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Evaluation of the Logan & Boyce plaque index for the study of dental plaque accumulation in dogs

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Abstract

The objectives of this study were to assess intra-examiner (experienced examiner) and inter-examiner agreements (experienced versus non-experienced examiners) of scores assessed with the Logan & Boyce plaque index and to evaluate whether a modification of this index, where anatomical landmarks are used for horizontal division [mod L&B-AL] and dye references are used for assessing intensity of dye (plaque thickness) [mod L&B-DR], would improve repeatability. The Logan & Boyce index was found to be inaccurate when scoring plaque coverage as it underestimated the total crown surface. The contribution of the gingival part to the total tooth score was minimized by the Logan & Boyce index compared to the mod L&B-AL/DR. Precision of global plaque scorings was significantly improved by the mod L&B-AL/DR. Intra-examiner agreement of plaque thickness and plaque coverage scorings on the gingival part of the tooth was significantly improved by the mod L&B-AL/DR. Studies evaluating plaque accumulation in dogs should therefore use the mod L&B-AL/DR rather than the Logan & Boyce index.

Keywords: Plaque index; Dental plaque; Dogs; Repeatability; Reproductibility

1. Introduction

Periodontal disease is a plaque-induced disease initiated by early colonization of the tooth surface with bacteria. This leads to an inflammatory reaction of the gingival margin. Because plaque accumulation is the key event in the initiation of gingivitis, assessment of the amount of plaque is essential in periodontal studies. Because of the prevalence of dental plaque and its association with dietary regimes, the effect of specific diets on plaque accumulation needs to be evaluated.

Numerous index systems have been designed to evaluate the amount of plaque accumulated on tooth surfaces. The Silness and Löe index system (1964) concentrates on the thickness of plaque accumulating on the tooth at the gingival margin, whereas most methods assess the coverage of plaque on the tooth surface after disclosing it with a dye: Quigley and Hein (1962), Turesky et al. (1970). More recently, an index system which is a modification of the Turesky index, has been introduced into veterinary dentistry by Logan and Boyce (1994) and has subsequently been used in studies investigating the plaque removal effect of chewing toys, bones or diets in dogs (Gorrel and Bierer, 1999; Logan et al., 2002). Because it significantly differs from the Turesky plaque index system, it has been suggested that it be named the Logan & Boyce index system (Hennet, 1999). In the original description of this index, a horizontal division of the crown surface into two halves (coronal and gingival) has been proposed but not precisely described (Logan and Boyce, 1994). Other human

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dental index systems such as the "Navy plaque index" are using a horizontal division of the crown surface which is based on anatomical features (Fischman, 1986, 1988). Contrary to Turesky's method, both the coverage and thickness of plaque are evaluated on each, mentally divided, halves of the crown surface with the Logan & Boyce index. The intensity of the dye in a three-scale system (light, medium, dark) is used to evaluate plaque thickness. It has been stated that the Logan & Boyce index has been validated for use in veterinary dental medicine (Gorrel and Bierer, 1999). To our knowledge, no study has been performed to assess the precision (intra-examiner repeatability and inter-examiner reproducibility) of this index in dogs.

The aim of this study was to assess the agreement between scores obtained by an experienced examiner (intra-examiner agreement) and the agreement between an experienced examiner and non-experienced examiner (inter-examiner agreement) using the Logan & Boyce index. A further aim was to evaluate whether a modified Logan & Boyce index, where anatomical landmarks are used for horizontal division and a shade scale is used for assessing intensity of dye (plaque thickness), would improve the repeatability of the scoring method.

2. Materials and methods

The study was conducted in an approved research facility. Eight seven-month old Beagle dogs with intact teeth and no visible calculus accumulation were selected. All examinations were performed under general anaesthesia. Anaesthesia was induced with 40 μg/kg IV medetomidine (Domitor® – Pfizer Santé Animale) and maintained with 5 mg/kg IV ketamine (Imalgene® 500 – Merial SAS). Plaque was disclosed with a red dye: FD and C red # 3 (erythrosin).

One side of the mouth was assessed. Five teeth per dog were scored: the maxillary third incisor, canine, third premolar, fourth premolar and first molar teeth. All teeth were successively and blindly assessed by an examiner who had ten years of experience in scoring dental plaque (experienced examiner [PH]) and by an examiner who was knowledgeable about dental indices but had never scored dental plaque [non-experienced examiner [HS]). Measurements were repeated five times in each dog.

The following scoring systems were used:

(1) Original Logan & Boyce scoring system (Logan and Boyce (1994)) [original L&B]

Plaque was disclosed with erythrosin dye gently applied to the crown surface and immediately rinsed with water. The crown surface was horizontally divided; the gingival and coronal halves were scored. This scoring system had two components: both coverage and thickness were assessed.

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

The score for each tooth half was calculated by multiplying the coverage and thickness scores. Gingival and coronal scores were then added to give the total tooth score. The mean of all tooth scores provided the mouth score.

(2) Plaque coverage scoring with anatomical landmarks for horizontal division [mod L&B-AL]

Each target tooth was horizontally divided according to set anatomical landmarks (Fig. 1). Based on these landmarks, a coronal and a gingival part was determined. Each part of the tooth crown (coronal and gingival) was successively covered and plaque coverage was assessed on the uncovered part (Fig. 2). Scores on coronal and gingival parts were summed to give a total score. The mean of all tooth scores provided the mouth score.

(3) Plaque thickness scoring with dye references [mod L&B-DR]

After disclosing plaque on each target tooth, the intensity of dye was determined by comparison of the disclosed tooth surface with three dye references obtained by dilution of the erythrosin solution with water to achieve three shades from pink to red (pink to light red, red and dark red). The shade which was the closest to that on the disclosed surface, was designated as the score. Scores on coronal and gingival parts (determined according to previously mentioned landmarks) were summed to give a total score. The mean of all tooth scores provided the mouth score.

(4) Modified Logan & Boyce index [mod L&B-AL/DR]

The global (coverage × thickness) plaque score was similar to the Logan & Boyce index except that the two previously mentioned modifications [mod L&B-AL and mod L&B-DR] were used to score coverage and thickness.

2.1. Statistical analysis

A general linear model (GLM) using a multifactor ANOVA with a repeated measure design was used to analyze the various factors: the examiners (experienced

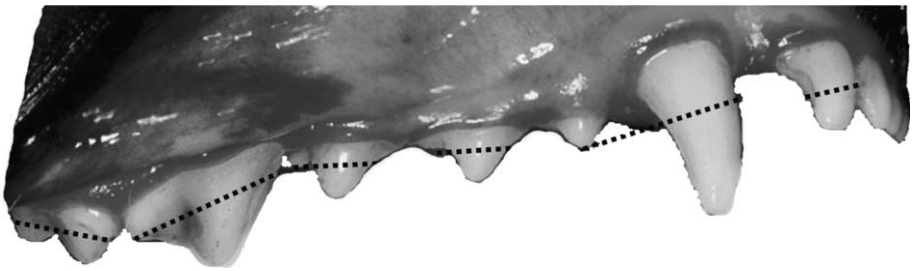

Fig. 1. Anatomical landmarks for horizontal divisions of maxillary teeth. 1. Third incisor tooth: the line horizontal to the gingival margin at the level of the distal cusp of the second incisor tooth. 2. Canine tooth: the line horizontal to the gingival margin and at the level of the cusp of the first premolar tooth. 3. Second and third premolar teeth: the line horizontal to the gingival margin and at the level of the distal cusp of the premolar teeth. 4. Fourth premolar tooth: the line horizontal to the gingival margin and at the level of the distal heel. 5. First molar tooth: the line horizontal to the gingival margin and at the level of the buccal cusps of the tooth.

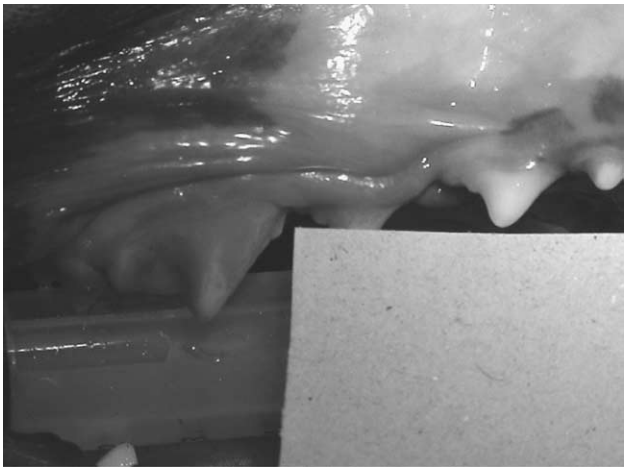

Fig. 2. Measurement on the gingival part of the tooth by hiding the coronal part.

and non-experienced), the scoring methods (original L&B, mod L&B-AL, mod L&B-DR and L&B-AL/DR), the tooth parts (gingival and coronary), the dogs ($n = 8$), the repetitions ($n = 5$) and the possible interactions between those factors (Neter et al., 1996). The following general linear model was used:

$$\text{Plaque}(ijklmn) = \mu + \text{repetition}(i) + \text{method}(j) + \text{dog}(k) + \text{scorer}(l) + \text{tooth part}(m) + (\text{scorer} \times \text{method})(jl) + (\text{scorer} \times \text{repetition})(il) + \sum(ijklmn),$$

where Plaque($ijklmn$) is the value measured for repetition i with method j on tooth part m of dog k by scorer l, μ is the mean of the observed values, repetition(i) is the differential effect of repetition i, method(j) is the differential effect of method j, dog(k) is the differential effect of dog k, scorer(l) is the differential effect of scorer l, tooth part (m) is the differential effect of tooth part m, (scorer × method)(jl) is the interaction term between scorer and method, (scorer × repetition)(il)) is the interaction term between scorer and repetition, and $\sum ijklmn$ is the model error.

The standard deviation (SD) of mouth scores observed by the experienced examiner for the different scoring methods was used as a measurement of precision when considering repeatability. The SD of examiner's scores for the different scoring methods was used as a measurement of precision when considering inter-examiner agreement (reproducibility). Coefficients of variation (CVs) were calculated for global plaque scorings. $p < 0.05$ was considered significant, using Statgraphics Plus 5.0.

3. Results

3.1. Comparisons of the effects of methods (experienced examiner)

3.1.1. Plaque coverage scoring

The method and the tooth part (coronary or gingival) were found to be significant factors (Table 1). Mean plaque coverage scorings with the mod L&B-AL were significantly greater (p-value <0.001) than these obtained with the original L&B. Mean plaque coverage scorings were significantly greater (p-value <0.001) on the gingival part than on the coronal part, both with the original L&B (2.81 vs 2.28) and with the mod L&B-AL (2.92 vs 2.39). The SD of plaque coverage scorings on the gingival and coronal parts is given in Table 2.

Table 1
p-Values for the influence of the different factors and their interactions

Plaque	Factors	p-Value	Interactions	p-Value
Coverage	Dog	<0.001	Dog * method	<0.05
	Method	<0.001	Dog * parts	<0.001
	Parts	<0.001	Method * parts	0.269
	Repetition	0.829	Method * repetition	0.769
Thickness	Dog	<0.001	Dog * method	0.065
	Method	0.228	Dog * parts	<0.001
	Parts	<0.001	Dog * repetition	<0.001
	Repetition	0.324	Method * repetition	<0.001

p-Value < 0.05 (significant factor or significant interaction).

Table 2
Comparison of the standard deviation (SD) of dogs' scores on a specific part of the tooth using the different scoring methods

Scoring methods		Tooth part	SD of mod L&B	SD of original L&B
mod L&B-AL vs original L&B	Coverage component	Coronal	0.20	0.20
		Gingival	0.16	0.18
mod L&B-DR vs original L&B	Thickness component	Coronal	**0.16***	**0.20***
		Gingival	0.16	0.17
mod L&B-AL/DR vs original L&B	Coverage × thickness	Total	**0.45***	**0.55***
		Coronal	**0.50***	**0.60***
		Gingival	0.65	0.70

Scorings repeated five times on eight dogs.
* $p < 0.05$.

3.1.2. Plaque thickness scoring

The tooth part was found to be a significant factor (p-value <0.001) (Table 1). Mean plaque thickness scorings were significantly greater on the gingival part than on the coronal part (p-value <0.001), both with the original L&B (1.85 vs 1.26) and with the mod L&B-DR (1.88 vs 1.26). The SD of plaque thickness scorings on the gingival and coronal parts is given in Table 2.

3.1.3. Global plaque scoring

Mean plaque scorings on the gingival part with the mod L&B-AL/DR were significantly greater (p-value = 0.007) than those obtained with the original L&B (Fig. 3). The SD of global plaque scorings on the gingival and coronal parts is given in Table 2. The CVs for the global method (coverage × thickness), on each tooth part and on the total tooth surface (coronal score + gingival score) using the original L&B and the mod L&B-AL/DR, are given in Table 3.

3.2. Inter-examiner agreement

3.2.1. Plaque coverage scoring

A significant interaction was detected (p-value <0.05) between examiners and methods. With the original L&B, the non-experienced examiner gave scores that were significantly higher (2.66 ± 0.12) than scores given by the experienced examiner (2.54 ± 0.14). The SD of examiners' scores for plaque coverage on the gingival and coronal parts is given in Table 4.

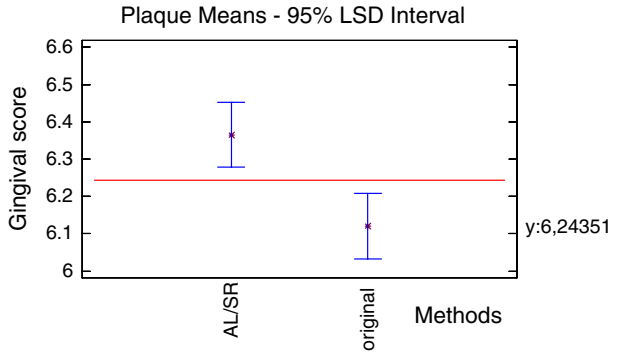

Fig. 3. Comparison of mean gingival scores with the original L&B and the mod L&B-AL/DR). Significant difference ($p < 0.05$).

Table 3
CVs for the global method (coverage × thickness) on each tooth part and on the total tooth surface (coronal score + gingival score) using the original L&B and the mod L&B-AL/DR

Method	Tooth part	Mean	SD	CV (%)
Original L&B	Coronal	3.89	0.6	15.42%
	Gingival	6.12	0.7	11.44%
	Total	5	0.55	**11.00%**
Mod L&B-AL/DR	Coronal	3.82	0.5	13.09%
	Gingival	6.37	0.65	10.20%
	Total	5.09	0.45	**8.84%**

3.2.2. Plaque thickness scoring

A significant interaction was detected (p-value <0.001) between examiners and methods. With the mod L&B-DR, the non-experienced examiner gave lower scores (1.43 ± 0.07) than the experienced one (1.57 ± 0.09). The SD of examiners' scores for plaque thickness on the gingival and coronal parts is given in Table 4. With repetition of scorings, values given by the non-experienced scorer differed significantly from the experienced examiner (p-value <0.05) when evaluating plaque thickness with original L&B (Fig. 4).

3.2.3. Global plaque scoring

A significant interaction was detected (p-value <0.001) between examiners and methods. The experienced examiner's scorings were consistent with both methods whereas the non-experienced examiner gave significantly higher scores with the original L&B than with the mod L&B-AL/DR. The SD of examiners' scores for global plaque scoring (coverage × thickness) is given in Table 4.

4. Discussion

Assessment of the amount of dental plaque accumulated on tooth surfaces is needed when evaluating the

Table 4
Comparison of the standard deviation (SD) of examiners' scores on a specific part of the tooth using the different scoring methods

Scoring methods		Tooth part	SD of experienced examiner	SD of non experienced examiner
Original L&B	Coverage × thickness	Coronal	**0.60***	**0.79***
		Gingival	**0.70***	**1.18***
mod L&B-AL	Coverage	Coronal	**0.60***	**0.78***
		Gingival	0.70	0.74
mod L&B-DR	Thickness	Coronal	0.20	0.24
		Gingival	0.18	0.15
mod L&B-AL/DR	Coverage × thickness	Total	**0.45***	**0.68***
		Coronal	**0.50***	**0.73***
		Gingival	0.65	0.71

Scorings repeated five times on eight dogs.
* $p < 0.05$.

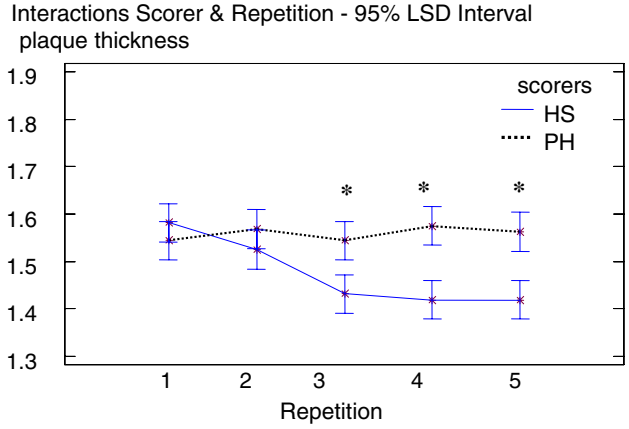

Fig. 4. Evolution of mean scores with repetition for the experienced (PH) and non-experienced (HS) examiner. *Significant difference ($p < 0.05$).

effectiveness of mechanical or chemical dental products aimed at preventing plaque accumulation. When assessing statistically significant differences in plaque accumulation between groups of dogs, it is important to know the precision of the scoring system. This study was designed to document both intra- and inter-examiner agreements of dental plaque scorings using the Logan & Boyce scoring system and to assess whether a modification of this system would improve precision.

In the original description of the Logan & Boyce index, plaque coverage was assessed on the gingival and coronal halves, but specific landmarks for division of the tooth surface into two halves were not described (Logan and Boyce, 1994). In the present study, we decided to rely on anatomical landmarks and to consider a gingival and a coronal part, rather than true halves. By masking successively one part of the crown and scoring the other part, the sum of both parts accurately gives the total tooth surface. Our results showed that, on repeated measurements, the mean total coverage scores with the mod L&B-AL were significantly greater (p-value <0.001) than those obtained with the original L&B index. Therefore, mental division of the crown surface without specific landmarks (original L&B) underestimated the total crown surface. Studies using the original L&B index without specific landmarks for horizontal tooth division might therefore result in inaccuracies.

Coverage and thickness scores were significantly higher (p-value <0.001) on the gingival part than on the coronal part of the tooth using both the L&B and mod L&B index systems. This is in agreement with natural development of periodontal disease which starts with plaque accumulation along the gingival margin and subsequently extends to the crown (Hennet and Harvey, 1992). Mean gingival global scores (coverage × thickness) were found to be significantly lower with the original L&B than with the mod L&B-AL/DR whereas total scores (coronal + gingival) were not significantly different ($p = 0.227$) (Fig. 3). Therefore, compared to the mod L&B-AL/DR, the original L&B minimized the contribution of the gingival score to the total tooth score. When studying periodontal disease, it might be of greater relevance to focus on plaque accumulating on the gingival part of the tooth and subsequently to use the mod L&B-AL/DR rather than the original L&B.

Precision (repeatability) of plaque thickness scorings on the coronal part of the tooth was significantly increased with the mod L&B-DR compared to the original L&B (p-value <0.05) (Table 2). Precision of global plaque scorings on the coronal part, and on the total tooth surface, was significantly improved with the mod L&B-AL/DR compared to the original L&B (p-value <0.05) (Table 2). CVs of the mod L&B-AL/DR were 8.84% compared to 11% with the original L&B (Table 3). A statistically significant difference of at least 10% in plaque accumulation is considered to be the minimum requirement when testing veterinary dental products claiming mechanical control of plaque (VOHC, 2004). According to our results, due to the variability of measurements, a statistically significant 10% difference

between two groups of dogs could not be considered significant when using the original L&B.

Contrary to coronal and global scorings, precision was not improved for gingival scorings. In this experimental setting, the dogs had natural plaque accumulation and showed much higher gingival scores than coronal scores (Table 3). Heavy plaque accumulation (close to maximum scores) is easier to assess, both in coverage and in thickness, than sparse accumulation of plaque and this might explain why improved precision was not observed on the gingival part.

Plaque scoring is subjective in nature and though experience of the examiner is considered an important factor, the significance of this has not been reported. Our results showed that when using the original L&B method the experienced examiner was more precise than the non experienced examiner (Table 4). With repetition of scorings, values given by the non-experienced scorer differed significantly from the experienced examiner ($p = 0.006$) (Fig. 4). With the mod L&B AL/DR, the experienced examiner was also more precise when scoring the coronal part of the tooth, but not the gingival part (Table 4). When evaluating the coverage and the thickness components of the mod L&B AL/DR scoring system separately, it was observed that "experience" improved precision only when scoring plaque coverage on the coronal part of the tooth. Our results confirmed the view that experience is a significant factor when scoring plaque for research purposes. However, the mod L&B-AL/DR significantly improved intra-examiner agreement (reproducibility) when scoring plaque thickness and plaque coverage on the gingival part of the tooth (SDs of measurements by the experienced and non experienced examiners are not statistically significantly different). According to our results, a non experienced examiner could be used to score plaque on the gingival part of the tooth using the mod L&B-AL/DR index system.

Studies evaluating plaque accumulation in dogs should therefore use the mod. L&B-AL/DR rather than the original L&B index. Other less subjective and more relevant means of evaluating plaque coverage and thickness should be investigated in the future. Recently, the relevance of partitioning the tooth and scoring each half with the same weight has been questioned and discouraged (Hennet, 1999; Harvey, 2002). A computerized image analysis system has been described for plaque accumulation assessment in humans (Smith et al., 2001). Development of such systems in the field of veterinary dental science would be valuable.

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