Influence of Chewing on Dental Health in Dogs

S Bjone[1], W Brown[2], J. Billingham[3], A. Harris[3] and P M^{c}Genity[3]

[1] School of Psychology, University of New England, Armidale, NSW, 2351, Australia
[2] Animal Science, University of New England, Armidale, NSW, 2351, Australia
[3] Masterfoods Complementary Petcare, UK

Abstract

Periodontal disease is a common problem in dogs. Previous studies have shown that dental deposits in dogs can be reduced by feeding a daily dental chew. This study compares the effectiveness of two chews of different toughness. Both chews significantly reduced plaque (p=0.003) and calculus (p=0.008). The tougher chew required significantly more time (p=0.001) and number of bites (p=0.001) to consume than the standard chew. The increased time and chewing to consume the chew with greater toughness was associated with a directional improvement in oral health, although not statistically significant, as compared to the standard chew.

Introduction

Periodontal disease is the most common oral condition in dogs (Gorrel, 1998; Hennet, 1995), and is possibly the most common disease in small animal practice (Gorrel & Robinson, 1995) or for dogs specifically (DuPont, 1998; Harvey, 1998). A study of 31,484 dogs examined at private veterinary practices in the United States found dental calculus and gingivitis to be the most commonly reported disorders (Lund, Armstrong, Kirk, Kolar, & Klausner, 1999).

A frank definition of periodontal disease would be "gingivitis that has been neglected" (Colmery & Frost, 1986). The disease has a multi-stage development initiated by bacterial plaque that accumulates on tooth surfaces, resulting in gingival inflammation (gingivitis). Gingivitis does not develop unless plaque is present (DuPont, 1998). Plaque that accumulates for extended periods calcifies and becomes calculus, which is difficult to remove without professional treatment (Harvey, 1998). Calculus, in itself, is not detrimental, but it does provide increased surface area upon which more plaque can accumulate (Gorrel, 1998; Lindhe, 1989). The gingivitis which results from plaque accumulation can lead to periodontitis, which gives rise to tissue destruction and possible tooth loss (Harvey, 1998).

Chewing mechanically disrupts the accumulating plaque, and is therefore a self-cleaning action (Hennet, 1995). Chewing also stimulates flow of saliva, which contains anti-bacterial agents that help clean the mouth (Gorrel, 2001). Therefore, chewing's initial physical abrasions as well as the resulting saliva flow help keep the mouth clean. In humans, studies have found no significant benefit from vigorous chewing of raw carrot or apples on oral health (Lindhe & Wicen, 1969; Wade, 1971); however, this may be due to the structure and spacing of human teeth (Lindhe, 1989). The scissor bite of the dog would be expected to impart greater benefit from vigorous chewing than the human teeth occlusion.

Previous studies have shown that dental deposits in dogs can be reduced by feeding a daily dental chew (Brown & M^{c}Genity, 2005; Gorrel & Bierer, 1999; Gorrel & Rawlings, 1996; Gorrel, Warrick, & Bierer, 1999). It was theorised that a greater reduction in dental deposits could be achieved by increasing the toughness of the dental chew, due to increased mastication and time for consumption. The present three-period crossover study investigated the effectiveness of two chews, which were formulated to have significantly different toughness properties. Efficacy was determined by measuring the extent of gingivitis and the accumulation of dental plaque and calculus (clinical signs of periodontal disease) in dogs fed the different dietary regimens. The number of bites and time to consume each of the chews was recorded.

Materials and Methods

Study Animals

Twelve dogs (7 males and 5 females) of mixed breeds were used in the current study. Dogs' ages ranged from 1 to 12 years and body weights ranged from 4 to 27 kg. All dogs were housed in kennels at the University of New England, Armidale, NSW, for the duration of the study. A qualified veterinarian examined all dogs before beginning experimental procedures, and any animal that was considered unsuitable on the basis of health or temperament was excluded from the study.

Animal Ethics and Welfare

Authority to conduct this study was granted by the UNE Animal Ethics Committee, in accordance with Section 25 of the Animal Research Act (1985). Written permission was obtained from all pet owners for the inclusion of their animals in this study. Animals received the highest standard of care throughout the study, in accordance with UNE Animal Ethics Committee guidelines.

Diet

Throughout the study, all dogs were fed a Reference Diet consisting of a premium complete and balanced commercial dry dog food[a] in combination with a premium complete and balanced commercial tinned food[b] in a ratio of 1:2 by weight. The Reference Diet was fed in the morning and any refusals were weighed and recorded. Dogs were fed maintenance energy requirements (MER) as determined by the formula MER (kcal) = 140 x $BW(kg)^{0.75}$ and amounts were adjusted as necessary to maintain ideal body weight. Fresh water was available *ad libitum*.

Study Design

The study was designed as a Latin square three-period crossover study. The following three dietary regimens were fed over the three periods:

1. Reference Diet + Chew A
2. Reference Diet + Chew B
3. Reference Diet + No Chew (Control)

The products tested in this study were two variations (a standard and a modified form) of a dental hygiene chew for dogs. These chews differed in their texture, by the inclusion of additional fibre in the experimental chew to increase toughness, but were otherwise identical.

Chew A: **Standard -** This is an extruded starch-based dental chew for dogs.

Chew B: **Modified -** This experimental chew included additional fibre to create a chew with increased toughness.

Chew A can be described as having a firm but chewy texture with the flexibility of a garden hose. Chew B, on the other hand, is more rigid and does not bend easily.

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[a] Pedigree®Advance™ Adult - Turkey and Rice (MasterFoods ANZ, Raglan, NSW)
[b] Pedigree®Advance™ Energy - Chicken and Rice (MasterFoods ANZ, Wodonga, VIC)

Experimental Procedures

Each period of the experiment consisted of a two-week pre-test phase followed by a four-week test phase. Dental scoring procedures were conducted under light general anaesthesia at the conclusion of each test phase.

Pre-Test Phase (14 Days)
On Day 1, the dogs' teeth were scaled and polished to provide a clean tooth surface. The dogs' teeth were then brushed each afternoon for the remainder of the 2-week pre-test phase using a double-ended toothbrush[c] and dental paste [d]. The purpose of the pre-test phase was to encourage clinically healthy gingivae prior to commencing the test phase. All dogs were maintained on the Reference Diet throughout the pre-test phase but no dental chews were given.

Test Phase (28 Days)
On Day 1, baseline gingivitis scores were recorded. Teeth were then scaled and polished to provide a clean tooth surface. During each 4-week test phase, dogs were fed either Chew A or Chew B each afternoon in addition to the Reference Diet fed each morning. The order of chew presentation per dog was determined by a Latin square crossover design as outlined in Table 1. Dogs received a small or large version of each chew depending on their weight. Both versions had the same cross sectional area and profile, but differed in length. Dogs that weighed under 10kg received the smaller chew (Dogs #1-4), while dogs over 10kg received the larger chew (Dogs #5-12). Dogs in the control group were fed the Reference Diet in the morning and received no chew in the afternoon. Gingivitis, plaque, and calculus scores were recorded on the final day of each test phase. Teeth were then scaled and polished in preparation for the next pre-test phase.

Table 1: Latin square three-period crossover design, showing the allocation of dogs to treatments (Chew A, Chew B, or no chew).

Dog	1st Period	2nd Period	3rd Period
1	A	B	-
2	A	B	-
3	B	-	A
4	B	-	A
5	-	A	B
6	-	A	B
7	-	B	A
8	-	B	A
9	A	-	B
10	A	-	B
11	B	A	-
12	B	A	-

[c] Dentipet™ (Arnolds®, Shrewsbury, UK)
[d] Dentipet™ Premier dental paste (Arnolds®, Shrewsbury, UK)

Dental Scoring

An examiner that was trained in these procedures and blind to designated treatment groups performed dental scoring. The order of assessment was always gingivitis, plaque, and then calculus. Plaque and calculus accumulation and the severity of gingivitis were scored using human techniques modified for veterinary use. The methods are summarized in Tables 2-4. For each dog, 22 teeth were scored for gingivitis, plaque, and calculus:

Left and Right Maxilla:	I3, C, P2, P3, P4, M1
Left and Right Mandible:	C, P2, P3, P4, M1

(I=Incisor; C=Canine; P=Pre-molar; M=Molar)

Table 2: Gingivitis

A modified Löe and Silness (1967) gingival index was used. The buccal gingiva for each scored tooth was divided into thirds (mesial, buccal, distal). Each site was evaluated by the following criteria.

Criteria

0 = No gingivitis
1 = Slight inflammation—slight redness but no bleeding on probing
2 = Mild inflammation—slight redness and swelling, with delayed bleeding on gentle probing of the gingival sulcus
3 = Moderate inflammation—the gingiva is red and swollen and bleeds on gentle probing of the sulcus
4 = Severe inflammation—the gingiva is red or reddish-blue, the gingival margin is swollen, and there is a tendency to spontaneous haemorrhage or profuse haemorrhage on probing and/or ulcerations along the gingival margin

Calculations

A total tooth score for each tooth was obtained by adding together the scores from each of the three sites. The tooth scores from all teeth scored were then averaged to obtain a mean whole mouth score for each dog.

Table 3: Plaque Index

A Quigley and Hein index (1962) as modified by Turesky, Gilmore and Glickman (1970) was used. Plaque was disclosed by applying Red Cote® dental disclosing solution (1.5% D&C Red No. 28; John Butler Company, Chicago, IL, USA) to the buccal surface of each tooth and immediately rinsing with water. The gingival and coronal halves for each tooth were scored for coverage and intensity.

Criteria

Coverage	Intensity
0 = No observable plaque	1 = Light—pink to light red
1 = 1-24% coverage	2 = Moderate—red
2 = 25-49% coverage	3 = Heavy—dark red
3 = 50-74% coverage	
4 = 75-100% coverage	

Calculations

The coverage was multiplied by the intensity factor to give a gingival and occlusal score for each tooth. The gingival and occlusal values for each tooth were added together to obtain a tooth total. The score for each dog was the mean score for all teeth scored.

Table 4: Calculus Index
The Warrick and Gorrel (1997) method was used. The disclosed plaque was removed with a toothbrush and the teeth were rinsed and air-dried. Each vertical third (mesial, buccal, distal) of the buccal surface of each tooth was scored for coverage and thickness.

Criteria

Coverage	Thickness	
0 = No observable calculus	1 = Light	<0.5mm
1 = 1-24% coverage	2 = Moderate	0.5-1.0mm
2 = 25-49% coverage	3 = Heavy	>1.0mm
3 = 50-74% coverage		
4 = 75-100% coverage		

Calculations
The coverage score was multiplied by the thickness score for each tooth surface. The tooth score was the sum of the scores for each of the three tooth surfaces. The sum of the teeth scores was averaged to obtain a whole mouth mean calculus score for each animal.

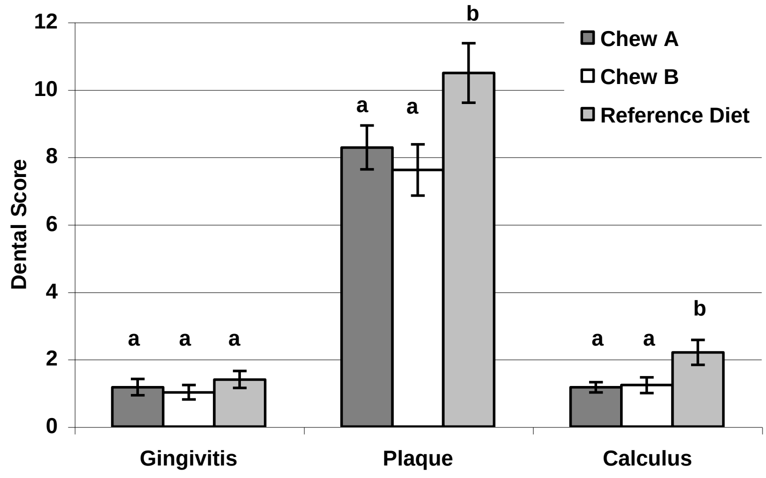
Chewing Measurements
Dogs were filmed eating dental chews three times per each week during each Test Phase. An electronic timer was used to record the time it took each dog to consume the whole chew, starting from the first bite until the chew was finished. The number of gnawing bites executed on the left and right side of the mouth and 'other bites' were recorded using a Laboratory Counter (Clay Adams, Parsippany, NJ, USA) while reviewing the video recordings. Gnawing bites were identified as bites used to sever a piece from the whole chew. Often, the chew was placed to the back of the mouth in the molar region for this gnawing motion. 'Other bites' were any bite that was not a gnaw bite. Total bites were calculated by adding together gnaws and other bites.

Texture Analysis
Texture analysis was carried out using an XHDi Texture Analyser (Stable Micro Systems, Surrey, UK). A penetration test entailed pushing a probe of 6mm diameter into the product at a speed of 1mm/sec, and measuring the force encountered. A fracture wedge test entailed pushing a V-shaped wedge into the product, again at a speed of 1mm/sec, and measuring the force encountered.

Statistical Analyses
Repeated measures analysis of variance was used to determine significant differences in the dental scores for Chews A and B and the reference diet. Two-tailed paired t-tests were used to estimate significant differences in chewing behaviours for Chew A and Chew B. Pearson correlations determined significant relationships between two variables. All alpha levels were set at $\alpha=0.05$.

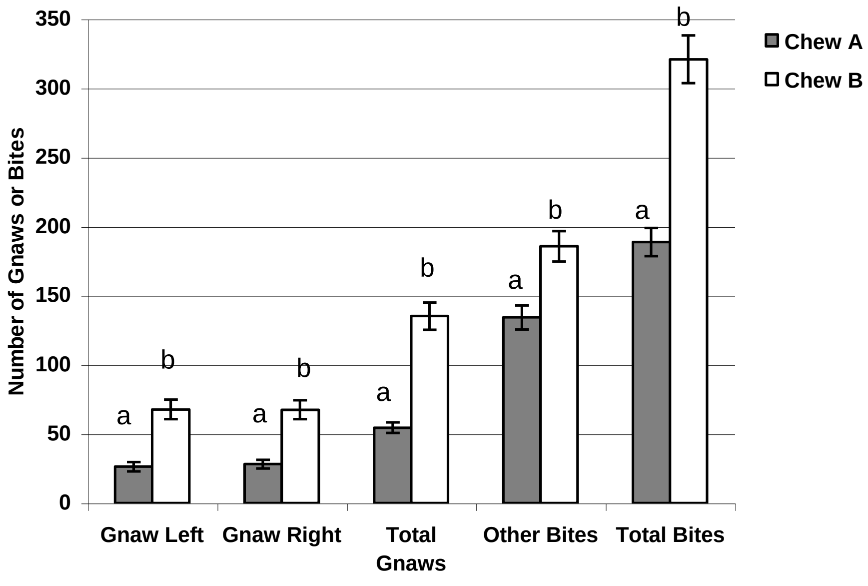
Results

Both chews were effective in significantly reducing the accumulation of plaque ($p=0.003$, $pn^2=0.42$) and calculus ($p=0.008$, $pn^2=0.35$) as compared to the Reference Diet (Figure 1). Gingivitis did not significantly differ during the baseline tooth brushing phases ($p=0.668$), and there was also no significant difference in gingivitis scores between both chews and the reference diet ($p=0.110$). In addition, there was no significant difference in gingivitis scores when comparing the three pre-test tooth brushing phases and the two Chews ($p=0.286$). Dogs had less plaque and gingivitis when fed Chew B than Chew A, but this difference was not significant.



[ab] Means within columns for each dental score not sharing a common superscript letter differ significantly ($p<0.05$).

Figure 1: Gingivitis, plaque, and calculus scores for Chew A and Chew B, and the Reference Diet. Data shown are group means (±SEM) of whole mouth scores for all dogs (n=12).



[ab] Means within columns for each chewing measure not sharing a common superscript letter differ significantly ($p<0.05$).

Figure 2: Mean number of gnaws and bites required to consume Chew A and Chew B. Total gnaws is the sum of left and right gnaws, while total bites includes left gnaws, right gnaws, and other bites. Data shown are group means (±SEM) for all dogs (n=12).

Chew B took significantly more time to consume than Chew A (p=0.001). Chew B also required more gnaws (p=0.001) as well as more 'other bites' (p=0.001) and total bites (p=0.001) to consume compared to Chew A (Figure 2). The bite rate (bites/minutes) did not differ between Chew A and Chew B (p=0.627).

Chew B required more gnaws on the left (p=0.001) and right side (p=0.001) to consume compared to Chew A. Overall, dogs did not show a preference for gnawing on the left or right side for either chew as indicated by the left and right gnaws in Figure 2. However, some dogs did show an individual preference for one side. Table 5 shows side preferences for each dog for both chews. A singular indication of side preference was determined by subtracting the number of gnaws on the right side from the number of gnaws on the left all divided by total gnaws. Eleven dogs were consistent in their side preference for both chews. One dog switched his side preference; Pogo gnawed more on the left side for Chew A and the right side for Chew B. Figure 3 presents two dogs each gnawing on a different side of the mouth.

Table 5: Side preference as determined by the mean percentage of gnaws, left side minus the right side, for each dog and Chew. A positive value indicates a dog that gnaws more on the left side whereas a negative value indicates a dog that gnaws more on the right side. For instance, Charlie gnawed 38.7% more on his right side than his left side for Chew A.

Dog		Chew A	Chew B	Preference
1	Jackie	5.5	9.6	Left
2	Bandit	17.2	23.0	Left
8	Toby	1.4	12.4	Left
9	Blackey	67.9	50.6	Left
12	Reba	38.5	5.4	Left
5	Pogo	6.2	-10.4	Left, Right
3	Snoop	-2.8	-4.9	Right
4	Charlie	-38.7	-14.2	Right
6	Tim	-9.3	-11.9	Right
7	Penny	-32.7	-47.1	Right
10	Smudge	-29.4	-11.7	Right
11	Perdy	-70.7	-30.9	Right

Despite the significant increases in chewing between Chew A and Chew B, there were no significant correlations between total gnaws or total bites and any dental score (gingivitis, plaque, calculus) for either Chew. There were also no correlations found between gnaws on the left or right side and any of the dental scores for the respective side.

Figure 3. Tim (on left) gnaws with his right side while Pogo gnaws with his left.

The texture of the chews was significantly different as confirmed by texture analysis. Fifteen samples of each chew were subjected to texture analysis using the 6mm probe penetration and the fracture wedge tests outlined in the Methods. Figure 4 shows typical force/time plots for the two chews from the penetration test, while Figure 5 shows similar plots using the fracture wedge test. It can be seen in both cases that the peak forces and areas under the curve are significantly larger for the tougher chew B. Table 6 displays mean key texture parameter values across the fifteen samples of each chew.

Figure 4: Penetration test for Chew A and Chew B.

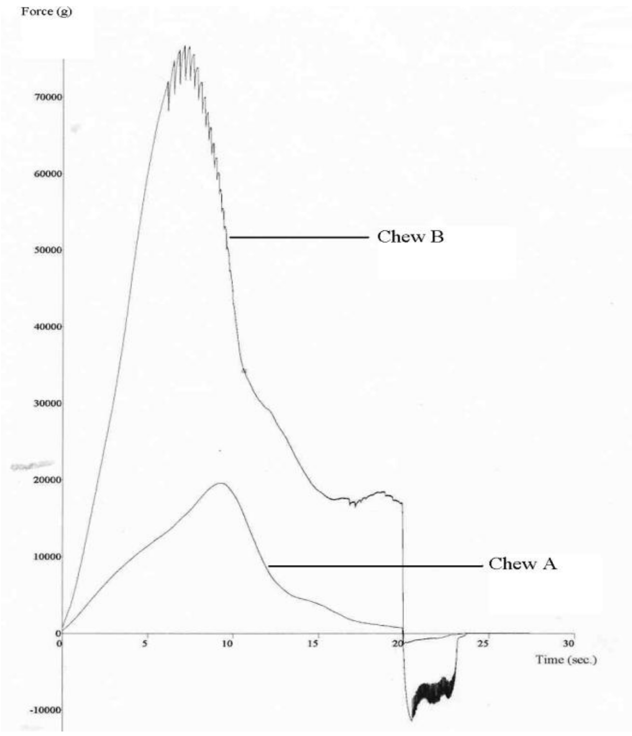


Figure 5: Fraction wedge test for Chew A and Chew B.

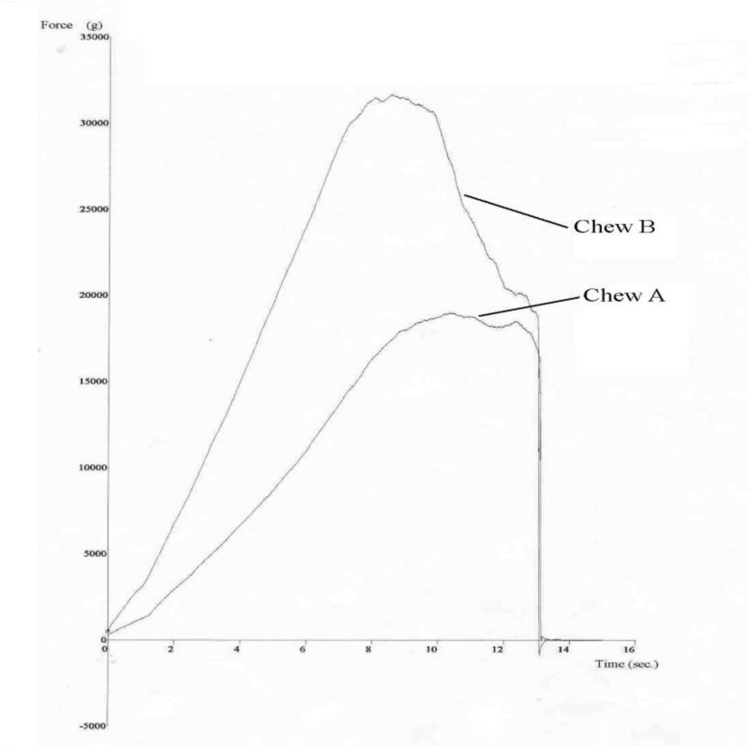


Table 6: Mean texture parameter values for Chew A and Chew B (n=15).

	Penetration Test		Fracture Wedge Test	
	Chew A	Chew B	Chew A	Chew B
Area Under Curve (kg·mm)	203.4	581.6	145.6	261.5
Peak Force (kg)	21.7	72.5	19.4	32.9

Discussion

Both dental hygiene chews were effective in reducing plaque accumulation and the severity of gingivitis as compared to the standard diet, concurring with previous research (Gorrel & Bierer, 1999; Gorrel & Rawlings, 1996; Gorrel et al., 1999; Rawlings et al., 1998). The effectiveness of both Chews was equal to the effect of tooth brushing on gingivitis. Therefore, for those non-compliant owners that do not brush their dogs' teeth daily (Miller & Harvey, 1994), daily provision of a dental chew would still maintain gingival health.

Rawlings et al. (1998) noted that the physical abrasiveness of their dental chew, rather than the chemical activity of chlorhexidine, might have had the greater impact on oral health in their study. The current study tested the physical attribute toughness, which was hypothesized to increase chewing, thus improving oral health. Although Chew B required significantly more bites and time to consume as compared to Chew A, there was no significant difference in any dental measure (gingivitis, plaque, calculus) between the two chews.

It has been found that ‘soft’ chewing is better than no chewing (Egelberg, 1965b) and that chewing a hard diet reduces plaque accumulation and the severity of gingivitis more so than chewing a soft diet (Egelberg, 1965a). It is surprising then that the increased chewing with Chew B did not significantly improve dental health. There may be a correlation between chewing and dental deposit removal; however, current dental health assessment methods may not be adequately sensitive to indicate a significant difference between dental chews. Both chews were identical, except that Chew B had increased fibre content resulting in greater toughness. Possibly, a different ingredient that increases toughness would have a greater impact on dental health. Or, it may be that Chew B was *too* tough requiring a more prehensile quality to grasp the teeth on the initial bite and on retraction.

The higher inclusion rate of the fibre ingredient in Chew B resulted in a different texture, indicated by the greater rigidity of Chew B as compared with the flexibility of Chew A. It is likely that the abrasive action against the tooth surface was altered by this change in texture. It appears that the softer Chew A was in fact more effective at cleansing the teeth on a per bite basis, and that Chew B, by comparison, required many more bites to have an equivalent impact on dental health. Therefore, a larger Chew A, rather than a chew with greater toughness, should be tested to determine the effect of increased chewing of the same material on oral health.

Earlier studies have found an improvement in oral health with the daily addition of oral hygiene chews to the diet, but do not report the number of bites necessary to consume the chews. However, one study did note the time required to consume the current study’s Chew A. On average, it took 2 minutes to consume Chew A with some dogs consuming the chew much faster (ie 44 seconds) (Brown, McGenity, & Servet, 2004). The time required to consume the chews in the present study ranged from 44 seconds (Chew A) to 4.5 minutes (Chew B). These short consumption times may lead the observer to believe that the chew was not effective when the dog “swallowed” it so quickly. However, these short-lived chews do require numerous bites to consume: number of bites ranged from 92 (Chew A) to 530 bites (Chew B). By comparison, the Reference Diet required, on average, between 269 and 827 bites to consume.

The current study is the first to document the number of bites in addition to the time required to consume a dental hygiene chew. While consumption times may be misleading in their brevity, the number of bites required to consume a chew offers a different perspective and illuminates the physical mechanism, chewing, by which these dental hygiene chews work.

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