Original Article

Quantification of tongue coating using quantitative light-induced fluorescence-digital image analysis and its correlation with visual evaluation

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ABSTRACT

Background: The tongue coating is a grayish-white deposit that quickly reflects the state of health or disease of the human body. Quantitative light-induced fluorescence (QLF) is a novel digital imaging system that objectively quantifies tongue coating. **Aims:** The present study aims to evaluate the correlation between the visual assessment of tongue coating and tongue coating by analysis of QLF-digital (QLF-D) images. **Settings and Design:** This was an *in vivo* explorative study. **Materials and Methods:** Fifty children aged 11–13 years with clinically visible tongue coating were selected for the study. Tongue coating was assessed clinically by the Tongue Coating Index (Shimizu *et al*., 2007) and digitally by QLF-D Biluminator™ 2, C3 software. **Statistical Analysis:** Data obtained were subjected to statistical analysis using SPSS 23.0 software. Spearman's rho correlation test was done, and $P < 0.05$ was considered statistically significant. **Results:** A statistically significant correlation was found between the visual assessment scoring and the QLF image analysis for the evaluation of tongue coating. **Conclusion:** The Digital QLF tongue imaging system was found to be reliable due to its correlation with the clinical score and objective nature.

KEYWORDS: Oral hygiene, quantitative light-induced fluorescence-digital, tongue coating, visual assessment

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Introduction

Tongue coating, a thin layer covering the dorsal surface of the tongue, plays a significant role in oral health, systemic well-being, and disease diagnosis. It is formed by the aggregation of microorganisms, debris, and metabolites on the tongue's dorsal surface, and is an essential element of the oral microbiome. Emerging evidence suggests that the composition and characteristics of tongue coating hold valuable insights into both oral and systemic health conditions. The color, thickness, and moisture level of tongue coating have been explored as a diagnostic tool for identifying conditions such as halitosis, gastroesophageal reflux disease, and even certain cardiovascular diseases.[1]

Evaluation of tongue-coating status is necessary in assessing the effect of oral health care and motivating patients to clean their tongues. Several methods have been developed for assessing tongue-coating status,

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such as visual methods, bacterial count on the tongue surface, and wet weight measurement of scrapings collected from the dorsum of the tongue.

Of the various methods available to evaluate tongue coating due to simplicity, rapidity, and convenience, visual inspection remains the cornerstone. The first visual method used was a simple index (0–3) without further details.[2] Later methods involved assessing the coating on the dorsal surface of the tongue,[3,4] and its distribution on the tongue.[5] Mantilla Gómez *et al*. divided the tongue into nine sections and assessed the discoloration and thickness of tongue coating in each of these.[6] Another index that assessed both the coated area and the thickness of tongue coating was adopted for studying oral malodor.[7,8] The Winkel Tongue Coating Index (WTCI) divided the tongue into 6 sections.[9] WTCI is most commonly used as its scores can be easily interpreted. In 2007, Shimizu *et al*.[10] divided the tongue into nine parts and scored the coating between 0 and 2 which is further used to calculate the value in percentage. However, these methods are subjective and can cause disagreement between the examiners. This necessitates the need for a more objective method for evaluating tongue coating.

Digital approaches offer objective, efficient, and often noninvasive methods for assessing various health parameters including the evaluation of tongue coating. Quantitative light-induced fluorescence (QLF) is a rapid, quantitative digital diagnostic tool that aids the clinician in clinical decision-making of various dental diseases.[11] However, in the literature, very limited studies correlated the QLF scoring with clinical in quantifying tongue biofilm.

The present study aimed to evaluate the correlation between the visual assessment of tongue coating and tongue coating by analysis of QLF-D images.

Materials and Methods

The present explorative study was conducted with the approval of the Institutional Review Board. Written informed consent was obtained from parents of children who participated in the study, and verbal assent was obtained from children.

The sample size was calculated with comparison of two proportions with 80% power and 95% confidence interval. The sample size obtained was 44 (n-master) if the accuracy of clinical identification is considered as 98% and that of QLF-D as 80%. To compensate for the possible error associated with digital imaging, another 10% was added making the total sample size 48.

The study was performed with 50 children with visible tongue coating aged between 11 and 13 years, recruited from the outpatients who visited the Department of Paediatric and Preventive Dentistry and agreed to the terms of the experiment. Subjects with systemic illnesses or with developmental disorders of the tongue were excluded from the study.

Clinical assessment

The children were instructed to refrain from having breakfast and performing any oral hygiene practices on the tongue such as brushing, use of oral rinses, and chewing gum <4 h before measurements. All measurements were recorded before lunch between 10:00 am and 12:00 pm. Tongue coating was assessed clinically by the Tongue Coating Index by Shimizu *et al*., 2007.[10]

According to it, the tongue is divided into nine parts and scored as follows:-

- Score 0: Tongue coating not visible
- Score 1: Tongue coating thin, papillae of tongue visible
- Score 2: Tongue coating very thick, papillae of tongue not visible.

Tongue coating in % was calculated with the formula explained below

$$\text{Tongue coating index} = \frac{\text{Total score}\,(0-18)}{18} \times 100 = X\%$$

Quantitative light-induced fluorescence imaging

QLF-D imaging was done using the QLF-D system (QLF-D Biluminator™ 2+, Inspektor Research Systems BV, Amsterdam, The Netherlands) and proprietary software (C3 version 1.0.0.7, Inspektor Research Systems BV, Amsterdam, The Netherlands) to control the camera setting conditions. Normal white light images and sequential fluorescence images of the tongue were captured with a "Live-View" enabled full-frame sensor Digital Single-lens reflex camera (DSLR) camera (model 550D, Canon, Tokyo, Japan) using a setting of white light images with a shutter speed of 1/30 s, an aperture value of 20.0, and an ISO speed of 1600 for blue light images shutter speed of 1/10 s, an aperture value of 10.0, an ISO speed of 1600, and a threshold of 51.

All images were taken in a darkened room maintained with the same lighting conditions to maximize the quality of the QLF-D image captured. A subsidiary cylindrical ring was equipped with the illumination tube of the QLF-D camera. This allowed the distance between light sources and the tongue to remain constant while capturing the whole tongue area. The subject was first instructed to protrude the tongue. The assistant used fingers and sterilized gauze to pull the subject's tongue as much as possible to expose a maximum area of the tongue and to minimize its movements before QLF-D images were captured.

Quantitative light-induced fluorescence-digital analysis

The tongue fluorescence in the QLF-D images was analyzed using a computer program. An area of interest (AOI) of the tongue was drawn around the boundary of the tongue from the normal white light image. The AOI that had previously been saved then was imported into the blue light image. QLF™ enhances the contrast between areas where porphyrins have accumulated and areas where they have not. The porphyrins show up orange/red and can be detected easily, even by the untrained eye.

The red fluorescence intensity value was derived from calculating the average red/green ratio (R/G value) of every pixel within the AOI for each image. The value of the fluorescence area was obtained as a percentage (%) by calculating the ratio of the number of red fluorescent pixels to total pixels within the AOI. This approach accounted for differences in tongue size between individuals. To represent the comprehensive fluorescence properties of individual tongue coating, integrated fluorescence score was calculated by multiplying the calculated value of intensity and the area of the tongue fluorescence [Figure 1].

Statistical analysis

Data obtained were entered in Microsoft Excel 2020, subjected to SPSS statistics Program (version 23.0 , SPSS, Chicago IL, USA). The Shapiro–Wilk test was performed for normal distribution by group. A descriptive analysis was carried out. The extent of agreement between *in vivo* assessment and QLF assessment was determined for each subject using Spearman's rho correlation test. $P < 0.05$ was considered statistically significant.

Results

The data were expressed as mean ± standard deviation.

The mean tongue coating value clinically, i.e., with the index by Shimizu *et al.*,[10] was 50.82 ± 8.75. The mean tongue coating value with QLF was 47.68 ± 13.41. The correlation coefficient was 0.775. The P value was 0.001, indicating that the correlation between clinical index and QLF value is statistically significant [Table 1].

Discussion

The more the need for the prevention of oral diseases has increased, the more the need for an assessment of tongue-coating status has grown. Clinical indices[5,9,10] allow an *in vivo* evaluation; however, they are subjective and their interpretation depends on the clinical experience of the examiner and visual settings. To prevent this, a digital imaging system is needed for the evaluation of tongue coating.

QLF-D unit used in the above study works on the principle that various (organic) substances in the mouth absorb light of a certain wavelength and then re-emit the absorbed energy at a different wavelength. By filtering away the illuminating light, the fluorescence- or QLF™-image is obtained.

During our literature search, we found that limited literature exists on the objective assessment of tongue coating. As per our knowledge, there are only five studies that have done a digital assessment of tongue coating.[12-15]

Table 1: Correlation between clinical index and quantitative light-induced fluorescence value

Tongue coating	*n*	Mean (%)	SD	Correlation coefficient	*P*
Clinical	50	50.82	8.75	1.000	0.001
QLF	50	47.68	13.41	0.775**	

**Correlation is significant at the 0.01 level (two-tailed). Spearman's rho. QLF=Quantitative light-induced fluorescence; SD=Standard deviation

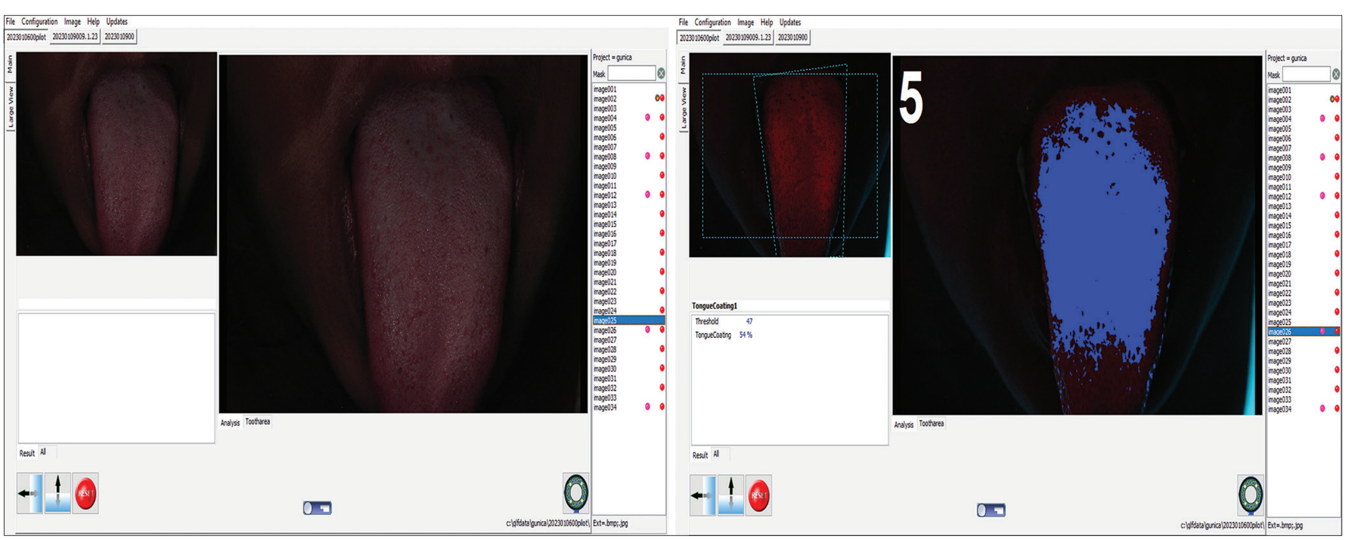

Figure 1: White light and blue light images using quantitative light-induced fluorescence

Kim *et al*., in 2009, did a study to evaluate the potential of digital tongue imaging system (DTIS) for clinical use by comparing it with the WTCI and concluded that DTIS was highly reliable and has potential clinical applications.[12]

Panov *et al*., in 2009, used Adobe Photoshop CS3 as an objective system evaluating the surface, density, and distribution of the tongue coating and found it to be a reliable way of assessment.[13]

QLF-D has been introduced as a complement to basic dental examinations and aids in providing a precise diagnosis of dental caries. This technology detects quantitative fluorescence changes in the light reflected from the tooth surface when irradiated with visible blue light of 405 nm. It can determine the depth as well as the bacterial activity of dental caries simultaneously.[16,17] QLF detects fluorescence loss (ΔF) which is representative of the mineral loss of the examined tooth and thus reveals the lesion depth.[18-20] QLF also detects red fluorescence (ΔR), which corresponds to the porphyrin derivatives of bacterial metabolism.[21] ΔR is usually increased in carious lesions, dental plaque, and dental calculus as these are formed by the aggregation of a plethora of microorganisms.[22,23] Recent studies have proved that ΔR is related to the lesion activity of dental caries.[24-26] QLF has the added benefit of being devoid of detrimental effects of radiation exposure that are associated with traditional radiographic examination and thus is a better technique for caries screening and detection.

Kim and Kang, in 2023, assessed the bacterial activity and the distribution of tongue coating in the diagnosis of oral malodor with QLF images providing significant accuracy during quantitative analysis in the identification of bacterial activity and the distribution of tongue coating.[14]

Lee *et al*., in 2015 and 2016, concluded that QLF can be used to assess plaque on the tongue and in the interdental area as a cause of oral malodor.[15]

However, out of these five articles, two used a different methodology like a DTIS and cropped images. These require different software and techniques. The studies that involve QLF focused more on oral malodor and bacterial load due to tongue coating as there is a correlation between them.

The settings mentioned by Lee *et al*., in 2015,[15] were not useful for the replication of images as a different software has been used to asses tongue coating.

Therefore, the present study aims to standardize the settings and the threshold at which the clinical index is correlatable with the QLF image value for tongue coating assessment. The Tongue Coating Index by Shimizu *et al*.[10] gives results in percentages similar to the result provided by QLF software, thus making it easier to find a correlation between the two values.

The results of the present study [Table 1] show a relatively high degree of correlation between the assessment of tongue coating using the Tongue Coating Index (Shimizu *et al*. 2007)[10] and QLF when the shutter speed is 1/10 s, the aperture value is 10.0, and ISO speed is 1600 (for blue light image) and the software threshold is set at 51.

Conclusion

Based on the present study, we can conclude that QLF image analysis for evaluation of tongue coating has clinical application as it is correlatable with the clinical score. The readings given by QLF-D are objective and quantifiable, thus it is highly reliable.

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Conflicts of interest
There are no conflicts of interest.

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