Journal of Veterinary Dentistry
1-10

DOI: 10.1177/08987564241255043
journals.sagepub.com/home/jov
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Effectiveness of a Daily Honeycomb-Shaped Dental Chew in Reducing Calculus, Plaque, Gingivitis and Malodor in Dogs

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Abstract

Periodontal disease in dogs is common. Client compliance with oral hygiene and oral care for pets is low. The gold standard is annual dental prophylaxis under general anesthesia with imaging followed by home care including daily brushing. Clients should be offered methods to reduce calculus, plaque, gingivitis, and resulting halitosis that are time efficient, cost-effective, and easy to administer between annual preventative dental prophylaxis with the goal to move into maintenance phase of managing periodontal disease. This study aimed to evaluate the efficacy of a honeycomb-shaped dental chew in reducing hardened calculus, plaque, gingivitis, and malodor in client-owned dogs in their normal home environment including various breeds, skull types, ages, and weights. Calculus, plaque, and gingival scores with volatile sulfur compounds readings were performed under sedation and evaluated under general anesthesia after 60 consecutive days of receiving a daily honeycomb-shaped dental chew treat. There was an overall statistically significant percentage reduction of calculus (26.6%), plaque (14.2%), and malodor (46.71%). Gingival scores did not demonstrate statistically significant reduction (0.99%). Use of this honeycomb-shaped daily dental chew significantly reduced calculus, plaque, and associated malodor in dogs when fed consecutively for 60 days.

Keywords

canine periodontal disease, calculus, plaque, malodor, veterinary dentistry, canine halitosis

Introduction

Periodontal disease prevalence in dogs has been well established and is an under-treated disease in dogs. The etiology of periodontal disease is multi-factorial and begins with gingivitis, an inflammatory disease. When left untreated gingivitis may progress to periodontitis, spreading inflammation and inciting the host's immune system as destruction spreads to the periodontium and deeper into the bone. The process begins with the pellicle consisting of salivary glycoproteins and extracellular polysaccharides. This pellicle forms less than an hour after a prophylaxis and just hours after tooth eruption. Mature salivary pellicles thicken and are inhabited by initial pellicle colonizers. The microbiota hiding within plaque and calculus progresses from gram-positive to gram-negative anaerobic bacteria. Inflammation from the host immune system and bacterial colonies and their by-products leads to destruction of tissue. The sequence of plaque formation involving early oral microorganism colonization occurs within 6 hours and plaque matures into calculus in 48 hours with the incorporation of minerals from the saliva.[1,2] Periodontal disease can manifest as edema, inflammation of gingiva, halitosis, change in gingival color and bleeding, ulceration, gingival recession and bone loss leading to mobile teeth. The development of periodontal and endodontic lesions can result in abscessation, tooth mobility, oral pain and with advanced lesions, eventual loss of tooth and root health and of function.[3]

Previous research has demonstrated that education is paramount to client compliance with tooth brushing and other measures to prevent the progression of periodontal disease. The educational model used in human plaque control consists of patient education regarding the incidence and cause of periodontal disease, demonstrating "in-office" plaque control methods, primarily tooth brushing, and directing patients to

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other devices like floss or flossing products (flossers), mouth rinses for chemical calculus retardation, anti-microbial benefits and xerostomia, gels, chewing gum, and other plaque control measures. At-home brushing in a dedicated subpopulation of dog owners revealed that only 47% were brushing weekly after 6 months or more after receiving client education and brushing demonstration.[4] Lack of proper oral care has been shown to be a significant risk factor for periodontal disease.[2] Numerous products are available for dental and oral health over-the-counter and online for pets with claims for fresher breath, "clean teeth" reducing calculus and controlling plaque or "promoting oral health" with no required evidence to market those claims. In 1997, The Veterinary Oral Health Council (https://vohc.org/) was established to recognize products that meet a defined standard of calculus and plaque retardation or reduction in dogs and cats.[5]

Client compliance with the "gold standard" of brushing has typically been low and incorporating daily dental chewing materials has resulted in reduction of calculus, less gingivitis and lower risk for attachment loss.[6] One study determined that feeding a daily dental hygiene chew 6 days a week reduced calculus deposits and promoted periodontal health. The long-term effects (21 months) of the dental hygiene chew in 38 mixed breed dogs included reduced calculus, plaque and gingivitis scores and reduced oral malodor measured by a halimeter.[7]

Halitosis is a common complaint of dog owners and affects all breeds. Without client education on the etiology and clinical signs of periodontal disease, pet owners might only recognize oral pathology by malodor. Malodor of the oral cavity often motivates clients to seek veterinary care for their pets. Oral malodor is associated with periodontal disease that commonly affects dogs and cats. Oral malodor can be measured with a trained organoleptic grader and/or a halimeter.[8-10]

This study aimed to evaluate the efficacy of a honeycomb-shaped dental chew[a] in reducing hardened calculus, plaque, gingivitis, and malodor in client-owned dogs in their normal home environment. The study includes various breeds, skull types, ages, and weights. Calculus, plaque, gingival and volatile sulfur compounds (VSC) scoring was performed under sedation and evaluated under general anesthesia after 60 consecutive days of receiving a daily honeycomb-shaped dental chew treat. The patients also received an oral evaluation under anesthesia with periodontal probing and a professional dental prophylaxis at the second evaluation.

Methods and Materials

Thirty-two canine patients were screened for enrollment. At initial consultation (Day 0), the study protocol, methods and materials, and expectations of the client with required visits were discussed with each owner. Clients were instructed when scheduling the initial consultation to fast their dog for 12 hours, but water was allowed ad libitum until the admit appointment time. Clients received a study letter outlining the protocol and follow-ups visits. Clients signed an informed consent and waiver form outlining the study protocol and expectations. Ingredients were listed and clients acknowledged that there were no known allergies to ingredients. Enrollment was voluntary and clients were informed that patients would receive a complimentary dental prophylaxis at the end of the study. If the patient met the inclusion criteria, they were asked if they would like to be included in the study. Clients consented verbally and with written consent for the duration of the study to "not use any home dental care products (e.g., toothpaste, rinses, dental chews), or direct application of any dental products while enrolled in the study including toothbrushes, finger brushes, wipes, and other gels." Clients acknowledged they would not make any changes to diet and that they would comply with the daily honeycomb dental chew administration. Owners further consented that no other hard treats, toys, or dental treats/chews would be offered while enrolled. Each dog served as their own control with a single subject design with each dog serving as a baseline for Day 0 and data compared against their own habits/anatomy and biological environment.

One patient was excluded at initial enrollment due to an oral tumor detected in the caudal maxilla. Another patient withdrew from the study due to a diagnosis of lymphoma after Day 0 scoring.

Patients with visible advanced periodontal disease (stage IV) denoted by severe gingival recession or mobility and dental pathology of enamel hypoplasia were excluded (2 dogs). During the intake and admit appointment for the second evaluation, one owner noted that they fed the chew less than 50% of the recommended times so this patient was withdrawn for non-compliance.

Twenty-seven client-owned dogs completed the study with over 25 different breeds. The mean age was 6.1 years (range 2 to 12 years). The mean weight was 23.69 kg (range 3.72 to 47.73 kg) (Table 1).

The environment remained unchanged with indoor housing typical of client-owned dogs. There were 24 dogs with normal occlusion (Class 0), 2 with Class III malocclusion and 1 with Class II malocclusion in the study.

Inclusion criteria required that the patient had visible calculus on their teeth and upon physical examination was deemed stable enough for sedated examination and general anesthesia. Exclusion criteria included any dog with a current diagnosis or history of cancer, uncontrolled metabolic disease, autoimmune, or immunosuppressive disease, obvious conscious exam findings of signs of stage IV periodontal disease, e.g., mobile teeth or severe gingival recession that prevented the enrolled dog from chewing a dental treat. At day 70, if radiographs or probing depths indicated stage IV periodontal disease, they were removed from the study. Dogs that had received a dental prophylaxis within the last 24 months were also excluded.

Seventy-four percent (20/27) of the dogs had never had a professional dental prophylaxis or dental procedure and of the dogs that had never received a dental procedure the dental prophylaxis free (DPF) time range averaged 5.7 years. Of the 7/27

Table 1. Dog's Signalment.

Breed	Weight (kg)	Sex
Border Collie	25.45	F
Chow Mix	28.86	N
Bassett Hound	28.64	S
Bassett Hound	26.82	N
Beagle Mix	14.77	S
Chihuahua	6.91	S
Shepherd Mix	28.41	N
Brittany Spaniel	21.82	S
Miniature Pinscher	4.68	F
Siberian Husky	20.23	S
German Shorthair	30.45	N
Boxer Mix	27.27	N
Mix	28.86	N
Labrador Retriever	24.09	S
Brussels Griffon	4.98	N
Standard Poodle	21.59	F
Labrador Retriever	37.95	N
Great Dane	47.73	N
English Bulldog	30.23	S
Miniature Pinscher	5.91	N
Australian Shepherd	11.18	N
Shetland Sheepdog	11.09	N
Shih Tzu	8.64	N
Golden Retriever	30.91	M
Golden Retriever	31.82	S
Mastiff Mix	38.64	S
Golden Retriever	41.82	N

(26%) that had received a dental prophylaxis prior to enrollment, the range of DPF was 2 to 12 years with an average DPF 4.1 years. Patients included 15 male dogs (one intact, 14 neutered) and 12 female dogs (three intact, nine spayed) (Table 1).

Study Timeline

Day 0: First consultation: initial screening, patient history, physical exam, rectal temperature, heart rate, and respiratory rate (TPR), body weight, a conscious oral exam, sedation and calculus, plaque, gingivitis scoring and VSC readings. Dogs received a honeycomb-shaped dental chew once daily based on bodyweight for 60 consecutive days.

Day 70 (±2 days): Patient history, physical exam, general anesthesia, calculus, plaque, gingivitis scoring and VSC readings, and a dental prophylaxis. Due to the schedules of client-owned dogs, some second evaluations were performed at 70 ± 2 days. Medetomidine-vatinoxam hydrochloride[b] was used with the recommended manufacturer dosing by body surface area using an intramuscular injection (IM) for sedation. If additional sedation was needed to achieve lateral recumbency and relaxation, methadone[c] was given at 0.2 mg/kg IM. Methadone was required for 9/30 dogs (30%) to provide additional sedation for scoring. Twenty-one of the 30 dogs (70%) evaluated on Day 0 for a sedated exam had adequate sedation with medetomidine-vantinoxam hydrochloride for scoring. Dogs were transferred to a dental operatory and placed in lateral recumbency for scoring. The same trained individual scored calculus, plaque, gingivitis and took halimeter readings for all dogs on both Day 0 and Day 70. The teeth scored included the right maxillary third incisor (103), canine (104), third premolar (107), fourth premolar (108), first molar (109), left maxillary third incisor (203), canine (204), third premolar (207), fourth premolar (208) and first molar (209) teeth (noted as maxillary I3, C, PM3, PM4, M1) and the right mandibular canine (404), third premolar (407), fourth premolar (408), first molar (409), the left mandibular canine (304), third premolar (307), fourth premolar (308), and first molar (309) teeth (noted as mandibular C, PM3, PM4, M1).

A portable halimeter[d] was used for measuring VSC and quantifying malodor numerically (Figure 1) for each dog. A clean plastic straw extension[e] was added to the halimeter for each dog and centered in the buccal area near the maxillary fourth premolar without touching any anatomy. The lips were closed around the straw during the reading. Between VSC readings the dog's mouth was closed to allow for malodor compounds to normalize in the oral cavity.

The halimeter was prepared by allowing the unit time to recalibrate before use. Each dog was measured three times and a mean VSC score was calculated and recorded. The halimeter was reset to 0 before the next measurement was obtained. Measurement of VSCs was recorded first prior to intubation, when possible, to avoid dilution of VSCs.

Gingivitis was scored using a modified Loe and Silness index using a periodontal probe[f].

The grader used the periodontal probe to gently probe on the buccal aspect of the teeth scored. The gingiva was scored as: 0 = no gingivitis; 1 = slight redness and swelling of gingiva, but no bleeding on probing; 2 = moderate gingivitis and bleeding on gentle probing; 3 = significant redness and swelling, spontaneous hemorrhage, or profuse bleeding upon probing[11,12] (Table 2).

Plaque was assessed based on the principle of the modified Logan and Boyce Index with use of an ultra-violet light[g] to aid in visualizing coverage rather than a disclosing solution.[11,12] The following scale was used to assess plaque coverage: A score of 0 = no plaque; 1 = 1–24% of the buccal tooth surface covered; 2 = 25–49% of the buccal tooth surface covered; 3 = 50–75% buccal tooth surface covered; 4 = more than 75% buccal tooth surface covered[13] (Table 3).

Calculus was graded on two criteria, coverage and thickness using a Warrick-Gorrel method and a whole tooth score.[11] The teeth were gently brushed to remove the plaque and then air-dried using an air water syringe to dry the buccal surface. The relative area of coverage criteria for both plaque and calculus was graded on the buccal surfaces of the teeth without division or sectioning. The following criteria were used for calculus: A score = 0 for no calculus; 1 = 1–24% of the buccal tooth surface covered; 2 = 25–49% of the buccal tooth

Figure 1. The portable halimeter used for measuring volatile sulfur compounds and quantifying malodor numerically.

Table 2. Description of Gingivitis Scoring.

Gingivitis Score Value	Description
0	No gingivitis
1	Slight redness and swelling of gingiva
2	Bleeding upon gentle probing
3	Significant redness, swelling and spontaneous bleeding

Table 3. Description of Plaque Scoring.

Plaque Score Value	Description
0	No plaque
1	1–24% of the buccal tooth surface covered
2	25–49% of the buccal tooth surface covered
3	50–75% buccal tooth surface coverage
4	More than 75% buccal tooth surface coverage

Table 4. Description of Calculus Scoring.

Calculus Score Value	Description
0	No calculus
1	1–24% of the buccal tooth surface covered
2	25–49% of the buccal tooth surface covered
3	50–75% buccal tooth surface coverage
4	More than 75% buccal tooth surface coverage

Table 5. Description of Calculus Thickness Scoring.

Calculus Thickness Score Value	Description
0	No calculus
1	Light (thin, chalky)
2	Medium up to 0.5 mm thickness
3	Heavy > than 0.5 mm thickness

surface covered; 3 = 50–75% buccal tooth surface covered; 4 = more than 75% buccal tooth surface covered[13] (Table 4).

Calculus thickness followed the following criteria: 0 = no evidence of calculus; 1 = Light (thin, chalky); 2 = Medium—up to 0.5 mm thickness; 3 = Heavy—greater than 0.5 mm thickness. A periodontal probe was used to assess thickness (Table 5).

Intra-oral photos were obtained of the buccal surfaces of each patient's right and left sides with cheek retraction[h] (Figures 2A–D, 3A–B, 4A–B). After scoring by a trained experienced grader and readings recorded, patients were transferred to a padded recovery cage and directly supervised until in sternal recumbency and monitored until standing.

Dogs were monitored while under sedation with an electrocardiogram (EKG), heart rate, oxygen, and end tidal CO_2 levels with documentation of blood pressure with a multiparameter monitor[i]. Visible dental pathology including missing teeth, discolored teeth, gingival recession, fractured teeth, and other

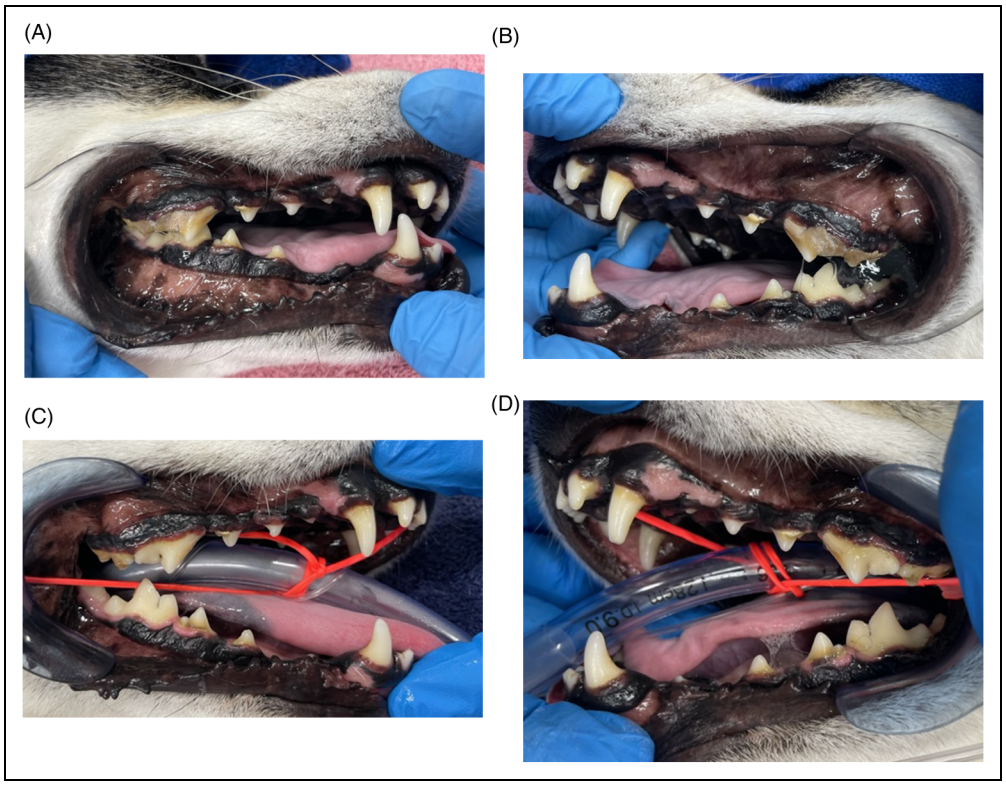

Figure 2. Photographs of dog #1. (A) Day 0—right side. (B) Day 0—left side. (C) Day 70—right side. (D) Day 70—left side.

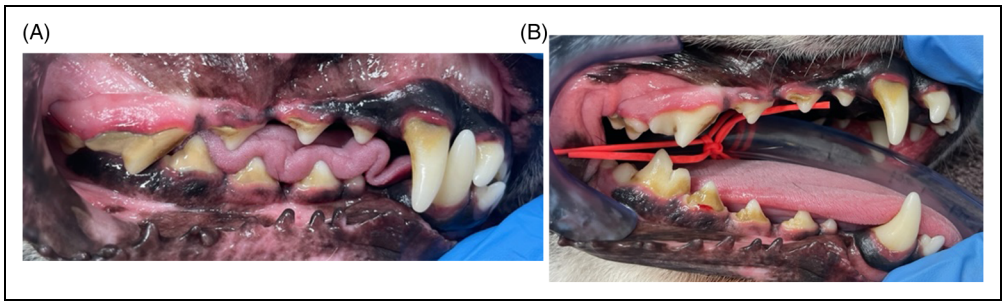

Figure 3. Photographs of right side of mouth in dog #2. (A) Day 0. (B) Day 70.

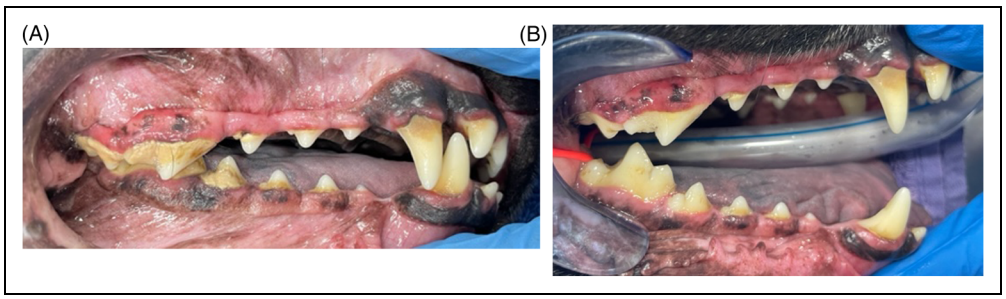

Figure 4. Photographs of right side of mouth in dog #3. (A) Day 0. (B) Day 70.

pathology was recorded to be addressed at a future appointment. One dog was noted to have halitosis secondary to a large black pigmented oral tumor and was withdrawn from the study.

At the discharge appointment the owner was given a daily compliance log calendar to check off as each daily treat was given and consumed. Each client received a new 60-day supply bag of the honeycomb-shaped dental chews based on the dog's weight, hospital contact information for any additional questions or adverse reactions, and verbal and written instructions on administering the chew under direct supervision.

After 60 consecutive days of administration of the daily honeycomb-shaped dental chew, the dog returned for repeat scoring and recording indices. At the Day 70 (± 2 days) visit, clients were instructed to have dogs fasted for 12 hours but water could be offered ad libitum until admit appointment time. Dogs received a physical exam, awake oral exam, rectal temperature, heart rate, respiratory rate, body weight and premedication with maropitant citrate[j] (1 mg/kg) by IM injection. Based on the sedative response of Day 0, anesthesia protocols were adjusted for adequate sedation for each dog. For dogs that did not achieve adequate sedation on Day 0 with the addition of methadone (0.2 mg/kg), dexmedetomidine hydrochloride[k] (0.005 mg/kg) was substituted. This occurred in 4 dogs where more sedation was desired from the Day 0 sedation protocol. An area over the cephalic vein was shaved, aseptically prepped and an intravenous catheter was placed for fluid administration. Lactated Ringers[l] was administered (5 mg/kg/h) during the evaluation and grading. Anesthesia was induced with propofol[m] to effect, dogs were orotracheally intubated and maintained on isoflurane[n]. Eighty-one percent (22/27) of dogs could be maintained at a lower than 1% setting with 100% requiring less than a 2% vaporizer setting with isoflurane.

Dogs were monitored with pulse oximetry, blood pressure, EKG, temperature, respiratory rate, heart rate with a multiparameter monitor. Thermoregulation was maintained using a warming system[o], which included a heating blanket placed beneath the patient and a forced air patient warming blanket[p] over the dog.

Calculus, plaque, gingivitis scoring, and measurement of VSCs followed the same procedure as listed for Day 0. Scoring was performed by the same grader and recording team.

Intra-oral photos of the buccal surfaces of the left and right sides of each dog were obtained with cheek retraction at Day 0 and Day 70 (Figures 2A–D, 3A–B, 4A–B). Anesthesia records were maintained, and parameters were recorded every 5 minutes. After grading and scoring, an oral health assessment and dental prophylaxis with subgingival and supragingival scaling and polishing were performed by a registered technician or board-certified veterinary dentist. The assessment included periodontal probing and charting. Owners had the option of additional imaging and treatment of pathology during the same anesthesia. After completion of the dental prophylaxis and any additional radiographs or treatment was selected, the intubated dogs were transferred to a padded recovery cage and extubated after the swallow reflex returned. A registered veterinary technician was patient-side in recovery until the dog was sternal and continuous visual monitoring occurred until the patient was standing.

Results

Each dog's mean mouth calculus, plaque, and gingivitis scores were determined by finding the mean of all the individual tooth scores. Each dog's measurements for halimeter readings of VSC were recorded per tooth evaluated and the whole mean

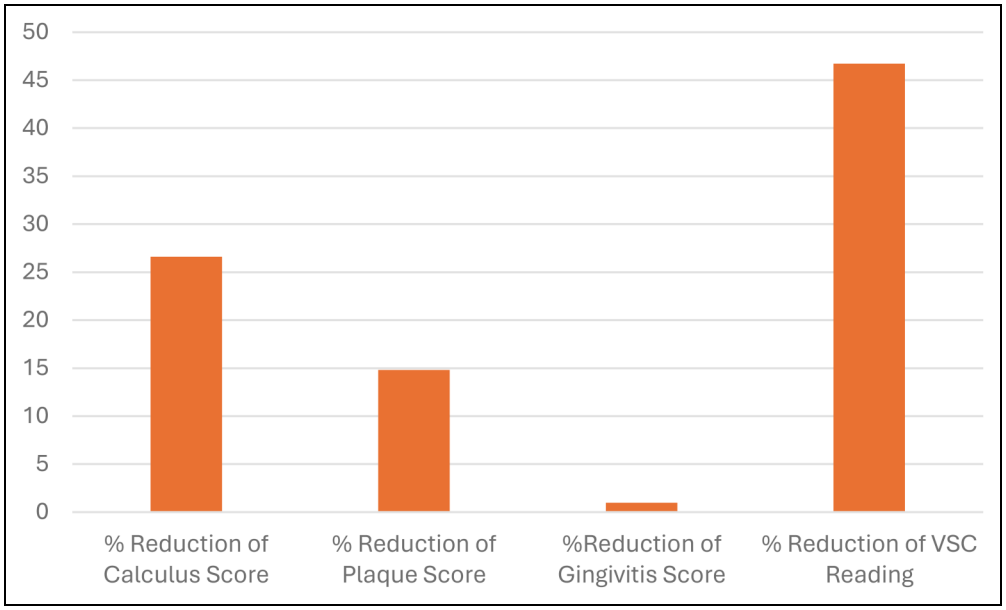

Figure 5. Overall percentage of reduction of calculus, plaque, gingivitis scores, and VSC readings.

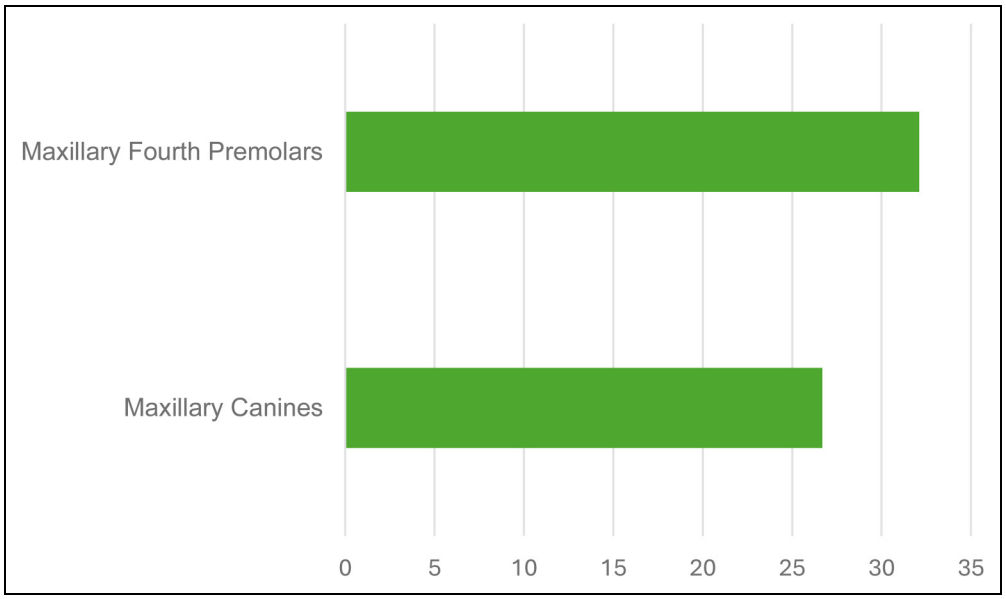

Figure 6. Overall percentage of reduction of calculus scores of maxillary canine versus fourth premolar teeth.

score was calculated per dog. Using a paired *t*-test there was a statistically significant difference in calculus between Day 0 and Day 70 ($P < .00001$). There was a statistically significant difference in plaque between Day 0 and Day 70 ($P < .00001$).

There was also a statistically significant difference in malodor between Day 0 and Day 70 ($P < .00001$). There was not a statistically significant difference in gingivitis between Day 0 and Day 70 ($P = .3302$).

There was an overall percentage reduction of the calculus score by 26.6%, plaque score by 14.2%, gingivitis score by 0.99%, and VSC measurements by 46.71% (Figure 5).

Halimeter readings were reported in parts per billion (ppb). VSC mean reading on Day 0 was 136.93 ppb. After 60 consecutive days of the daily dental chew, the halimeter mean reading was 66.33 ppb for the 27 dogs. The standard deviation for VSC readings was 20.73.

All dogs included in the study ingested the treat without any known adverse events. From Day 0 to Day 70 scoring there was an average weight gain of 0.48 kg. Diet was not adjusted for the additional calories from the chew (69 kcal/medium treat) while in the study so increased weight was not surprising. The honeycomb-shaped dental treat was more efficacious in removing calculus from maxillary fourth premolars than canines, consistent with the functionality of the tooth types and shapes with premolars and molars serving for chewing and grinding (Figure 6).

Discussion

Client compliance with home care such as tooth brushing has been documented to be low.[4,14] Veterinary dental education is clearly needed to increase client compliance. In order to instruct clients in the best practices for oral hygiene and maintenance of periodontal health, education of veterinarians in the pathophysiology of periodontal disease, prevention and treatment is critical. The close daily interaction of veterinary technicians, nurses, and team members with dog owners/care givers necessitates increased education of these team members. They need to have tools to effectively educate the pet owning public that the oral cavity needs preventative care with the same attention that is given to dermatological, cardiovascular, and gastrointestinal disease in comprehensive veterinary care.[14]

Reduction of Malodor and the Role of VSCs

One study found a significant positive correlation between plaque and calculus indices on maxillary fourth premolar teeth and VSC readings. A significant correlation was also found between increased plaque indices and increased VSC readings. The study concluded VSC readings could be used to determine effectiveness of dental hygiene products.[15] Increased levels of VSC may play a role in the pathophysiology of periodontitis by increasing collagen destruction and membrane permeability.[16,17] Professional periodontal therapy with a dental prophylaxis has been shown to reduce malodor for up to 3 months in the dog.[18,19] Studies in humans have used organoleptic measurements, halimeters, and gas chromatography to measure VSC.[9,10] Previous studies have examined gingivitis, plaque, calculus, and halitosis in toy-breed dogs over 9 weeks.[20]

VSC involved in canine halitosis are hydrogen sulfide (H_2S) and methyl mercaptan (CH_3SH). These VSC are byproducts of microbial metabolism and breakdown of proteins. Gram-negative anaerobic bacteria have been associated with VSC.[21,22] Gram-negative bacteria, specifically, *Bacteroides forsythus, Porphyromonas gingivalis, Actinobacillus actinomycetemcomitans, and Prevotella intermedia* have been implicated in the production of VSC originating from substrates in food. VSC have also been previously related to the breakdown of

food and oral cells, proteins, and bacterial byproducts.[10,22] In humans, VSC can be decreased more than 50% with tongue scraping.[23] Tongue coating scores (TCS scores) have had significant ($P < .001$) linear correlation with VSC levels.[24] In human studies, methods of controlling halitosis include mechanical debridement, brushing dentition with and without toothpaste, chewing gum, and tongue scraping. Other methods of controlling halitosis target chemical control with deodorizing solutions, topical application of rinses or gels, mouth rinses, tablets, and a combination of these interventions.[25] Some authors have noted that sulfur compounds have shown to increase the permeability of the oral mucosa allowing substances such as endotoxins and prostaglandins to penetrate the tissue barrier.[26] Research has demonstrated that a change in ingredients of diet, kibble, or chew texture can decrease the level of canine calculus and oral malodor measured by trained organoleptic evaluation and the use of a portable monitor to measure sulfur compounds.[1,27] For example, a chewing rawhide demonstrated greater reduction of calculus scores on supragingival buccal surfaces of maxillary premolars compared to a cereal biscuit.[13] A study with ten Beagles using organoleptic scoring showed significant correlation of halitosis with gingivitis, furcation bone loss, and periodontal probing depths.[28]

Limitations of the Study

The Turesky plaque index, which uses a disclosing solution like basic fuchsin dye, was not performed on Day 0 due to the sedated examination of client-owned dogs and resultant fur staining. Newer technologies like quantitative light-induced fluorescence (QLF) may be beneficial in studies with client owned dogs to avoid staining and provide less subjective grading.[29,30] Plaque score reduction may be underestimated due to the variability of 10–12 days from last dental chew to second evaluation at Day 70.

The benefits of daily dental hygiene may be greatest in the short term after a dental prophylaxis. The gingivitis scores did not show significant improvement in this study. Another study demonstrated after 21 months of feeding a daily hygiene chew the gingivitis scores between the test group and control group were no longer statistically different, but malodor, calculus and plaque scores were still significantly lower.[7] More research is needed to determine the interventional methods and timing to significantly reduce gingivitis. Mechanical removal of plaque in the dog with daily brushing has been demonstrated to control periodontal disease and brushing has been shown to be effective in controlling plaque and calculus build-up.[2,29]

Other limitations of this study include the lack of double blinded scoring and patients entering the study with various degrees of calculus, measured against their own time-zero baseline value. Study design with client-owned dogs and voluntary enrollment results in variable DPF times as well as variabilities in study population relating to breed, skull shape, and patient weight. A larger sample size would provide a better representation of the client owned dog population.

Future Studies

The canine tooth of the dog has an anatomical curvature for apprehending prey and advancing into the prey as it moves forward to escape. The honeycomb-shaped dental treat was more efficacious in removing calculus from maxillary fourth premolars than canines, and similar finding were found in a study comparing rawhides on the calculus reduction scores on maxillary fourth premolars versus maxillary canines.[13] Additional studies and research into chew shape that would allow penetration into a chew to remove marginal plaque and calculus further apical on canine teeth may benefit more morphology-specific areas where calculus begins to form. Considering the variations in tooth morphology, it might be beneficial to use two different types of treats, much like how brushing and flossing together help control periodontal disease in humans.

Tooth brushing of pets by owners usually does not involve the lingual or palatal surfaces of teeth or the tongue thus home care routines that involve tools and treats that remove plaque from teeth and tongue surfaces may provide more efficacious means of controlling malodor and or periodontal disease.[26] The chew used in this study demonstrated a reduction in VSC readings in all study participants. This effect might be attributed to its "flossing action," and while a "scraping action" on the tongue is plausible, it was not specifically evaluated in this study.

Future standardized methods for measuring tongue coating, plaque thickness and distribution with identification of the microbiome, may aid in controlling VSC and/or malodor and the association with periodontal disease.

There are anatomical differences found among dogs including varying occlusions, crowding, root and crown anatomy and pre-existing attachment loss. There are differing factors of host behavioral patterns like mastication or lack thereof, length of time of mastication, and location of mastication (side preference). Diet and edible treats and chews can affect plaque and calculus with size, texture and chemical composition design. Non-edible oral devices (toys) may also provide mechanical influence. There are host-specific factors like salivary secretion volumes, viscosity, composition, plaque composition, variety in bacterial communities, host immune response, and other yet-to-be determined genetic influences which all contribute to individualized challenges in controlling periodontal disease.[4,27]

Understanding that periodontal disease is affected by many factors can help educate owners in caring for their pet's oral health such as anatomical, behavioral, dental aids, and host specific factors. The risk for periodontal disease increases as age increases and body weight decreases.[3] Knowing the factors that the owner may not be able to control (e.g., genetics, host factors) may aid in what outcomes the clients can influence like diet, edible treats, chew toys, and home care such as brushing or water additives.[28,31]

Duration of Study

Traditionally veterinary dental focused study designs have been cross-over "clean mouth" studies where dogs begin with clean

tooth surfaces then are fed a dental diet or daily dental treat, or application of chemicals to tooth surface and evaluated over a specific time period. The control and treatment groups are then switched or "crossed over" and the study repeated. Studies are commonly designed with research Beagles or focused on one breed for uniformity. There are many studies evaluating the efficacy of dental hygiene chews and other methods of plaque control in research canines housed in research facilities that use a cross over trial design of plaque and calculus accumulation over the duration of 7 days, 21 days, 28 days, 14 weeks, 16 weeks, 63 weeks, and 21 months, but not many studies in animals with years of hardened mature calculus.[7,11,20,27,32-36] The variance of ±2 days for the second evaluation may have underestimated the potential of reduction of calculus, plaque, and malodor.

This study is novel due to the evaluation of a non-bone dental chew in over 25 breeds of client-owned canines with mature plaque and hardened calculus of more than 4.1 years.[37,38]

Plaque and Periodontal Disease

Plaque, a microbial biofilm matrix contributes to the development of periodontal disease. Controlling plaque can reduce the host responses of cascading inflammatory mediators and slow attachment loss, destruction of the periodontal ligament, and alveolar bone loss.[30] The results of this study highlight the effects of dental chews in significantly reducing plaque (14.2%). Although frequent brushing is best for plaque control measures, dental chews may provide a useful adjunct to plaque control.[8]

Conclusion

Periodontal disease in dogs is common.[39] Client compliance with oral hygiene and oral care for pets is low. Clients should be offered methods to reduce calculus, plaque, gingivitis, and resulting halitosis that are time efficient, cost-effective, and easy to administer between annual preventative dental prophylaxis with the goal to move into the maintenance phase of managing periodontal disease. Use of this honeycomb-shaped daily dental chew significantly reduced calculus, plaque scores and VSC readings in dogs when fed consecutively for 60 days.

Materials

a. Yummy Combs® Pet's Best Life LLC, North Kansas City, MO, USA
b. Zenalpha®, Dechra Veterinary Products, Northwich, UK
c. Methadone Hydrochloride200 mg/20 ml, Akorn, Lake Forest, IL, USA
d. Halimeter, Model 4170BLU, Interscan corporation, Simi Valley, CA, USA
e. Plastic disposable drinking straw, Grainger, Lenexa, KS, USA
f. Periodontal Probe XP23/UNC-15, Hu Friedy, Des Plaines, IL, USA
g. UV Dental Exam Tool with UV LED light, Hill's, T/D Marketing Tool, Topeka, KS, USA
h. Cheek retractor, Plasdent, Pomona, CA, USA
i. Midmark Multiparameter Monitor 12", Midmark, Versailles, OH, USA
j. Dexdomitor® Zoetis LLC Parsippany, NJ, USA
k. Cerenia®, Zoetic LLC, Parsippany, NJ, USA
l. Lactated Ringer's Solution, Baxter Healthcare Corporation, Deerfield, IL, USA
m. PropoFlo®, Zoetis LLC, Parsippany, NJ, USA
n. Isoflurane USP, Patterson Veterinary, Loveland, CO, USA
o. Hot Dog® Veterinary Warming System, Augustine Surgical Inc, Eden Prairie, MN, USA
p. Bair Hugger Temperature Management Solutions, 3M, St. Paul, MN, USA

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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