Review of Studies Assessing Plaque Accumulation and Gingival Inflammation in Dogs

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Summary: *Periodontal disease is difficult to measure objectively. Many indices measuring plaque accumulation and gingivitis have been designed for humans, the Silness and Löe plaque index and Turesky modification of the Quigley and Hein plaque index being examples of well-accepted systems. It may, however, be beneficial to consider new or modified measurement systems for dogs, and such veterinary modifications need to be supported and clearly identified. This article reviews the origins of clinical periodontal indices now in common use in studies that examine the effectiveness of oral hygiene products.* ***J Vet Dent 16(1); 23-29, 1999.***

Dogs have been extensively used as a model to study periodontal disease since the 1960's. Studies have been based on clinical, histomorphometric, histometrical, and bacteriological assessments[1,2] and have concerned both spontaneous and experimental (ligature-induced) periodontal disease.

The early stages of periodontal disease have been documented by evaluating plaque accumulation and gingival inflammation. Clean teeth can be obtained either with young dogs that have been subjected to thorough dental hygiene since eruption of permanent teeth, or after thorough scaling and polishing in dogs with pre-existing dental plaque accumulation. The latter method used to achieve clean tooth surfaces is referred to as the "clean tooth model."[4] This model can be improved in order to achieve not only clean tooth surfaces but also clinically healthy gingiva by complementing the scaling/polishing by toothbrushing over a sufficient period of time.

In order to be able to evaluate plaque accumulation and gingival inflammation over time, index systems have been designed. The original descriptions of the index systems are quoted in Table 1. As stated in Carranza and Newman's *Clinical Peridontology:* "Unlike dental caries, periodontal disease does not lend itself easily to objective measurement, because the signs of periodontal pathologic alteration involve color changes in the soft tissues, swelling, bleeding, and bone changes that are reflected in crevice depth changes or pathologic pockets, as well as loss of tooth function because of tooth mobility." This paper is not a complete review of all clinical periodontal indices that have been used in dogs. It is designed to trace the origins of and comment on those indices that are now in common use in studies that examine the effectiveness of oral hygiene products.

Plaque Accumulation

Plaque index systems

Plaque accumulation on crown surfaces can be evaluated by several index systems that have proved to be reliable. The indices estimate plaque quantitatively either in terms of tooth area covered, thickness of material in the area measured, or both.[8]

In 1962, Quigley and Hein described a plaque index (PI) based on assessment of plaque coverage on teeth after disclosing with basic fuchsin.[32] In their system, plaque was assessed on buccal, labial, and lingual surfaces of teeth. The modification introduced in 1970 and known as the Turesky index or Turesky modification of the Quigley and Hein index incorporates a more specific description of plaque accumulation on the gingival third of the crown surface.[36] The Turesky plaque index emphasizes the difference in plaque accumulation on the gingival third of the tooth and tends to overscore the incisal half of the crown at the expense of the gingival margin.[7,8] Plaque in this system is defined as "stainable material" because it usually includes pellicle as well as bacterial deposits.[8] Different dyes have been used since the original description. Most are red dyes such as FD and C red # 3 (erythrosine). Antimicrobial activity of disclosing dyes has been mentioned but is seldom considered in studies where it is used. Erythrosine and fluorescein have been shown in vitro to inhibit most gram-positive and gram-negative organisms associated with dental plaque and to be bactericidal on selected strains.[2] Clinical significance in longitudinal studies is unknown.

The plaque index originally described by Silness and Löe (1964) and later clarified more precisely by Löe in 1967 is based on assessment of the thickness of plaque accumulation along the gingival margin on four areas: distal-facial, facial, mesial-facial, and lingual.[26,34] After drying of the tooth surface, plaque is detected by running a pointed probe across the tooth surface at the entrance of the sulcus. In this index, no attention is given to the coronal extent of the plaque.[8] This restriction can be supported as Marthaler stated in a discussion paper "from the viewpoint of pathogenicity for the periodontium; however, plaque at the gingival margin may be considered to be more important."[30] It has been reported to be a "disruptive" index, as plaque must be disturbed to differentiate between scores of 0 and 1.[8]

Both of these PIs as well as others have been used in numerous human studies.[8] Recently, veterinary studies have focused on the ability of specific diets or chewing devices to remove or prevent plaque accumulation on tooth surfaces. A veterinary modification of the Turesky index has been introduced[28] and used in numerous studies;[9,10,15,27,28,33] both coverage and thickness are assessed. Thickness is assessed through the color intensity left by a disclosing dye. With this modification, it mimics the Lobene stain index,[25] which has demonstrated as reproducible (intra-examiner correlation) but less reliable (inter-examiner correlation) results than the original Turesky modification of the Quigley and Hein plaque index, reliability being low for the stain index.[29] Other modifications include the division of the tooth surface into gingival and occlusal halves which are scored separately, and use of the 0-4 scale (tooth surface is divided in thirds), instead of the 0-5 scale (tooth surface is divided in fourths) in the original index.[36] With these latter modifications, greater emphasis is given to coronal extent of plaque

Table 1. Plaque Index and Stain Index Systems

Silness and Löe Plaque Index System[26, 34]

After the tooth has been properly dried, plaque is detected first with the naked eye, then assessed by running a pointed probe on the neck of the tooth along the gingival margin and assessing the amount of plaque collected on the probe. Each of the four gingival areas of the tooth (distal-facial, facial, mesial-facial, lingual) is given a score from 0 to 3.

0 No plaque in gingival area. After the tooth has been properly dried, no soft matter adheres to the point of the probe which is run across the tooth surface at the entrance to the gingival crevice.

1 No plaque can be seen with naked eyes but a film of plaque adhering to the free gingival margin and adjacent area of the tooth can be detected with the pointed probe.

2 Moderate accumulation of soft deposits within pocket or on free gingival margin area can be seen with the naked eye.

3 Heavy accumulation (1-2 mm thick) of soft matter in the pocket and/or on the adjacent tooth surface.

Turesky et al. Modification of the Quigley and Hein Method (Turesky Plaque Index)[32, 36]

Plaque is disclosed with 0.075 per cent basic fuchsin (in humans, a 30-second mouthrinse is followed by two rinses of water). A score of 0-5 is assigned to each facial and lingual nonrestored surface of all teeth except third molars, as follows:

0 No plaque.
1 Separate flecks of plaque at the cervical margin of the tooth.
2 A thin continuous band of plaque (up to 1 mm) at the cervical margin of the tooth.
3 A band of plaque wider than 1 mm but covering less than 1/3 of the crown of the tooth.
4 Plaque covering at least 1/3 but less than 2/3 of the crown of the tooth.
5 Plaque covering 2/3 or more of the crown of the tooth.

An index for the entire mouth is determined by dividing the total score by the number of surfaces examined.

Logan and Boyce Modification of the Turesky Plaque Index[28]

Plaque is disclosed with 2% erythrosin solution gently applied to the crown surface and immediately rinsed with water. The crown surface is horizontally divided; the gingival and coronal halves are scored. Both coverage and thickness are assessed. *The facial surface can also be divided into thirds: mesial, facial or middle, distal.*

Coverage

0	No observable plaque
1	Less than 25% coverage
2	Between 25% and 50% coverage
3	Between 50% and 75 % coverage
4	Between 75% and 100 % coverage

Thickness

1	Light	Pink to light red
2	Medium	Red
3	Heavy	Dark red

The score for each tooth half is calculated by multiplying the coverage and thickness scores. Gingival and coronal scores are added to give the total score per tooth.

Lobene Stain Index[25]

The index involves two measurements, one for intensity and one for area, on the lower and upper six anterior teeth as follows:

Area

0	No stain detected, only tooth color
1	Stain up to 20% of tooth region
2	Stain between 20% and 40% of tooth region
3	Stain between 40% and 60% of tooth region
4	Stain between 60% and 80% of tooth region
5	Stain over 80% of tooth region

Intensity

0	No stain
1	Light stain
2	Moderate stain
3	Heavy stain

on tooth surface which minimizes the effect of plaque accumulation at the gingival margin; e.g., a dog with a thick band of plaque along the gingival margin but not extending more than one-third of the crown surface would be given, at most, a 3 out of 5 score with the Turesky index whereas it would be, at most, a 2 out of 8 score for coverage in the Logan and Boyce modification in which both halves are scored. If color intensity is then used to assess thickness, the score would be, considering a thick band of plaque, 6 (= 2x3) out of 24, which would be a low score with a totally different meaning than in the Turesky index (3 out of 5 in this case). This system seems to be very effective in evaluating coronal extent of plaque, but the significance of the results as far as the effect of plaque on periodontium has to be evaluated. Horizontal division of the crown surface is part of other index systems such as the "Navy plaque index,"[7,8] which divides the tooth by an imaginary line, based on anatomical features ("the line connecting the crests of the interdental papillae and roughly parallel to the gingival margin"). In the Logan and Boyce modification of the Turesky version of the Quigley and Hein index, no anatomical reference mark is indicated, and the reliability and reproducibilty of such a division has to be questioned. Use of the original Turesky version of the Quigley and Hein index may be more appropriate when evaluating agents designed to prevent plaque accumulation, as it has been shown to be more reliable and reproducible.[29] The Logan and Boyce modification of the Turesky version of the Quigley and Hein index is sufficiently different from the original index system to be deserving of a separate name. It should probably be referenced as the Logan and Boyce index.[28]

Many other index systems have been used in human studies. The Addy modification of the Shaw & Murray stain index is a system in which disclosed plaque on buccal tooth surfaces is evaluated by a planigraphic area measurement method.[1] The ability to detect differences has been shown to be greater with this plaque area method compared to the Turesky modification of the Quigley and Hein index.[6]

Natural plaque accumulation in a clean tooth model

Dogs naturally accumulate dental plaque after all teeth have been cleaned and kept free of plaque during a period of meticulous toothbrushing (clean tooth model, clinically healthy gingiva). Early studies, still considered reference studies, have shown that plaque quickly accumulates on the tooth surface after termination of plaque prevention: after 4 weeks of plaque accumulation, mean Silness and Löe plaque index ranged between 2.0 and 2.4.[20,21,22] Since the maximum score with this system is 3, there is a plateau effect, leading to reduced ability to determine additional accumulation. When using the Logan and Boyce plaque index, mean scores of about 11 have been reported after 1 week of undisturbed plaque accumulation, and this level was stable over the following weeks.[4] With this system, where plaque is disclosed and evaluated separately on the coronal and gingival halves of the crown, maximum possible tooth score would have been 24.

The rate and amount of plaque accumulation may differ from one study to another. After 4 weeks, Silness and Löe plaque index scores ranging from 0.8 to 2.4 have been reported in 7 to 12 month-old beagle dogs (Table 2). With the Logan and Boyce plaque index, mechanical effects on the tooth surface such as those induced by a dry premium food compared to a reference canned food can affect the amount of plaque and the final score (Table 5).

Effect of antibacterial substances

Substances with antibacterial properties may affect plaque accumulation. Chlorhexidine is considered to be the most effective anti-plaque agent. Silness and Löe plaque index scores ranging between 0 and 0.41 have been reported after 4 weeks in young beagle dogs where different concentrations and formulations of chlorhexidine were used (Table 3). After one week of treatment with 0.12% of chlorhexidine solution, the mean Logan and Boyce plaque index of several studies from the same group was about 5, and was about 10 in the control group (maximum tooth score being 24), resulting in about 50% plaque reduction on tooth surfaces (Table 4).

Table 2. Gingival Index[26] and Plaque Index[34] in Beagle Dogs Subjected to Plaque Accumulation in a Clean Tooth Model.

Age:	Reference 22 10 months	Reference 13 12 months	Reference 17 7 months	Reference 31 12 months	Reference 11 10 months
			PLAQUE INDEX		
Week 0	0	NR	0	0.1	NR
Week 1	1.3	NR	1.07	0.6	1.52
Week 2	1.8	1.25	0.88	0.7	1.52
Week 4	2.4	1.25	0.93	0.8	1.52
			GINGIVAL INDEX		
Week 0	0	NR	0.34	0.1	NR
Week 1	1.0	NR	0.76	0.6	NR
Week 2	1.9	NR	0.87	0.7	NR
Week 4	2.1	NR	0.91	1.0	0.5

NR = not recorded

Mechanical effect on plaque accumulation

Recently, there has been a focus on prevention of plaque accumulation on tooth surfaces produced by the mechanical effect of chewing. In these studies, the Logan and Boyce plaque index has been used. This system places greater emphasis on coronal extent of plaque. A specific diet (Prescription Diet Hill's t/d™) as well as a dental chew (Rask™/Dentabone™, Pedigree) have been reported to reduce plaque accumulation (Table 5). Reduction in scores has been less than those achieved with chlorhexidine (Tables 4 and 5). Reductions in plaque accumulation of 19% and 27% have been reported with t/d™ after 1 and 2 weeks, and a 14% plaque reduction after 1 week can be extrapolated for Rask™ (Table 5). Though statistically significant, the clinical relevance of such a reduction has to be considered. With this index system, half of the total score may be due to plaque accumulation on the coronal half of the tooth surface, as both halves are scored separately. If we imagine that a chewing device removes all plaque on the coronal half of a tooth of which the crown is fully covered with plaque, the result would be a 50% reduction in plaque accumulation. This result may, however, have no clinical significance, as the gingival half will still be covered with the same amount of plaque. Another factor to be considered with the Logan and Boyce plaque index is the thickness aspect of the score. A total score of 3, for example, may be due to a score of 3 for coverage and 1 for thickness, or a score of 1 for coverage and 3 for thickness. Both scores may not have the same pathological meaning. This type of index may be better adapted to stain where, cosmetically, coverage and intensity are both aesthetically, if not clinically, significant.

A study reported in 1973 gives interesting clues to the significance of plaque accumulation per se.[19] In human volunteers with healthy periodontium who began performing complete plaque control every 12h, 48h, 72h, or 96h, only the group with plaque control every 12h significantly accumulated less plaque over 6 weeks, as assessed by the Silness and Löe plaque index. The author concluded that the amount of plaque assessed in a given patient does not reflect the pathogenicity of the plaque accumulation and should always be evaluated in conjunction with the host response; i.e., the parameters for the assessment of gingival inflammation.[19] It has been shown using the Turesky plaque index and the Löe and Silness gingival index that reduction in plaque accumulation may not always be associated with reduction of gingival inflammation.[35]

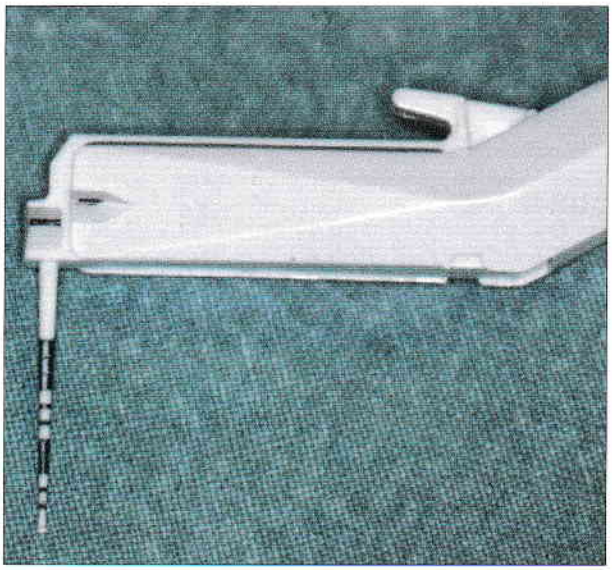

Figure 1. Pressure-sensitive probe (TPS Vivacare, Vivadent, Liechtenstein).

Gingival Inflammation

There is no single universal index for measurement of gingivitis. Many indices have been proposed, based on two main criteria. These criteria are the changes in contour and color of the gingiva, and bleeding on probing. All are to some degree subjective in nature. Among these indices, the gingival index (GI) described by Löe and Silness[26] has gained the most widespread acceptance and use.[25] Bleeding on probing, which is fully part of this index system, has been considered by some authors to be unreliable because of the mechanical trauma caused by the periodontal probe. Subsequently, although still referring to it as the Löe and Silness gingival index, some authors do not include bleeding on probing in their assessment; when bleeding on probing is included, there is great variability in probing force, probe placement, and the motion used to elicit bleeding.[5] Systems not including bleeding have been called "noninvasive" indices. A modified gingival index has been described by Lobene.[23] It is a modification of the Löe & Silness gingival index in which only visual assessment is performed with expansion of the low end of the scale. While some authors have called into question the value of bleeding as the most sensitive indicator of gingivitis, it has also been stated that, by virtue of inclusion of a bleeding component in addition to visual criteria, the Löe & Silness gingival index is generally considered to provide a more objective assessment than indices which rely solely on visual criteria.[25]

In humans, a number of gingival indices, such as the sulcular bleeding index (SBI), interdental bleeding index (IDI), and papillary bleeding index (PBI), have been developed which rely upon bleeding (following "gentle probing") as signs of gingivitis that may precede visual changes in gingival contour or color.[23,24] Indices evaluating interdental or papillary bleeding may not pertain to dogs because their dental and interdental anatomy differs from that of humans. The specific technique and instrumentation used when evaluating an index based on bleeding have to be considered. The pressure exerted on the tissue is of major importance. A study performed with dental students has shown that the use of uncontrolled force to examine for bleeding on probing (BOP) to the bottom of the sulcus may give false positive readings, and it is very likely that the sulcular tissues of clinically healthy gingiva will be traumatized if a probing force exceeding 0.25 N is applied with a standardized point diameter of 0.4 mm.[18] A convenient way to evaluate the force is to use a pressure-sensitive probe (Fig. 1). Most such probes are calibrated with a standardized probing force of 20g to 25g (0.20-0.25 N). A study in beagle dogs has shown that 0.6 mm is the most consistently discriminating periodontal probe diameter variation of gingival health using a gingival index.[16] Another important feature of the pressure-sensitive probe is the way it is inserted in the sulcus and what motion is used to elicit bleeding.[3,5] It has been shown that probing to the bottom of the pocket results in a higher bleeding index score as compared to probing of the marginal gingiva, and that the presence of bleeding provoked while probing the marginal gingiva is dependent on the angulation of the probe.[37] Probing of the mar-

Table 3. Mean Gingival Index[26] and Plaque Index[34] in Beagle Dogs Treated with Chlorhexidine (CHX) in a Clean Tooth Model.

Age: % CHX:	Reference 13 12 months 0.5%[A]	Reference 17 7 months 2%[B]	Reference 11 10 months 0.2%[C]
	PLAQUE INDEX		
Week 0	NR	0	0
Week 1	NR	0.3	0
Week 2	0.25	0.57	0
Week 4	0.25	0.41	0
	GINGIVAL INDEX		
Week 0	NR	0.37	0
Week 1	NR	0.46	0
Week 2	NR	0.67	0
Week 4	NR	0.53	0.1

Footnotes:

A 0.5% CHX gluconate gel painted on teeth once daily

B 2% CHX gluconate (8 mg total amount) film-forming solution painted on teeth every two days

C 0.2% of aqueous solution CHX gluconate administered with a syringe twice daily

NR = not recorded

ginal gingiva is performed as follows: after lightly drying the gingiva with compressed air, a manual probe is inserted into the gingival sulcus to a depth of approximatively 2 mm or until slight resistance is felt, then the probe is run gently along the marginal gingiva in contact with the soft tissue wall using a single stroke over a length of about 2mm. With this technique, the angulation of the probe can be parallel to the long axis of the tooth or angulated at about 60° to the longitudinal axis of the tooth.[37] In a study with dental students, Van der Weijden (1994) showed that the bleeding index of choice in the experimental gingivitis model is the (angulated) BI.[38] Recently, revisions to American Dental Association guidelines for measurement of gingivitis have recommended the use of an index of gingival bleeding, and either a purely visually-based gingivitis index or, alternatively, a comprehensive gingivitis index which incorporates both bleeding and visual appearance.[14] A non-invasive index system should not be used by itself.

Development of gingival inflammation in a clean tooth model

Results from different studies cannot always be compared, even though the same types of dog and the same protocols are used; after 4 weeks of plaque accumulation, the reported mean gingival index ranged from 0.5 to 2.1 (Table 2). To better comprehend this range, one should remember that a mean gingival index score of 0.5 would mean that, on average, 50% of the target teeth do not show any sign of gingival inflammation (i.e., are clinically healthy) and the other 50% show a mild inflammation with a slight change in color; whereas a mean gingival index score of 2.1 would mean that, on average, any target tooth will have shown redness and moderate inflammation with bleeding on probing.

Effect of antibacterial substances on the development of gingival inflammation in a clean tooth model

When a plaque retardant substance is used, the plaque-induced gingival inflammation is expected to be reduced. Mean GIs ranging from 0.1 to 0.53 have been reported (Table 3). As explained previously, this represents a very healthy state in which only 10 to 50% of the teeth show the mildest sign of inflammation on average, and the other teeth are clinically healthy.

Mechanical effects on the development of gingival inflammation in a clean tooth model

The gingival index has also been used to assess the effect of t/d™ and Rask™ on plaque-induced gingivitis. After 2-3 weeks, mean gingival index scores ranged between 0.3 and 0.75 compared to 0.37 and 0.98 in control groups (Table 5). If a comparison between studies is made, it is surprising to see that scores in control dogs in the Rask™ studies were lower than scores achieved in dogs subjected to natural plaque accumulation in a clean tooth model (Table 2), and that the lowest scores achieved with the test product in one study were close to those reported with chlorhexidine (Table 3). This paradox may be explained by the way the gingival index is assessed. Comparison of results between closely related studies is also troublesome. In two studies from the same group where a dry diet and a dental chew (Pedigree PAL, Rask™) were fed daily, the mean GIs at 3 weeks were respectively 0.75 and 0.51 (Table 5). One main difference in the protocol between the two studies was the administration of an antibiotic for 6 days prior to the beginning of the study in order to improve baseline gingival health. In the first study,[10] baseline gingival index was greater than in the second study,[33] 0.44 vs. 0.07. Because of use of different groups of dogs and protocols, correlation of results between studies is often impossible, even in closely related studies such as those reported in references 10 and 33 (Table 5).

Careful reading of results is necessary to reach correct conclusions. To date, published studies have shown a 19% statistically significant reduction in plaque accumulation after 1 week with Prescription Diet Hill's t/d™ and about 14% for Rask™; however, for the latter, the difference was no longer significant at 3 weeks.[9,15] Feeding Prescription Diet Hill's t/d™ or daily feeding of Rask™ significantly reduces gingival index, by 33% at 2 weeks and 18% at 3 weeks, respectively (Table 5).[9, 27]

Conclusions

Many indices measuring plaque accumulation and gingivitis have been described in humans, including modifications of previously reported indices. Some

Table 4. Veterinary Modification (Logan and Boyce) of the Turesky Plaque Index System-Results in Dogs Treated with Plaque Retardant Agents.

Plaque Retardant:	Reference 27 0.12% CHX spray BID	Reference 4 0.12% CHX spray BID	Reference 4 0.12% CHX spray BID
Day 0	NR	0	0
Day 7: Agent	4.93	4.6	5.55
Day 7: Control	9.44	9.15	10.47
% Reduction of Agent vs. Control	48%	50%	47%

CHX = Chlorhexidine
Teeth of all dogs were scaled and polished on day 0 of the study
NR = not recorded
BID = twice daily

of these 'modifications' alter the index in such a way that a new name should be given, rather than using the original name. There may be legitimate reasons to consider a new or modified system in dogs, and these changes must be clearly described and supported. Once established, validation studies may be considered for these new systems unless they can be based on already published data. More specifically concerning plaque accumulation, the Silness & Löe plaque index and Turesky modification of the Quigley & Hein plaque index are both well-accepted systems. The veterinary modification of the latter may be fully justified, but needs to be supported and clearly identified. When looking at disease processes, evaluating plaque reduction may be considered the first step when discriminating between effective and non-effective agents. However, once identified, the effect of these agents on gingival inflammation must be demonstrated. Gingivitis may be monitored in different ways. In accordance with ADA guidelines, both visual assessment and bleeding should be evaluated. As for plaque, indices evaluating gingival inflammation are often modified. Recent studies have shown that probe placement, probing force, and motion to elicit bleeding are of critical importance. As much as possible, information from published studies should be used to standardize the procedure, and a clear description of how it is performed should be provided. Finally, the magnitude of reductions observed has to be considered - is it clinically significant? According to "recommended revisions to the ADA guidelines for acceptance of chemotherapeutic products for gingivitis control" (1994), the following requirements should apply to gingivitis indices: at least a 15% statistically significant difference should be observed in favor of the active agent in at least two studies, and the mean of the reduction across the two studies should be no less than 20%.[14] No published veterinary studies to date meet these requirements. For mechanical control of plaque or calculus, the ADA Seal guidelines do not require assessment of gingivitis.

References

1. Addy M, Willis L, Moran J: Effect of toothpaste rinses compared with chlorhexidine on plaque formation during a 4-day period. *J Clin Periodontol* 10; 89-99, 1983.
2. Baab DA, Broadwell AH, Williams BL: A comparison of antimicrobial activity of four disclosant dyes. *J Dent Res* 62(7); 837-841, 1983.
3. Barnett ML: Suitability of gingival indices for use in therapeutic trials. *J Clin Periodontol* 23; 582-586, 1996.
4. Boyce EN, Logan EI: Oral health assessment in dogs: study design and results. *J Vet Dent* 11(2); 64-69, 1994.
5. Cianco SG: Current status of indices of gingivitis. *J Clin Periodontol* 13; 375-380, 1986.
6. Claydon N, Addy M: The use of plaque area and plaque index to measure the effect of fluoride and chlorhexidine toothpastes on 24-h plaque regrowth. *J Clin Periodontol* 22; 540-542, 1995.
7. Fischman SL: Current status of plaque. *J Clin Periodontol* 13(5); 371-380, 1986.
8. Fischman SL: Current index systems used to assess the efficacy of mouth-rinses on plaque and gingivitis. *J Clin Periodontol* 15; 506-510, 1988.
9. Gorrel C, Rawlings JM: The role of a "dental hygiene chew" in maintaining periodontal health in dogs. *J Vet Dent* 13(1); 31-34, 1996.
10. Gorrel C, Rawlings JM: The role of toothbrushing and diet in the maintenance of periodontal health in dogs. *J Vet Dent* 13(4); 139-143, 1996.
11. Hamp SE, Lindhe J, Löe H: Long term effect of chlorhexidine on developing gingivitis in the beagle dog. *J Periodont Res* 8; 63-70, 1973.
12. Hennet PR, Harvey CE: Natural development of periodontal disease in the dog: A review of clinical, anatomical and histological features. *J Vet Dent* 9(3); 13-19, 1992.
13. Hull PS, Davies RM: The effect of a chlorhexidine gel on tooth deposits in beagle dogs. *J Small Anim Pract* 13; 207-212, 1972.
14. Imrey PB, Chilton NW, et al: Recommended revisions to American Dental Association guidelines for acceptance of chemotherapeutic products for gingivitis control. *J Periodont Res* 19; 299-304, 1994.
15. Jensen L, Logan E, et al: Reduction in accumulation of plaque, stain and calculus in dogs by dietary means. *J Vet Dent* 12(4), 1995.
16. Keagle JG, Garnick JJ, et al: Gingival resistance to probing forces. I. Determination of optimal probe diameter. *J Periodontol* 60(4); 167-171, 1989.
17. Kozlowsky A, Sintov A, et al: Inhibition of plaque formation and gingivitis in beagle dogs by topical use of a degradable controlled-release system containing chlorhexidine. *J Dent Res* 71(9); 1577-1581, 1992.
18. Lang NP, Nyman S, et al: Bleeding on probing as it relates to probing pressure and gingival health. *J Clin Periodontol* 18; 257-261, 1991.
19. Lang NP, Mombelli A, Attström R: Dental plaque and calculus. In: Lindhe J, Karring T, Lang NP, eds. *Clinical Periodontology and Implant Dentistry.* Copenhagen: Munksgaard, 102-137, 1997.
20. Lindhe J, Hamp SE, Löe H: Experimental periodontitis in the beagle dog. *J Periodont Res* 8; 1-10, 1973.
21. Lindhe J, Rylander H: Experimental gingivitis in young dogs. *Scand J Dent Res* 83; 314-326, 1975.
22. Lindhe J, Hamp SE, Löe H: Plaque-induced periodontal disease in beagle dogs. *J Periodontal Res* 10; 243-255, 1975.
23. Lobene RR, Weatherford T, Ross NM: A modified gingival index for use in clinical trials. *Clinical Preventive Dentistry* 8; 3-6, 1986.
24. Lobene R: Discussion: Current status of indices for measuring gingivitis. *J Clin Periodontol* 13; 381-382, 1986.

Table 5. Plaque Index[28] and Gingival Index[34] - Results in Dogs Provided with Materials that Require Chewing.

	Reference 4	Reference 27	Reference 27	Reference 15	Reference 9*	Reference 10*	Reference 33*
Dogs	Beagle (n=50)	Mongrels/Beagle (n=40)	Mongrels/Beagle (n=40)	Various (n=120)	Beagle (n=18)	Various (n=14)	Various (n=15)
Protocol	S/P	S/P	S/P + T	S/P	S/P + T	S/P + A	S/P + A
MEAN PLAQUE SCORE (% reduction)							
	Canned Fod	Premium Dry Food	Hill's t/d	Dry Food	Hill's t/d	Dry Food	Hill's t/d	Dry Food	Dry Diet + RASK SID	Dry Diet	Dry Diet + RASK SID + T	Dry Diet + T**	Dry Diet + RASK SID	Hill's t/d
Day 0	0	0	0.1	0.1	0	0	0	0	0	0	0	0	2.26	2.01
Week 1	10.12	**6.80**	5.78	**7.13 (19%)**	NR	NR	7.25	**8.99 (19%)**	9.0	**10.5 (14%)**	4.11	4.66 (12%)	4.16	3.82
Week 2	NR	NR	NR	NR	6.83	**9.4 (27%)**	NR	NR	NR	NR	NR	NR	NR	NR
Week 3	NR	NR	NR	NR	NR	NR	NR	NR	10	9.5 (0%)	4.64	5.46 (15%)	5.41	5.21
MEAN GINGIVITIS SCORE (% reduction)														
Day 0	NR	NR	NR	NR	0	0	NR	NR	0.44	0.47	0.08	0.06	0.07	0.10
Week 1	NR	NR	NR	NR	NR	NR	NR	NR	0.79	0.8 (1%)	0.17	0.19 (10%)	0.23	0.18
Week 2	NR	NR	NR	NR	0.37	**0.55 (33%)**	NR	NR	NR	NR	NR	NR	NR	NR
Week 3	NR	NR	NR	NR	NR	NR	NR	NR	0.75	**0.98 (18%)**	0.30	0.37 (19%)	0.51	0.50

Gingival and coronal halves of the crown surface are scored separately and then added to give the total score of the tooth
Maximum score per tooth with this system is 24
S/P: Teeth are scaled and polished immediately prior to the beginning of the study
S/P + T, A: S/P followed by toothbrushing (T) and/or antimicrobial treatment (A) for 6 days
NR = not recorded
* Data extrapolated from graphs in the reference
** Teeth were brushed every other day
SID = once daily

Figures shown in bold indicate results significantly different from control.

25. Lobene R, Mankodi SM, et al: Correlations among gingival indices: A methodology study. *J Periodontol* 60(3); 159-162, 1989.
26. Löe H: The gingival index, the plaque index and the retention index systems. *J Periodontol* 38; 610-616, 1967.
27. Logan EI: Oral cleansing by dietary means: Results of six-month studies. Proceedings of a Conference on Companion Animal Oral Health, University of Kansas, Lawrence, March 1-3, 1996.
28. Logan EI, Boyce EN: Oral health assessment in dogs: Parameters and methods. *J Vet Dent* 11(2); 58-63, 1994.
29. Marks RG, Magnusson I, et al: Evaluation of reliability and reproductibility of dental indices. *J Clin Periodontol* 20(1); 54-58, 1993.
30. Marthaler TM: Discussion: Current status of indices of plaque. *J Clin Periodontol* 13; 379-380, 1986.
31. Paquette DW, Waters GS, et al: Inhibition of experimental gingivitis in beagle dogs with topical salivary histatins. *J Clin Periodontol* 24; 216-222, 1997.
32. Quigley GA, Hein JW: Comparative cleaning efficiency of manual and power brushing. *J Am Dent Assn* 65; 26-29, 1962.
33. Rawlings JM, Gorrel C, Markwell PJ: Effect of two dietary regimens on gingivitis in the dog. *J Small Anim Pract* 38; 147-151, 1997.
34. Silness J, Löe H: Periodontal disease in pregnancy. II. Correlation between oral hygiene and periodontal condition. *Acta Odontol Scand* 22; 121-135, 1964.
35. Spindel LM, Chauncey HH, Person P: Plaque reduction unaccompanied by gingivitis reduction. *J Periodontol* 57(9); 551-554, 1986.
36. Turesky S, Gilmore ND, Glickman I: Reduced plaque formation by Chloromethyl analogue of vitamin C. *J Periodontol* 41; 41-43, 1970.
37. Van der Weijden GA, Timmerman MF, et al: Comparison of different approaches to assess bleeding on probing as indicators of gingivitis. *J Clin Periodontol* 21; 589-594, 1994.

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