Cross-sectional investigation of the association between bone feeding and periodontal disease in dogs

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ABSTRACT

Australian dogs are commonly fed bone in their diets and there is a widespread belief that it benefits oral health. However, there is a lack of evidence that dietary bone has either a positive or negative effect on periodontal disease (POD). The aim of this study was to investigate the association between dietary whole bone and severity of POD in dogs. A secondary aim was to investigate the epidemiology of POD in the private setting. Client-owned dogs presenting for routine vaccination were assigned a POD score during clinical examination. Owners were asked to complete a dietary survey questioning access to a range of chewing materials and frequency of feeding. Breed group, address for Socio-Economic Index (SEI), age, sex and neuter status were extracted from medical records. 374 surveys were completed. POD was strongly associated with feeding bone at least weekly as well as with increased dog age and certain breed groups. In particular, Terriers, Gundogs and Working dogs had significantly lower risk of POD when compared with Toy breeds. Sex, neuter status and SEI were not associated with POD. Inclusion of whole bone in dog diets at a frequency of at least once per week could be an effective option in canine dental homecare plans and would need to be confirmed with a prospective study design.

KEYWORDS

Dental prophylaxis, POD, Periodontal disease, Dog, Diet, Bone

INTRODUCTION

Periodontal disease (POD) is one of the most common diseases of dogs (Harvey, 1998) affecting between 60 and 97% of adults (Gad, 1968; Hamp et al., 1984; Kortegard et al., 2008; Kyllar and Witter, 2005). POD has a significant impact on oral health, including pain, tooth loss, and difficulty in eating (Harvey, 1998). POD is also associated with systemic effects including damage to cardiac, hepatic and renal tissues (DeBowes et al., 1996; Pavlica et al., 2008), cardiovascular-related conditions (Glickman et al., 2009), and elevations in systemic inflammatory variables and worsening renal function (Rawlinson et al., 2011).

POD is initiated when a microbial biofilm, known as plaque, establishes along the gingival margin of the tooth. As the disease progresses, the resulting gingivitis and periodontitis causes destruction of the periodontal ligament and alveolar bone (Kinane, 2001). Older and smaller size dogs have a higher risk of POD (Harvey et al., 1994).

There is considerable interest in homecare methods which may prevent the development and severity of POD. There is good evidence of improved POD scores for daily toothbrushing (Harvey et al., 2015; Allan et al., 2019), and weak evidence for products containing chlorhexidine, textured dental foods, proprietary dental treats and short-term use of dental sealants (Roudebush et al., 2005). There is a widespread belief that the addition of chewable bone to the diet of dogs may prevent POD (Billinghurst, 1993; Watson, 1994), but evidence for this is scarce (Freeman et al., 2013). A large scale study (n = 1,350 dogs) found less gingivitis and periodontal bone loss in dogs that had access to a range of chewing materials such as rawhides, bones, biscuits, and chew toys (Harvey et al., 1996). Two small size ($n < 20$) studies reported less dental calculus in research Beagles fed with raw bone (Brown and Park, 1968; Marx et al., 2016). However, to the authors' knowledge, there are no reports investigating the relationship between dietary whole bone and POD in dogs.

The aim of this study was to investigate the association between bone feeding frequency and POD in dogs. A cross-sectional survey was conducted among client-owned dogs attending a veterinary practice in Adelaide, Australia. Our hypothesis was that increased frequency of bone feeding is associated with reduced risk of POD. This report follows the STROBE-VET reporting guidelines (Sargeant et al., 2016).

MATERIALS AND METHODS

Survey population

A cross-sectional survey was conducted for a twelve-month period from July 9, 2010 to July 10, 2011 targeting exclusively apparently healthy adult dogs. Only dogs presenting for routine vaccination at the Walkerville Vet clinic, metropolitan Adelaide, South Australia were recruited. Dogs' owners were asked by nursing staff to participate in a questionnaire survey about their dog's diet and dental care (i.e. exposures). For each dog, questionnaire data were matched to their medical records including residential address, signalment (breed, sex, reproductive status, age), date of most recent dental procedure and their POD status at the time of visit.

POD status

As per practice routine, all dogs' premolars and molars were graded by the consulting veterinarians (AMS, CMD) during the physical examination using the American Veterinary Dental College POD severity scale (American Veterinary Dental College, 2017). In detail, the 5-grade scoring was:

Grade 0 - Clinically normal, gingival inflammation or periodontitis is not clinically evident.

Grade 1 - Gingivitis only without attachment loss; the height and architecture of the alveolar margin are normal.

Grade 2 - Mild periodontitis, less than 25% of attachment loss.

Grade 3 - Moderate periodontitis, 25-50% of attachment loss, but furcation in multi-rooted teeth not yet exposed from one side to the other.

Grade 4 - Advanced periodontitis, more than 50% of attachment loss, or furcation in multi-rooted teeth now exposed from one side to the other.

Dogs with POD grade ≥ 1 were considered POD positive.

Survey questionnaire

A simple paper-based questionnaire was developed with seven questions concerning diet and dental care. The questionnaire had been neither trialled nor validated prior to its full scale use in this study.

Questions asked were: how often are raw bones fed, (choices being never, less than monthly, monthly to less than weekly, weekly to less than twice weekly or twice weekly or more), what is your pet's usual daily diet (with space for types and percentages of each dietary item), what type of bones do you feed, what treats do you feed and how often, how often do you feed fruit and vegetables, do you brush (patient name)'s teeth, how many dental procedures has (patient name) had and when was the most recent one..

Dog owners who agreed to participate then completed the questionnaire immediately following the veterinary consultation. The template of the questionnaire is accessible at DOI: 10.25909/5e321e8dbea9b.

Statistical analysis

Questionnaire and medical data were manually entered into a spreadsheet for data quality control and formatting and then transferred to Stata Statistical Software®, Release 15. The final data and Stata code for the analysis are accessible at DOI: 10.25909/5e321e8dbea9b.

Data handling

Dog breeds were classified into the seven Australian National Kennel Club breed groups (Australian National Kennel Council, 2017). A Socio-Economic Index (SEI) was allocated to each participating owner corresponding to the decile ranking of their residential suburb within South Australia based on the Australian Bureau of Statistics (2016).

Surveyed dogs were excluded from the analysis if their records were incomplete (n=23), conflicting such as by stating a bone type after stating that no bones were fed (n=6), if they were fed other dental treats (n=18) or chicken bones (n=38), or if they received a dental intervention in the previous 12 months (n=20).

Inferential statistics

The association between POD and each of the available predictors was first explored unconditionally using simple mixed logistic regression with owner included as a random effect to account for the fact that some owners had more than one dog surveyed. Significance of the association was assessed by comparing the likelihoods of models with a predictor to the ‘null’ model without predictor using the likelihood ratio test. After verifying collinearity between significant predictors, the final conditional model was build using a forward stepwise process. Potential interactions between pairs of predictors were investigated. The ‘subject specific’ model estimates were converted into ‘population averaged’ values using an approximation approach (Rosenblatt et al., 2018).

RESULTS

Study population

Out of 965 dogs presenting for vaccination, a total of 479 dogs participated in the survey (49.6% participation). Because of missing or erroneous data or interfering intervention, 105 surveyed dogs were excluded from study. Ultimately, 374 dogs, belonging to 342 owners (32 owners presented with two dogs), were included in the analysis. The demographics of the final study population are reported in Table 1. 38.8% (n = 145) of the study dogs were POD positive (POD grade ≥ 1) and 17.7% (n= 66) were never fed bones. Almost a third of the study dogs were Toys (29.3%) and the rest was more evenly split between the other breed groups. Uneven distribution across the ten decile SEI categories suggests that three of the top four suburb categories were under-represented in the study population (Table 1). This may reflect dog ownership across SEI categories in the region.

Unconditional association (univariable analysis)

Table 2 reports the estimated unconditional association between POD and the predictors of interest. Bone feeding frequency was strongly associated with POD. The occurrence of POD decreased significantly when dogs were fed bones at least weekly. Bone feeding frequency categories were therefore binarised into less and at least weekly for simplicity of interpretation. Significant association was also found between age or breed groups and POD. There was no evidence of association between sex, neuter status or SEI and POD. The factors significantly associated with POD were kept for the final multivariable model building (see below).

Conditional association (multivariable analysis)

No evidence of interaction between age, breed groups or weekly bone feeding was found when predicting POD. All three predictors remain strongly significantly associated with POD when combined into the final model ($P < 0.0001$, Table 3). Increase in dog age significantly increased the probability of POD. When compared to Toys dogs, Terriers, Gundogs and Working breed dogs were significantly at a lower risk of POD. Finally, feeding bones at least weekly was significantly associated with an approximately 80% (OR = 0.186) reduction in the probability of POD.

DISCUSSION

The purpose of this study was to investigate the association between canine dietary whole bone and POD. Dogs which were fed bone at least weekly were approximately five times more likely to not experience POD (POD grade of '0') compared to dogs that were fed bone less frequently or not at all. To the authors' knowledge this is the first study to demonstrate reduced risk of POD when bone is included in the diet of dogs.

Our results are supported by the studies of Brown and Park (1968) and Marx et al. (2016) showing an association between bone feeding and a reduction in dental calculus in laboratory Beagles. Calculus, while of little effect itself, contributes to the pathogenesis of POD (Harvey, 1998). Our results are also consistent with the observation in Roudebush et al.

(2005) that mechanical or abrasive chewing materials can reduce the incidence and severity of POD.

Our results indicate that the optimal effect of bone feeding is likely to be at least once per week. However, it is reasonable to suppose that dog owners do not reliably remove old bones before they are replaced. Therefore we consider the reported frequencies to be an underestimate of contact time that the dogs in our study had with bone.

We also found that when controlled for diet and age, dog breeds in the Terrier, Gun dog and Working dog ANKC groups had a lower grade of POD than Toy breeds. This is in partial agreement with Harvey et al. (1994) that smaller breeds of dogs have a higher prevalence of POD.

The study also showed that the prevalence of POD increases with age, a result consistent with Harvey et al. (1994) and Kortegard et al. (2008). The lack of association between POD grade and sex or neuter status is consistent with previous reports.

A distinct feature of this study was the use of a partial POD grading system. The use of only part of the dentition (premolars and molars only) for POD grading was chosen to standardize readings between dogs. One area of the mouth is usually affected to a very different extent than other areas, such that it is more accurate to state that a particular tooth does (or does not) have periodontal disease, rather than that the dog does or does not (Harvey, 1998). The teeth chosen were considered by the authors to be those most important for health and function.

Additionally, a total mouth periodontal score as per Harvey et al. (2008) would have been impractical due to time constraints on the examiners and the requirement for anaesthesia. Use of partial recordings is likely to have led to an underestimation of the prevalence (Kingman and Albandar, 2002) and underestimation or overestimation of the extent and severity (Beck and Löe, 1993). Attachment loss and furcation involvement were estimated visually and therefore gradings are likely to further underestimate true levels of disease in all groups of dogs.

There are a number of limitations of this study due to its design and execution in a private clinic setting. It is likely that there was a sampling bias in the recruitment of the study population. Some of the 486 dogs who were not enrolled could have had owners who were less motivated by animal health and therefore less likely to engage in preventive dental care. In absence of a formal random process, it is also possible that there was an unconscious sampling bias in encouraging some owners to participate more than others. The 105 excluded dogs were likely to have a different average POD grade to those retained in the study. Additionally, the assessors of POD grade (AMS, CMD) were not blinded to the diets of the study subjects. Therefore it is likely that POD grading was differential across bone feeding frequencies resulting into an unpredictable direction of association bias (Dohoo et al., 2009).

Owners' awareness about POD and bone feeding may have resulted into unquantifiable degree of confounding bias. There is a high frequency of bone feeding in Australian dogs (Laflamme et al., 2008) which is likely to be due to a pre-existing belief in the potential benefits of bone feeding. Dog owners at Walkerville Vet are often advised to feed whole raw bone as part of oral health management. Therefore, owners who were more aware and concerned about POD were probably more likely to feed bones while simultaneously adopting other preventive strategies not captured by our study. It is also possible that these dog owners carry a recall bias and were more likely to (over-)report the use of bone in the study questionnaire.

The collection of bone feeding frequency and POD grade at the same time make it impossible to determine if bone feeding preceded or followed the development of POD (reverse causation). For example, it is possible that some owners of dogs with more advanced POD had stopped feeding bones as a response to a reduced ability to chew. Prospective studies would be necessary to show a stronger causal relationship between the feeding of bone and reduced POD severity in dogs.

Further research is also needed to determine the safety of diets containing bone. Billinghurst (1993) states that raw bone is safer due to reduced splinter formation, however Laflamme et al. (2008) raise concerns about gastrointestinal obstruction or perforation and infectious agents. These areas would be fertile ground for future study.

CONCLUSIONS

The present study provides preliminary evidence that bone feeding could provide a benefit to the oral health of dogs. Inclusion of whole bone in dog diets at a frequency of at least once per week could be an effective option in canine dental homecare plans and would need to be confirmed with a prospective study design.

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Table 1. Summary of the demographics of the 374 study dogs surveyed between July 1st, 2009 and June 30th, 2010. Average age is reported as the median age and range between brackets.

Demographic feature	**n**	**average**
Age (year)	374	4 (1-14)
Sex		
Female	168	44.9%
Male	206	55.1%
Neutered		
No	19	5.1%
Yes	355	94.9%
ANKC Breed Group		
Group 1 (Toys)	110	29.4%
Group 2 (Terriers)	68	18.2%
Group 3 (Gundogs)	60	16.0%
Group 4 (Hounds)	11	2.9%
Group 5 (Working dogs)	64	17.1%

Group 6 (Utility)	26	7.0%
Group 7 (Non-sporting)	35	9.4%
Periodontal disease grade		
Grade 0	229	61.2%
Grade 1	96	25.7%
Grade 2	34	9.1%
Grade 3	11	2.9%
Grade 4	4	1.1%
Bone feeding frequency		
Never	66	17.7%
< monthly	68	18.2%
1-3 times per month	78	20.9%
1-2 times per week	68	18.2%
≥ twice per week	94	25.1%
Socio-Economic Index for suburb		

1st decile	6	1.6%
2nd decile	45	12.0%
3rd decile	15	4.0%
4th decile	18	4.8%
5th decile	62	16.6%
6th decile	38	10.2%
7th decile	38	10.2%
8th decile	49	13.1%
9th decile	27	7.2%
10th decile	47	12.6%
Missing value	29	7.8%

Table 2. Observed prevalence of Periodontal Disease (POD) score higher than zero and unconditional association estimated using odds ratio (OR) for all recorded independent variable. OR are population-average estimates of association after accounting for some owners having more than one dog surveyed. For age, the observed prevalence correspond to the median age of 4 year old in the study dogs. *P*-values were generated using the likelihood ratio test and values in bold were significant at the 5% level.

Independent variables	**Observed prevalence**	**OR**	**95% CI**	***P*-value**
Age (year)	47.6%	1.226	1.08-1.39	**<0.0001**
Sex				**0.5324**
Female	41.1%	1.000	-	-
Male	36.9%	0.869	0.56-1.34	0.528
Neutered				**0.7869**
No	36.8%	1.000	-	-
Yes	38.9%	1.148	0.42-3.15	0.789

Breed Group				**0.0001**
Group 1 (Toys)	55.5%	1.000	-	-
Group 2 (Terriers)	32.4%	0.364	0.36-1.52	0.016
Group 3 (Gundogs)	21.7%	0.202	0.2-1.74	0.004
Group 4 (Hounds)	54.6%	1.110	1.11-2.02	0.882
Group 5 (Working dogs)	29.7%	0.343	0.34-1.52	0.011
Group 6 (Utility)	26.9%	0.283	0.28-1.79	0.031
Group 7 (Non-sporting)	48.6%	0.817	0.82-1.52	0.630
Bone feeding frequency				**<0.0001**
Never	72.7%	1.000	-	-

< monthly	50.0%	0.328	0.12-0.92	0.034
1-3 times per month	41.0%	0.234	0.08-0.72	0.011
1-2 times per week	20.6%	0.085	0.02-0.42	0.003
≥ 2 times per week	18.1%	0.072	0.01-0.38	0.002
Weekly bone feeding				**<0.0001**
< weekly	53.8%	1.000	-	-
≥ weekly	19.1%	0.192	0.07-0.52	0.001
Socio-Economic Index for Areas				**0.9028**
1st decile	50.0%	1.000	-	-
2nd decile	40.0%	0.674	0.11-4.20	0.672

3rd decile	33.3%	0.533	0.07-4.24	0.552
4th decile	33.3%	0.523	0.07-3.94	0.530
5th decile	38.7%	0.634	0.10-3.85	0.620
6th decile	34.2%	0.472	0.07-3.15	0.438
7th decile	42.1%	0.690	0.11-4.41	0.695
8th decile	49.0 %	0.965	0.16-5.89	0.969
9th decile	48.2%	0.923	0.14-6.10	0.934
10th decile	40.0%	0.518	0.08-3.30	0.486

Table 3. Conditional association estimated using odds ratio (OR) between Periodontal Disease (POD) score higher than zero and remaining independent variables in the final multivariable model. OR are population-average estimates of association after accounting for some owners having more than one dog surveyed. Bold *P*-values were generated using the likelihood ratio test.

Independent variables	**OR**	**95% CI**	***P*-value**
Age (year)	1.288	1.06-1.56	<**0.0001**
Breed Group			<**0.0001**
Group 1 (Toys)	1.000	-	-
Group 2 (Terriers)	0.259	0.08-0.85	0.026
Group 3 (Gundogs)	0.141	0.03-0.65	0.012
Group 4 (Hounds)	1.202	0.25-5.77	0.818
Group 5 (Working dogs)	0.332	0.12-0.93	0.036
Group 6 (Utility)	0.380	0.12-1.21	0.102
Group 7 (Non-sporting)	0.971	0.39-2.42	0.951
Weekly bone feeding			<**0.0001**
< weekly	1.000	-	-
≥ weekly	0.186	0.06-0.62	0.006