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Research Article

Determination of gingival temperatures of dogs with healthy gums by means of a thermal camera

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ABSTRACT

In this study, the gingival inflammation degree of dogs was determined according to the Gingival Index (GI). According to this index, it was aimed to determine the free gingiva (FG), attached gingiva (AG) and alveolar mucosa (AM) temperatures of the gingiva of dogs with healthy gums by means of a thermal camera. The material of the study consisted of the gingiva of 140 dogs aged 2 years and older, who were brought to Burdur Mehmet Akif Ersoy University, Faculty of Veterinary Medicine, Animal Hospital, Surgery Clinic, non-brachiocephalic and without periodontal destruction in their gingiva. Healthy maxillary (n= 427) and mandibular (n= 671) gums in addition maxillary (n=432) and mandibular (n= 463) gums with gingivitis were included in the study. The FG temperature of the buccal surface of the healthy maxillary gingiva was 36.25±1.43°C, the AG temperature was 36.81±1.37°C, and the AM temperature was 37.53±1.30°C. The FG temperature of the buccal surface of the healthy mandibular gingiva was 35.46±1.42°C. In addition the AG temperature was 36.26±1.35°C, and the AM temperature was 37.01±1.22°C. The FG temperature of the maxillary gums with gingivitis was 36.40±1.32°C, the AG temperature was 36.95±1.21°C, and the AM temperature was 37.57±1.21°C. The FG temperature of the mandibular gums with gingivitis was 35.82±1.26°C, the AG temperature was 36.57±1.16°C, and the AM temperature was 37.27±1.10°C. Temperature difference (r) between in maxillary and mandibular FG (r= 0.78°C and p= .000), AG (r= 0.52°C and p= .000) and AM (r= 0.51°C and p= .000) of dogs with healthy gums temperatures were found to be significant. Temperature difference between maxillary and mandibular FG with gingivitis (r= 0.58°C and p= .000), AG (r= 0.38°C and p= .000) and AM (r= 0.29°C and p= .000) were found to be statistically significant. It was concluded that the thermal camera can be an effective diagnostic tool in detecting inflammatory changes in the gingiva.

INTRODUCTION

Healthy gingival tissue is coral pink, with weak and sharp edges (Wiggs & Lobprise, 1997). Edema, hyperemia and bleeding in the gingival margin are the most important findings of gingivitis (Gorrel, 2013). It is the most common oral disease in dogs. It is diagnosed in 80% of dogs over 2 years (Wiggs & Lobprise, 1997). Gingivitis manifests itself with erythema and rounding at the gingival margin. As the inflammation increases, gingival hemorrhages occur and erythema may spread to the entire gingiva (DeBowes, 2010). There is no recession, furcation or tooth mobility in the gingiva (Gorrel, 2013). If the progression of gingivitis is not prevented, infection in the periapical region of the tooth root leads to pulpitis and tooth loss. Endodontic diseases arise as a result of severe periodontal diseases (Reiter & Harvey, 2010). However, early diagnosis and treatment is crucial because this situation causes many important health problems in the animal before tooth loss (Niemiec, 2013).

Subgingival plaque plays a role in the progression of the disease from gingivitis to periodontitis. Bacteria in subgingival plaque secrete metabolic products that initiate inflammation as well as toxins (Harvey & Emily, 1993). In addition, cytotoxins produced and bacterial endotoxins that can directly invade tissues cause inflammation of the gingiva and periodontium (Wiggs & Lobprise, 1997). The inflammatory response occurs thanks to mediators that recruit and activate cells of the immune system. These defenders assemble and activate other proteins and chemical messengers. Some of these messengers are pyrogens and cause an increase in tissue temperature. Some factors cause local swelling by increasing vascular permeability. Increased vascular permeability allows agents of the immune system to enter damaged tissues (Reiter & Harvey, 2010). This inflammation leads to gingivitis, which initially only damages the gingival tissues. If the inflammation is not treated, this leads to the destruction of periodontal tissue and the structures that support the tooth. Thus, it causes the formation of periodontitis, which is the irreversible stage of the disease (Wiggs & Lobprise, 1997).

The gingival vascular system is a microcirculation zone. Increased vascular density in the gingiva is associated with some of the first non-specific defenses against periodontitis. The capillaries of the FG are the first to react when gingivitis occurs (Nuki & Hock, 1974). Anatomically, the periodontal vascular system is diverse. It is stated that along the length of the periodontium, it also differs along the mesial, distal, oral and buccal aspects of the alveoli (Mörmann et al., 1985). Differences in the position of fine capillaries between incisive and premolar teeth in dogs have also been demonstrated (Söderholm

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& Egeleerg, 1973). In human temperature measurements, it is stated that gingival pockets, different points around the same tooth, temperatures between different tooth types, temperatures between maxillary and mandibular regions differ due to the variation in the functional status of blood flow (Maeda et al., 1979; Mukherjee, 1981). In thermometric studies, it is observed that there is a difference between the rewarming times of the gums of patients with healthy gingiva and periodontitis, which were previously cooled by cold airflow. It is stated that the warming time of the tissues in patients with clinically healthy gingiva is faster than in patients with periodontitis. It has been reported that the slower warming time of the tissues of patients with periodontitis is due to the pathophysiological feature of the relevant vascular system (Mörmann et al., 1985). Acute inflammation, chronic inflammation, and periodontitis in the gingiva in dogs are associated with typical changes in the microvascular system (Hock et al., 1980).

Changes in the vascular circulation in living organisms cause an increase or decrease in tissue temperature, allowing us to evaluate the state of the tissue in which the change is observed (Kunc & Knizkova, 2012). The use of thermography also plays an important role in monitoring the efficacy of treatment in dental-oral diseases and systemic diseases (Mörmann et al., 1985). Temperature is a valuable and objective finding for the diagnosis of periodontal disease, as changes in blood flow also cause changes in local tissue temperature. For this reason, it is thought that the change in tissue temperatures can also eliminate the misconceptions arising from subjective observations (Barnett et al., 1989; Păunică et al., 2009). In addition, the American Academy of Thermology states that infrared thermal imaging, as a rapid diagnostic tool, has a definite benefit in monitoring dental and oral health conditions also emphasizes that it would be appropriate to include this technique in clinical medicine (Schwartz et al., 2015).

Anatomical and histological changes occur in the gingival microcirculation during the initial and formation stages of gingivitis (Kunc & Knizkova, 2012). The increase in local blood flow as a result of the vascular reaction causes an increase in gingival temperature (Maeda et al., 1979). When interpreting the thermographic images of the oral cavity, it is accepted that a pathological condition is diagnosed when the temperature difference exceeds 0.5°C (Dobrzyński et al., 2014). It was also reported that it facilitates the determination of the degree of inflammation of the gingival tissues in dogs (Yiğitarslan et al., 2022). It is reported that the resting dental papilla in healthy gingiva has a higher blood flow than the FG. Gingival blood flow was observed to be significantly lower in patients with chronic periodontitis compared to healthy individuals (Nakamoto et al., 2012). It is suggested that this is due to the decrease in vascularization in chronic diseases. It has been reported that from early periodontitis, thermal properties, including the acute phase, have a higher temperature associated with inflammation (Haffajee et al., 1992). The mean gingival pocket temperature is 33.9±0.4°C in people who appear clinically healthy; The mandibular gingiva was found to be 0.7±0.2°C higher than the maxillary gingiva. It is also stated that molar teeth have a temperature profile 1.5±0.3°C higher than incisive teeth (Ng et al., 1978). It is stated that FG has a lower temperature than AG and AM in dogs with healthy gingiva (Yiğitarslan et al., 2022).

In this study, it was aimed to determine the reference ranges of FG, AG and AM temperatures of dogs with healthy gingiva with a thermal camera. In addition, it was aimed to determine the change in gingival temperatures according to different clinical findings.

MATERIAL and METHODS

Animal Material

In this study, 140 non-brachiocephalic dogs with healthy gums, aged 2-11 years (81 females, 59 males), 86 crossbreds and 54 different breeds were used.

Tools Used in Gum Examination

Periodontal probe was used to determine the gingival bleeding of the dogs and to measure the gingival pocket depths. Thermal camera (Trotec® EC060V, France) was used to take gingival thermograms.

Equipment Used in Anesthesia

An anesthesia device with automatic ventilator and double vaporizer (Draeger Primus®, Draegerwerk AG&Co. KGaA, Germany) was used for general anesthesia of dogs. 0.1 mg/kg diazepam (Diazem® IM/IV, 10 mg/2 ml, Deva, Istanbul) was administered as preanesthetic and 3 mg/kg propofol (Propofol® 1%, Fresenius, Germany) was administered intravenously for induction. A disposable endotracheal tube (Rüsch®, Willy-Rüsch, Germany) was used to ensure the patency of the respiratory tract. Sevoflurane (Sevoflurane®, USP, United States) was used as an inhalation anesthetic for maintenance of anesthesia.

Taking Thermograms

Under the general anaesthesia, dogs were placed in the lateral position. Thermograms were taken with a thermal camera to measure the temperature of the buccal gingival surface. First, the lips covering the tooth surface were removed and the teeth and gums were made visible. Then it was waited for 30 seconds for the temperature to stabilize. After the first image was taken, thermographic images of the buccal gingiva of the right maxillary and mandibular half were taken from a distance of 20 cm for 120 seconds at 30-second intervals. The same procedure was repeated for the left maxillary and mandibular half.

Recording of Clinical Examination Findings

According to the GI in Table 1, clinical findings such as redness, edema and bleeding in the gums were evaluated and recorded (Löe & Silness, 1963). The degree of disease was determined according to the index system. Dogs with tooth mobility and gingival furcation were not included in the study. After the clinical findings of the gums of the dogs determined to have healthy gums were recorded in the examination form, the dogs were discharged.

Table 1. Gingival indeks (Löe & Silness,1963)

Grade	Clinical Finding
0	Healthy gums, no inflammation.
1	Mild inflammation; slight change in color and slight edema. No bleeding on probing.
2	Moderate inflammation. There is edema, redness, shine and bleeding on probing.
3	Severe inflammation. There is edema, redness and ulceration are present. There is spontaneous bleeding.

Evaluation of Thermograms

Thermal images obtained with thermography camera were analyzed with the IC IR Report Software® program. The temperature values of the FG, AG and AM at each tooth level were determined linearly and recorded.

Statistics

IBM SPSS 20 program was used in the analysis of the data. In the evaluation of normal distribution, skewness and kurtosis values were considered. As a result of the analysis, the data with skewness and kurtosis values between -1.5 and +1.5 were normally distributed. ANOVA Tukey test was used to control the importance of the temperature difference between the index grades of the gingival regions. $p<0.05$ was considered statistically significant.

RESULTS

The study included 140 dogs, 86 crossbreds and 54 mixed breeds. 81 of the cases were female and 59 of them were male dogs. It was determined that their body weight was between 15-72.3 kg (26.01±9.58) and their age was between 2-11 years (3.45±1.54).

Table 2. Surface temperatures of the maxillary gingiva according to gingival index

Indeks Grade	n	FG Temperature (°C)	AG Temperature (°C)	AM Temperature (°C)
0	427	$36.25±1.43^{A,a}$	$36.81±1.37^{A,b}$	$37.53±1.30^{A,c}$
1	432	$36.40±1.32^{A,a}$	$36.95±1.21^{A,b}$	$37.57±1.21^{A,c}$
2	849	$36.05±1.16^{B,a}$	$36.62±1.08^{B,b}$	$37.28±1.07^{B,c}$
3	0	-	-	-

There is a statistical difference between different uppercase superscripts in the same column (p<0,05).
There is a statistical difference between different lowercase superscripts on the same line (p<0,05).
n: Number of cases.

In the maxilla, 1708 teeth and their gums were examined. 427 of them were grade 0 GI (no bleeding, hyperemia and edema), 432 grade 1 GI (no bleeding, hyperemia and edema are present) and 849 grade 2 GI (hemorrhage). Since spontaneous bleeding was not observed in any of the gingiva, there is no grade 3 GI. Average temperature values of different gingival regions are shown in Table 2**.** The results of the analysis are given in Table 3**.** The temperature difference (r) between the gums of dogs with grade 0 and grade 1 GI was not found to be significant. Statistically significant temperature difference was observed between grade 0 GI and grade 2 GI in FG (r= 0.35°C and $p<0.05$), AG (r= 0.33°C and $p<0.05$) and AM (r=0.29°C and $p<0.05$).

In the mandible, 1893 teeth and the gums of these teeth were examined. 671 of them were evaluated as grade 0 GI, 463 as grade 1 GI and 759 as grade 2 GI. Since spontaneous bleeding was not observed in any of the gingiva, there is no grade 3 gingiva. Average temperature values of different gingival regions are shown in Table 4. The results of the analysis are given in Table 5. Grade 0 GI gingival temperature was statistically significantly different from grade 1 GI and grade 2 GI gingival temperatures ($p<0.05$). However, no significant difference was observed between grade 1 GI and grade 2 GI gingival temperatures ($p>0.05$). There is a positive correlation between mandibular FG ($p<0.001$), AG ($p<0.001$) and AM ($p< .000$) temperature values and GI grades. As the index grade increased, a significant increase was observed in gingival temperatures ($p<0.05$).

Temperature difference between maxillary and mandibular FG (r= 0.78°C and p= .000), AG (r= 0.52°C and p= .000) and AM (r= 0.51° C and p= .000) in dogs with grade 0 GI were found to be statistically significant. Temperature difference between maxillary and mandibular FG (r= 0.58°C and p= .000), AG (r= 0.38°C and p= .000) and AM (r= 0.29°C p= .000) were statistically significant in dogs with grade 1 GI. Temperature difference between maxillary and mandibular FG (r= 0.32°C and p= .000) and AG (r= 0.12°C and p= 0.024) in dogs with grade 2 GI were statistically significant. The temperature difference between maxillary and mandibular AM temperatures ($p>0.05$) were not statistically significant. Maxillary gingival temperature was higher than mandibular gingival temperature in all groups with significant difference.

The temperature difference of FG, AG and AM, which are different anatomical regions of the gingiva, was determined. The temperature difference between different index grades of gingivitis were also determined (Figure 1).

Tablo 3. Statistical analysis of gingival temperatures according to gingival index grade in the maxilla

Dependent Variables	(I) Indeks Grade	(J) Indeks Grade	Mean Temperature Difference (I-J)	Standard Error	p
Free Gingiva	0	1	-.15117	.08733	.194
		2	.20331*	.07593	.020
	1	0	.15117	.08733	.194
		2	.35448*	.07563	.000
	2	0	-.20331*	.07593	.020
		1	-.35448*	.07563	.000
Attached Gingiva	0	1	-.14340	.08163	.185
		2	.18474*	.07097	.025
	1	0	.14340	.08163	.185
		2	.32814*	.07069	.000
	2	0	-.18474*	.07097	.025
		1	-.32814*	.07069	.000
Alveolar Mukosa	0	1	-.03571	.08009	.896
		2	.24927*	.06963	.001
	1	0	.03571	.08009	.896
		2	.28498*	.06936	.000
	2	0	-.24927*	.06963	.001
		1	-.28498*	.06936	.000

ANOVA Tukey Test (* p<0.05)

Tablo 4. Surface temperatures of the mandibular gingiva according to gingival index

Indeks Grade	n	FG Temperature (°C)	AG Temperature (°C)	AM Temperature (°C)
0	671	$35.46\pm1.42^{A,a}$	$36.26\pm1.35^{A,b}$	$37.01\pm1.22^{A,c}$
1	463	$35.82\pm1.26^{B,a}$	$36.57\pm1.16^{B,b}$	$37.27\pm1.10^{B,c}$
2	759	$35.73\pm1.21^{B,a}$	$36.50\pm1.12^{B,b}$	$37.28\pm1.00^{B,c}$
3	0	-	-	-

There is a statistical difference between different uppercase superscripts in the same column (p<0,05).
There is a statistical difference between different lowercase superscripts on the same line (p<0,05).
n: Number of cases.

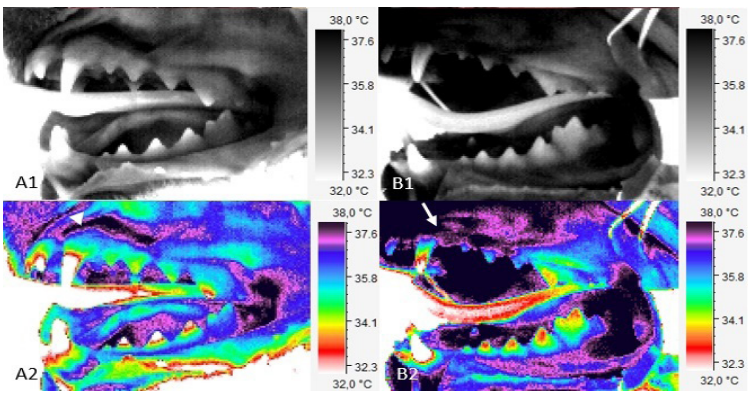

Figure 1. Color distribution of the thermographic image of healthy gingiva (A1, A2) and gingivitis (B1, B2) in dogs (Yiğitarslan et al. 2022)

Tablo 5. Statistical analysis of gingival temperatures according to gingival index grade in the mandibula

Dependent Variables	(I) Indeks Grade	(J) Indeks Grade	Mean Temperature Difference (I-J)	Standard Error	p
Free Gingiva	0	1	-.34542*	.07846	.000
		2	-.25689*	.06885	.001
	1	0	.34542*	.07846	.000
		2	.08854	.07647	.479
	2	0	.25689*	.06885	.001
		1	-.08854	.07647	.479
Attached Gingiva	0	1	-.28751*	.07313	.000
		2	-.21812*	.06417	.002
	1	0	.28751*	.07313	.000
		2	.06939	.07127	.594
	2	0	.21812*	.06417	.002
		1	-.06939	.07127	.594
Alveolar Mukosa	0	1	-.26200*	.06715	.000
		2	-.26468*	.05892	.000
	1	0	.26200*	.06715	.000
		2	-.00268	.06544	.999
	2	0	.26468*	.05892	.000
		1	.00268	.06544	.999

ANOVA Tukey Test (* p<0.05)

DISCUSSION

Edema, hyperemia and bleeding in the gingival margin are the most important findings of gingivitis (Gorrel, 2013). There is no recession, furcation or tooth mobility in the gingiva (Gorrel, 2013). Animals with gingival furcation and gingival mobility were not included in this study.

If the progression of gingivitis is not prevented, infection in the periapical region of the tooth root leads to pulpitis and tooth loss. Endodontic diseases arise as a result of severe periodontal diseases (Reiter & Harvey, 2010). However, early diagnosis and treatment is crucial because this situation causes many important health problems in the animal before tooth loss (Niemiec, 2013). Grade 0 refers to healthy gums. Grade 1 represents the gingiva with edema and hyperemia. However, a specialist physician can distinguish at first view the difference between healthy gingiva and hyperemic and edematous gingiva Since bleeding is an easily distinguishable clinical finding, it will be easier to identify grade 2 gingiva. In this study, buccal gingival surface temperature of grade 0 and grade 1 GI dogs was compared. Thus, the effectiveness of the thermal camera was evaluated in the diagnosis of dogs with gingival inflammation but no bleeding.

The gingival vascular system is a microcirculation zone. Increased vascular density in the gingiva is associated with some of the first non-specific defenses against periodontitis. The capillaries of the FG are the first to react when gingivitis occurs (Nuki & Hock, 1974). Anatomically, the periodontal vascular system is diverse. It is stated that along the length of the periodontium, it also differs along the mesial, distal, oral and buccal aspects of the alveoli (Mörmann et al., 1985). In this study, the variation of buccal gingival surface temperatures according to the index grade was determined. Temperature difference between grade 0 and grade 2 in the maxillary FG (r= 0.35°C and $p<0.05$), AG (r= 0.33°C and $p<0.05$), and AM (r = 0.29°C and $p<0.05$) had a significant decrease was observed. In the mandible, the grade 0 GI gingival temperature was statistically significantly different from the grade 1 and grade 2 gingival temperatures ($p<0.05$). There is a positive correlation between mandibular FG ($p<0.001$), AG ($p<0.001$) and AM ($p<.000$) temperature values and GI grade. In other words, as the grade of gingival index increased in the mandible, a significant increase was observed in gingival temperatures ($p<0.05$). In addition, in this study, the temperature difference of FG, AG and AM, which are different anatomical regions of the gingiva, was determined. The temperature difference between different grades of gingivitis was also determined. This was thought to be due to the different anatomic regions having different vascular densities. It was thought that vascular density changed according to the degree of disease.

When interpreting the thermographic images of the oral cavity, it is accepted that a pathological condition is diagnosed when the temperature difference exceeds 0.5°C (Dobrzyński et al., 2014). However, in the maxilla, FG (r= 0.35°C and $p<0.05$), AG (r= 0.33°C and $p<0.05$) and AM (r= 0.29°C and p<0,05) temperature difference was found to be an indicator of gingivitis. In the mandible, FG (r= 0.36°C and $p<0.05$), AG (r= 0.31°C and $p<0.05$) and AM (r= 0.26°C and p<0,05) temperature difference was found to be an indicator of gingivitis.

Gingival blood flow was observed to be significantly lower in patients with chronic periodontitis compared to healthy individuals (Nakamoto et al., 2012). It is suggested that this is due to the decrease in vascularization in chronic diseases. In a study on gingival surface temperature, it is reported that thermal properties, including the acute phase, have a higher temperature associated with inflammation from early periodontitis (Haffajee et al., 1992). In this study, a significant decrease in maxillary gums was observed in dogs with gingivitis. A significant temperature increase was detected in the mandibular gingiva. It was thought that this situation was caused by the different vascular behaviors in different anatomical regions.

It is stated that the average gingival pocket temperature in people with healthy gums is 33.9±0.4ºC. The mandibular gingiva was found to be 0.7±0.2ºC higher than the maxillary gingiva (Ng et al., 1978). The FG temperature of the buccal surface of the dogs with healthy gingiva in the maxilla was 36.25±1.43°C. The AG temperature was 36.81±1.37°C and the AM temperature was 37.53±1.30°C. In the mandible, in dogs with healthy gums, the FG temperature was 35.46±1.42°C. The AG temperature was 36.26±1.35°C and 37.01±1.22°C. In contrast to the study in humans, the maxillary gingival temperature was found to be higher than the mandibular gingival temperature in dogs with healthy gums. This temperature difference was measured as 0.78°C in FG, 0.52°C in AG and 0.51°C in AM. This situation supports the literature knowledge that different anatomical regions have different vascular densities.

CONCLUSION

In this study, buccal gingival temperatures of dogs with healthy gingiva were determined. It can be stated that different anatomical regions of the gingiva have different vascular density. In addition, temperature changes in the gingiva according to the disease grade were also revealed. Thus, it was analyzed what kind of temperature behaviors could be in order to diagnose gingivitis at an early stage. The sensitive sensors of the thermal camera can detect even the smallest temperature changes. Thus, it provides an advantage to the physician in order to determine possible disease states and to initiate treatment intervention early. As a result, it was concluded that the thermography is an auxiliary diagnostic tool for detecting inflammatory changes in the gingiva in dogs and thus, irreversible diseases such as periodontitis can be prevented.

DECLARATIONS

Ethics Approval

This research was carried out on the basis of the permission of Mehmet Akif Ersoy University Local Animal Ethics Committee dated 13.03.2019 and numbered 504.

Conflict of Interest

The authors declare that there have no conflict of interests.

Consent for Publication

Does not need a publication consent.

Author Contributions

Idea, concept and design: KY, CÖ

Data collection and analysis: CÖ, KY

Draft of the article: CÖ, KY

Critical review: KY, CÖ

Data Availability

The data collected within the scope of the study has not been shared.

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