingivitis, respectively.[1] If left untreated, gingivitis often progresses to painful inflammation and periodontal disease. Further, thousands of dogs and cats are placed under general anesthesia daily for veterinary removal of accumulated plaque and calculus above and below the gumline to help treat halitosis and delay the progression of periodontal disease. Unless the owner initiates a plaque and calculus control program, calculus, gingivitis, and halitosis soon return.

Plaque and Calculus Formation

Within minutes after professional plaque and calculus removal under general anesthesia, salivary proteins actively adhere to the exposed tooth surfaces, creating a conditioning film (the acquired pellicle). This film acts as a connective layer between the enamel and exposed dentin tooth surfaces and a bacterial plaque, which colonizes within hours.

Supragingival plaque forms on the coronal tooth surfaces. Subgingival plaque occurs after microorganisms penetrate and colonize the gingival sulcus. Supragingival and subgingival bacteria form microenvironments of bacterial colonies called *biofilms*, which are separated from the junctional epithelium by a wall of neutrophils. Gram-positive, nonmotile, aerobic cocci bacteria naturally occupy the area between the tooth and gingiva (sulcus). As periodontal infection progresses, the number of bacteria increases at the gingival margin, decreasing the subgingival oxygen. These anaerobic conditions allow gram-negative, motile, anaerobic rods and spirochetes to predominate. Toxins produced by these bacteria cause prostaglandin stimulation and lysosome release, which can damage the neutrophil wall, allowing invasion of the junctional epithelium. Supragingival calculus is composed of plaque, food debris, calcium, and phosphate on coronal surfaces. Over time, calcium and phosphorus, acting on an abundant plaque substrate, form more and harder calculus[2] (**FIGURE 1**).

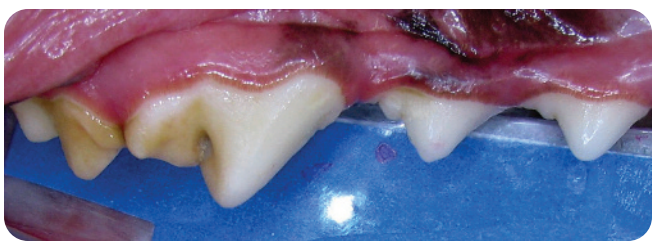

FIGURE 1. Plaque and calculus accumulation around the maxillary fourth premolar in a dog fed dry dog chow for 1 month after a professional dental cleaning.

In dogs, calculus is composed of the calcite form of calcium carbonate mixed with small amounts of apatite. Other calcium phosphates that are common in human calculus are not present in the calculus of dogs. Calcium salts from human saliva are mainly apatite; for dogs, the principal precipitated salt is calcium carbonate (calcite form). This may be due to the less acidic condition and low phosphate concentration in canine saliva compared with human saliva.[3]

Subgingival calculus is preceded by supragingival plaque. With the increased buildup of plaque on the surface of the subgingival calculus, the combination has the potential to extend the radius of destruction and the rate of displacement of the adjacent junctional epithelium, which loosens the seal between the tooth and gingiva, creating periodontal disease.

Toy (smaller) canine breeds are prone to developing periodontal disease because small dogs have short tooth roots, allowing bacteria by-products to destroy a greater percentage of the tooth support than in larger dogs.

Calculus is always covered with bacteria, playing a role in maintaining and accelerating periodontal disease by keeping plaque in close contact with gingival tissue. This decreases the potential for repair and new attachment.

Consequences of Plaque and Calculus Formation

Plaque initiates and promotes continued inflammation of the gingiva as well as the progression toward periodontal disease through the presence of toxic stimulators (cytokines and prostaglandins) of bone resorption. Calculus covered with plaque produces mechanical irritation and physical interference with normal plaque removal during mastication. Once formed, calculus can only readily be removed through time-consuming scaling, often in areas that are difficult to visualize and/or access. The rough surface and porosity of calculus compared with hard enamel encourages the accumulation of more plaque. The combination of plaque and calculus is more irritating to the gingiva than either one alone. The early colonizing bacteria are not pathogenic. They cannot cause periodontitis but can cause gingivitis. As the plaque biofilm continues to grow, periodontal pathogens colonize and become the predominant species.

The establishment of periodontal disease depends on the complex regulatory interaction between bacteria and immune modulators of the host's response. Many

variables influence why some animals develop disease and others do not. Animals with compromised health often cannot fight periodontal pathogens. Diseases and conditions that predispose dogs and cats to periodontal disease include diabetes, hypothyroidism, hyperadrenocorticism, pemphigus, lupus, FIV infection, and FeLV infection.

Toy (smaller) canine breeds are prone to developing periodontal disease because small dogs have short tooth roots, allowing bacteria by-products to destroy a greater percentage of the tooth support than in larger dogs. Additionally, small dogs tend to live longer than larger dogs. The longer an animal lives, the more time periodontal disease has to cause damage. Small dogs are also more prone to dental malocclusions. Crowding abnormalities decrease the normal dental self-cleaning process, predisposing these dogs to periodontal disease.

The Stages of Gingival/Periodontal Disease

Gingivitis is an inflammatory process affecting the soft tissue without clinically affecting the tooth's support (i.e., alveolar bone, periodontal ligament, cementum). Periodontitis is inflammation and destruction involving the periodontal ligament, alveolar bone, and cementum. Periodontal disease can be further classified as active or quiescent based on evidence of inflammation. The American Veterinary Dental College has identified four stages of periodontal disease[4]:

- **Stage 1** (gingivitis) appears as inflammation at the free gingival margin. As gingivitis progresses, advanced gingivitis appears as gingival inflammation, edema, and bleeding on probing. Gingivitis is limited to the epithelium and gingival connective tissue. There is no tooth mobility or attachment loss (**FIGURE 2**). Gingivitis can be present without periodontitis, but periodontal disease cannot occur without gingivitis. Periodontal disease can exist without gingivitis in an area that has been treated and controlled, relieving inflammation but not attachment loss. Gingivitis is reversible with proper therapy: while the patient is under general anesthesia, plaque and calculus are removed through professional dental cleaning (supragingival and subgingival), and the teeth are polished with power instrumentation to remove the biofilm.

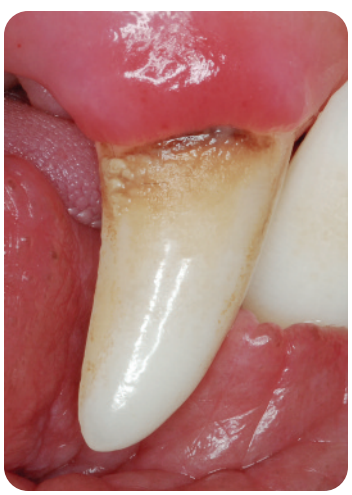

FIGURE 2. Gingivitis. Inflamed gingiva of the maxillary canine secondary to plaque and calculus.

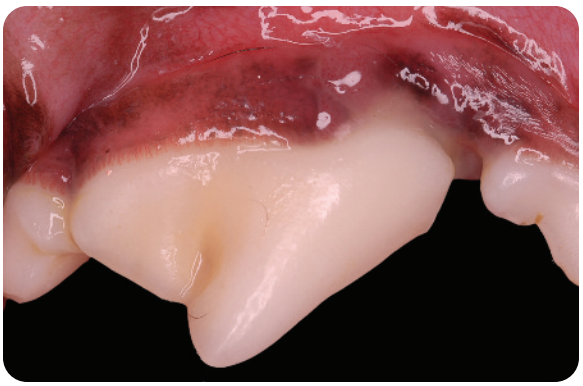

FIGURE 3. Stage 2 periodontal disease of the mesial root of the maxillary fourth premolar.

- Periodontal tissue supports the tooth in the alveolar socket. **Stage 2** (early periodontitis) denotes the early establishment of periodontal disease, resulting in a deeper sulcus called a *pocket* or in gingival recession when there is apical migration of the junctional epithelium. With stage 2 disease, up to 25% of gingival attachment is lost (**FIGURE 3**). Treatment involves removal of plaque and calculus as described above plus local application of the antimicrobial Doxirobe™ (Pfizer Animal Health) in areas of significant pocketing. In nonpocketing defects (gingival recession), removal of irritants and debris from the tooth surfaces usually helps decrease progression of support loss.

- **Stage 3** (moderate periodontitis) is diagnosed when 25% to 50% of support has been lost. Slight tooth mobility often occurs in single-rooted teeth. Early

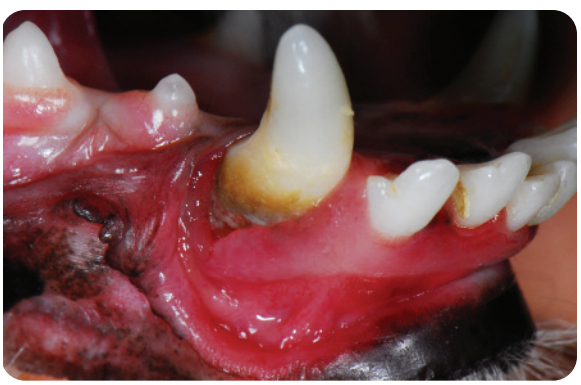

FIGURE 4. Stage 3 periodontal disease of the mandibular canine.

furcation exposure and/or gingival recession may exist (FIGURE 4). Unless the client (and patient) is committed to stringent daily plaque prevention, the best choice is often tooth extraction. Dogs generally do better without teeth compared with living with a painful dentition.

- **Stage 4** (advanced periodontitis) results when >50% of attachment loss occurs. Clinical findings of stage 4 periodontal disease include furcation exposure in multirooted teeth, tooth mobility, deep pockets, and/or gingival recession (FIGURES 5 and 6). Extraction is the treatment of choice in most cases.

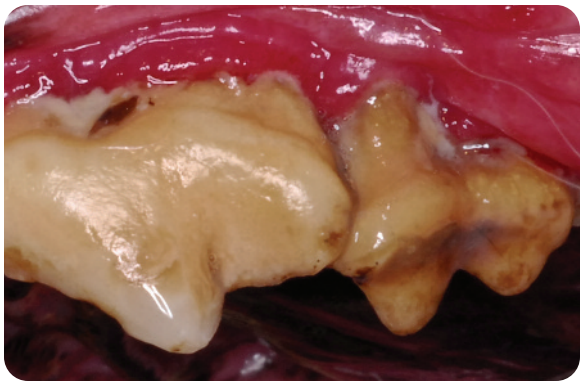

FIGURE 5. Stage 4 periodontal disease of the maxillary fourth premolar and first molar.

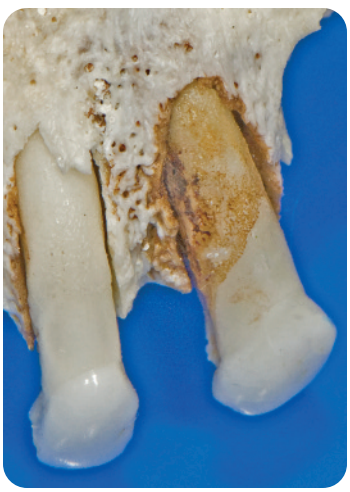

FIGURE 6. Skull showing alveolar bone loss secondary to stage 4 periodontal disease of the maxillary incisors.

Plaque and Calculus Prevention

Although plaque bacteria are responsible for gingivitis and periodontal disease, calculus is more visible by dog owners. Thus, elimination of calculus, which is covered with plaque, will go far to promote oral health. The best approach to decreasing the chance of a dog developing periodontal disease is the prevention of plaque and calculus. The gold standard of plaque control is twice-daily toothbrushing similar to human oral hygiene. Unfortunately, this is rarely accomplished because of (1) the caregiver's lack of desire, time, or ability or (2) the dog's reluctance to accept toothbrushing.[5]

Fortunately, there are other forms of plaque and calculus control, including mechanical and/or chemical management through diets, treats, and additives to drinking water.

Sodium Hexametaphosphate

Sodium hexametaphosphate (SHMP) is classified as a chelating or sequestering agent and a crystal-growth inhibitor. It forms soluble complexes with calcium in plaque by ion-pairing in solution and at the surface through attraction of the cationic (positive) charge of calcium to the negative charges of oxygen on the phosphate anions.[6] These complexes are then carried away in the dog's saliva, preventing the formation of calculus (FIGURE 7).

Several animal studies were conducted to study the efficacy of SHMP to reduce calculus formation in dogs. When beagles were fed plain biscuits coated with SHMP in addition to dry dog chow for 1 month, there were significant dose-dependent reductions (60% to 80%) in dental calculus formation compared with dogs fed control chow and plain biscuits.[7]

Another group of studies was conducted over a 5-year period to see if a crystal-growth inhibitor (1.5% soluble pyrophosphate) or a sequestrant (SHMP) incorporated as a coating on dry dog food would alter calculus formation. Each dog was first followed in three separate studies to determine the amount and thickness of calculus produced in 28 days of eating plain dog chow. The dogs were divided into evenly weighted groups based on calculus formation. All dogs started the study comparing pyrophosphate with SHMP with clean teeth. The dogs fed plain dog chow plus biscuits with topical pyrophosphate showed a 31.8% decrease in calculus formation compared with controls. The group fed SHMP-coated food had a reduction in calculus formation of 60% to 80% compared with controls. In another group, feeding a daily snack of two SHMP-coated plain biscuits in addition to plain

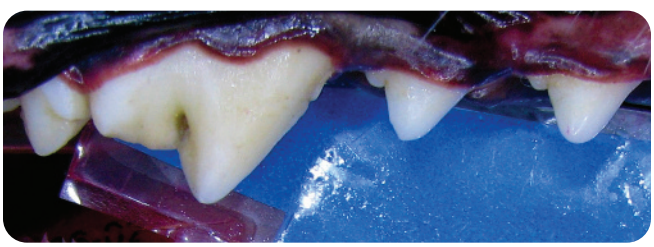

FIGURE 7. Appearance of the maxillary fourth premolar and first premolar in a dog fed SHMP-coated dog biscuits for 1 month.

chow decreased calculus formation nearly 80% compared with controls. The study was continued to see what effect increasing concentrations of SHMP had on the accumulation of calculus. All concentrations of SHMP tested resulted in reductions of calculus formation of 61% or greater, with no apparent dose response. Two significant conclusions from the study were that SHMP proved to be a potent chemical in decreasing calculus formation and that SHMP needed to be applied to the outside of the biscuit, food, or chew to be effective.[7]

In a related experiment, beagles were given a thorough dental prophylaxis immediately before initiation of the study. The animals were then divided into (1) a control group that was fed only a standard diet, (2) a group that was fed two untreated biscuit treats 4 hours after the control chow diet, (3) a group that was fed four untreated biscuits, and (4) a group that was fed biscuits coated with 0.6% SHMP. After 4 weeks of the feeding protocol, the animals were anesthetized and examined for dental calculus. The results showed that the dogs fed the SHMP-coated biscuits had 46% less calculus than the dogs in the other three groups. There were no significant differences in calculus formation between the two groups of dogs fed non–SHMP-coated biscuits. There were no apparent deleterious effects from ingestion of SHMP in this study. Additionally, the SHMP-coated biscuits increased phosphorus ingestion by a minimal amount (66 mg) compared with the 1620 mg of phosphorus ingested through the diet.[8]

Control of calculus by adding SHMP to the surface of dry dog food, biscuits, and/or rawhide chews has been shown to be clinically effective for significantly decreasing the production of calculus compared with controls.

The feeding of SHMP-coated rawhide strips was compared with the feeding of rawhide chews coated in soluble pyrophosphate. Experimental rawhide strips were coated with solutions containing either 0.6% or 1.8% SHMP. The dogs were provided a single meal of dry dog chow each morning followed by a single piece of rawhide 5 hours later. The results confirmed the potential value of feeding SHMP-coated rawhide and suggested little difference in efficacy between the use of 0.6% and 1.8% SHMP in the coating solution.[9]

In another study, the efficacy of SHMP-coated rawhide for calculus prevention was studied using a colony of 26 beagles. The dogs were given a thorough dental prophylaxis to remove all existing dental plaque and calculus immediately before initiating each test period. The dogs were then stratified into three groups of eight or nine dogs according to their previously determined rate of calculus formation. The individually housed dogs were provided a single meal of 250 g of dry dog food each morning with fresh tap water available ad libitum. Five hours later, the dogs in two groups were provided a single rawhide strip either with or without the SHMP coating; the third group received no rawhide strips. This daily regimen was maintained for 4 weeks, after which the dogs were anesthetized and examined for clinical calculus formation. The study procedures were then repeated twice, and the treatment regimens were rotated between the groups so that all the animals could be evaluated

when exposed to each of the three experimental regimens. The provision of noncoated rawhide strips numerically reduced calculus formation by 27.0%, but this reduction was not statistically different from the no-treatment control regimen. The SHMP-coated rawhide strips resulted in a statistically significant reduction in calculus formation of 41.5% compared with the control regimen.[10]

Safety of Sodium Hexametaphosphate

SHMP is used as an emulsifier, sequestrant, and texturizer in foods. It is recognized by the FDA as a safe substance used in food products, including baked goods, nonalcoholic beverages, frozen dairy desserts, jams, jellies, and infant formulas. As a chelator of calcium and iron, SHMP helps prevent scale formation in pipes of potable water used in raising poultry. SHMP is also used as a precipitation retardant for dental impression materials.

In one experiment, 0.93% and 3.5% SHMP were fed to rats (0.6% SHMP is used in canine dental treats), initially elevating the phosphorus concentration, which was reduced through urination. After 60 days, the rats were euthanized and examined. None of the internal organs showed evidence of disease. It was later determined that the oral LD_{50} of SHMP was 3.7 ± 0.17 g/kg.[11]

Two additional oral feeding studies involving SHMP have been published. In one study, dogs were fed 0.1 g/kg/d of SHMP for 1 month. No adverse effects were found.[12,13] In another study lasting 154 days, a dog was fed 1 g/kg/d initially and 4 g/kg/d for the final month of the study. The dog lost weight and developed left ventricular hypertrophy and renal changes.[12] In humans, no health hazards have been associated with the presence of SHMP in foods or potable water.[13]

Summary

Dental disease is a common problem in companion animals. Many owners think that "dog breath" is normal and do not regard it as a sign of illness. However, halitosis is caused by periodontal disease, which can be treated and prevented. Plaque is the root cause of periodontal disease. Calcified plaque is called *calculus*. Prevention of calculus can help control and prevent periodontal disease.

Control of plaque and calculus is important to help prevent periodontal disease. However, most pet owners do not regularly brush their pets' teeth. Control of calculus by adding SHMP to the surface of dry dog food, biscuits, and/or rawhide chews has been shown to be clinically effective for significantly decreasing the production of calculus compared with controls.

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Dr. Bellows reports that he has received honoraria from The Hartz Mountain Corporation.

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