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ORIGINAL ARTICLE

A digital tongue imaging system for tongue coating evaluation in patients with oral malodour

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OBJECTIVE: Several simple visual methods have been developed for assessing tongue coating, but it is difficult to eliminate biases associated with these. The digital tongue imaging system (DTIS) was designed to acquire tongue surface images using a digital camera under controlled conditions, and to calculate tongue coating area. The aim of this study was to evaluate the potential of DTIS for clinical use by comparing it with the Winkel tongue coating index (WTCI). MATERIALS AND METHODS: Forty participants with oral malodour were rated on WTCI by two independent examiners, and photographs of their tongues were assessed using the DTIS. The photographs were also rated by the examiners (blinded to *in vivo* WTCI and DTIS statuses).

RESULTS: Agreements between *in vivo* **WTCI** ratings and DTIS assessments were relatively high at r = 0.561 for one examiner and r = 0.736 for the other (P < 0.01), while agreements between the *in vivo* **WTCI** ratings and tongue photograph-based ratings were also high at r = 0.645 for one examiner and r = 0.742 (P < 0.01) for the other.

CONCLUSIONS: Digital tongue imaging system was found to be highly reliable and as having potential clinical applications. However, the algorithm for determining *in vivo* tongue coating status requires improvement. *Oral Diseases* (2009) **15**, 565–569

Keywords: digital tongue imaging system; tongue coating; tongue coating index

Introduction

The coating of the tongue consists not only of bacteria but also of desquamated keratinized epithelium (mainly

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from the filiform papillae), leucocytes from periodontal pockets, metabolites and various nutrients (Yaegaki and Sandada, 1992). These substances are believed to be the main sources of volatile sulphur compounds such as H_2S and CH₃SH, which are major factors in oral malodour (Miyazaki *et al*, 1995; Lee *et al*, 2003). Volatile sulphur compounds are produced by the putrefactive action of oral microorganisms on sulphur-containing amino acids, peptides, or proteins found in the mouth (Tonzetich and McBride, 1981). Therefore, oral hygiene practices, such as cleaning the tongue coating, can be effective means of reducing oral malodour (Tonzetich, 1977).

Several methods have been developed for assessing tongue coating status, such as visual methods, bacterial count on the tongue surface (Shimizu et al, 2007) and wet weight measurement of scrapings collected from the dorsum of the tongue (Yaegaki and Sandada, 1992). Of the various methods, the visual methods are predominantly used in clinical practice because of their simplicity, rapidity and convenience. The first visual method used was a simple index (0-3) without further details (Gross et al, 1975). Later methods involved assessing the coating on the whole dorsum of the tongue (Bosy et al, 1994; De Boever and Loesche, 1995), and evaluating tongue coating status in terms of distribution area (Miyazaki et al, 1995; Morita and Wang, 2001). Gomez et al (2001) divided the tongue into nine sections, and assessed the discolouration and thickness of tongue coating in each of these. Another index that assessed both the coated area and the thickness of tongue coating was adopted for studying oral malodour (Oho et al, 2001; Hinode et al, 2003; Tanaka et al, 2003). The Winkel tongue coating index (WTCI) was recently introduced, in which the tongue is divided into six sections (Winkel et al, 2003; Roldan et al, 2004). The utility of the WTCI seems to be potentially high because its scores are relatively easy to interpret.

However, the high number of visual methods for evaluating tongue coating often results in considerable disagreement between examiners. A previous study found percentages for agreement on the thickness of tongue coating to be 69% and 58% for within- and

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between-examiner assessments respectively (Gomez *et al*, 2001). For ratings of tongue coating based on the visibility of tongue papillae and the thickness of coating, the Cohen's kappa for inter- and intra-observer agreement was reported as 0.66 ± 0.08 and 0.80 ± 0.09 respectively (Shimizu *et al*, 2007). Although some visual methods are useful and convenient in clinical settings, their ratings are prone to disagreement both within and between examiners.

Avoiding the disagreement on ratings using visual methods necessitates a more objective method for evaluating tongue coating. The digital tongue imaging system (DTIS) was designed to obtain a digital image of the tongue surface, segment this into regions and extract the areas corresponding to tongue coating (Eo *et al*, 2006).

Before using the DTIS to evaluate tongue coating status in clinical settings, it is necessary to determine the accuracy by which it reflects tongue coating status. The aims of the present study were (a) to investigate the extent of agreement between *in vivo* and photograph-based assessments of tongue coating and (b) to evaluate the strength of correlation between *in vivo* WTCI scores and the percentage of tongue coating area determined by the DTIS.

Materials and methods

Participants

Forty participants (13 males and 27 females, mean age = 34 years, range = 9-67 years) were recruited for the study from the Department of Gastroenterology and Halitosis Clinic of the Hospital of Oriental Medicine, Kyung Hee University. The chief complaint of these participants at their initial visit was oral malodour. We excluded participants with a pale tongue body associated with conditions including anaemia, protein malnutrition and decline of basal metabolism, because the DTIS is based on an algorithm that distinguishes tongue coating from a total tongue image on the basis of its white-yellow colour. Informed consent was obtained from each participant

before enrolment, as approved by the Institutional Review Board of Kyung Hee University Hospital.

The digital tongue imaging system (DTIS)

The DTIS consists of four parts: (a) exterior, with an interface for the patient's face, (b) image acquisition, (c) illumination and (d) software. The exterior part is structured for easily positioning a patient's face and tongue for stable imaging (minimizing the movement of the face and tongue), and ensures constant illumination regardless of external light conditions (Figure 1). The DTIS software controls image acquisition, locating an appropriate region of the tongue, isolating this from the background using a snake algorithm (Pang et al, 2005), and extracting areas with tongue coating. In calculating the area of tongue coating across the entire tongue, colours in the image are converted to a standard colour temperature space (D 5600K) using a colour reproduction algorithm. With the monitor adjusted to this colour space, the conversion process produces images that are standardized across differences in colour representations as influenced by illumination and camera colour distortion. Our heuristic algorithm for extracting areas of tongue coating is based on the tongue body and tongue coating corresponding to red and white-yellow colour spaces respectively (Chiu, 2000; Pang et al, 2005; Eo et al, 2006).

In the present study, the DTIS divided the tongue surface into six sections, as per the method of Winkel *et al* (2003), and calculated the percentage of tongue coating area for each section, and for the tongue as a whole (Figure 2).

Assessment of tongue coating using the WTCI

In vivo tongue coating ratings were made using the WTCI (Winkel *et al*, 2003). The dorsum of the tongue was divided, from the circumvallate papillae to the tip, into six sections (three on the anterior part and three on the posterior part), and tongue coating assessed in each of these as: 0 = no coating, 1 = light coating, and 2 = heavy coating. The differentiation between light and heavy coating was based on whether pink



Figure 1 Overview of the digital tongue imaging system (DTIS). The lower right side shows the exterior part of the DTIS, with the interface for a patient's face designed for easy presentation of the patient's tongue to the digital camera. The upper left and right sides show the internal composition of the DTIS, which contains a computer system and software, and parts for image acquisition and illumination

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Figure 2 The digital tongue imaging system (DTIS) programme display showing the acquired tongue image (left), extracted tongue coating image (middle) and the percentage score diagram for tongue coating (right)

colouration could be observed underneath the coating. Scores for each section were summed to give a total WTCI score, ranging between 0 and 12 (Method 1). All WTCI assessments were made by two examiners (authors J.K. and Y.J.) well-trained in using the method in a standardized manner.

Assessment of tongue coating with the DTIS

Seated participants fixed their face on the DTIS interface, extruded their tongue as far as possible and maintained this pose while photographs were taken. The examiners (blind to *in vivo* WTCI and DTIS status) made WTCI ratings of the DTIS-acquired tongue photographs (Method 2). The percentage of tongue coating was calculated from the photographs with the DTIS algorithm (Method 3).

Statistical analysis

The extent of agreement between in vivo and photograph-based WTCI scores (Methods 1 and 2, respectively) was determined for each examiner using Pearson's correlation. This approach was also used to determine the extent of agreement between examiners for each of Methods 1 and 2, and to determine the extent of agreement between Method 1 ratings and the percentage of tongue coating determined by the DTIS (Method 3). Factors potentially affecting the extent of correlation between ratings for Methods 1 and 3, including the use of WTCI score 1 (light coating) and region of the tongue surface (anterior or posterior), were also analysed using Pearson's correlation. P < 0.05 was considered statistically significant. Analyses were performed using the Statistical Package for the Social Sciences 14.0 (SPSS for Windows, Chicago, IL, USA).

Results

Extent of agreement between in vivo (Method 1) and photograph-based (Method 2) WTCI scores

Mean WTCI scores and the extent of agreement between Methods 1 and 2 for each examiner are shown in Table 1 (P < 0.01). The degree of correlation between Method 1 scores and Method 2 scores was relatively high for both Examiner 1 at r = 0.681 and Examiner 2 at r = 0.742.

Inter-examiner agreement for Methods 1 and 2

Inter-examiner agreement for Methods 1 and 2 is presented in Table 2 (P < 0.01). As indicated by the

Table 1 Mean values of the Winkel tongue coating index (WTCI) scores in *in vivo* (Method 1) and photograph-based (Method 2) methods between both examiners and extent of agreement between Methods 1 and 2 scores by Pearson's r

	Examiner 1	Examiner 2
WTCI scores In vivo (Mean ± s.d.) Photograph-based (Mean ± s.d.) Pearson's r of WTCI scores (In vivo vs photograph-based)	$\begin{array}{r} 7.25 \ \pm \ 2.02 \\ 8.61 \ \pm \ 1.76 \\ 0.645^* \end{array}$	$\begin{array}{r} 7.45 \ \pm \ 1.81 \\ 7.64 \ \pm \ 1.86 \\ 0.742 * \end{array}$

n = 40, *P < 0.01

Table 2 Inter-examiner coefficients of correlation (Pearson's r) between the Winkel tongue coating index (WTCI) scores in *in vivo* (Method 1) and photograph-based (Method 2) methods, and between Method 1 and the percentage of tongue coating determined by the Digital tongue imaging system (DTIS, Method 3)

	WTCI Scores	
	In vivo	Photograph-based
Examiner 1 vs Examiner 2	0.762*	0.773*
Examiner 1 vs Method 3 (DTIS)	0.561*	0.670*
Examiner 2 vs Method 3 (DTIS)	0.736*	0.748*

n = 40, *P < 0.01.

strength of correlation, the extent of agreement between Methods 1 and 2 was relatively high (r = 0.762 and r = 0.773).

Correlation between Methods 1 and 3

In evaluating the potential clinical utility of the DTIS, the extent of agreement between Methods 1 and 3 was analysed, and the results are presented in Table 2 (P < 0.01). The percentage values produced by Method 3 showed a relatively high correlation with the scores of both Method 1 and Method 2 (Table 2). However, the strength of correlation was higher between Methods 2 and 3 than between Methods 1 and 3.

Correlations between Methods 1 and 3 for particular tongue regions

Results for the analysis of regional correlations between Method 1 scores and Method 3 percentages were r = 0.242 (Examiner 1, non-significant) and r = 0.527(Examiner 2, P < 0.01) for the anterior part of the 568

tongue surface, and r = 0.517 (Examiner 1, P < 0.01) and r = 0.534 (Examiner 2, P < 0.01) for the posterior part of the tongue surface.

Discussion

The results of this study show a relatively high degree of correlation between assessments made with Method 3 (DTIS) and those made with Methods 1 and 2 (Table 2). However, the strength of correlation between Methods 2 and 3 was higher than that between Methods 1 and 3. Contributing to this might be the different circumstances (time and place) under which the examiners conducted Method 1, circumstances which were less likely to influence in an examination of tongue photographs (Methods 2).

Our findings, and those of previous studies, suggest two problems associated with using the visually based WTCI method for evaluating tongue coating status. First, despite being well-trained, there are unavoidable individual differences in how examiners apply visual methods (Gomez *et al*, 2001; Lundgren *et al*, 2007). Second, without well-defined dividing landmarks on the dorsum of the tongue, there is ambiguity in the criteria of visual methods (Miyazaki *et al*, 1995; Shimizu *et al*, 2007).

The rationale for assessments made using the DTIS (Eo *et al*, 2006) suggest that the method should be reliable and accurate in evaluating tongue coating. We thus saw the DTIS as a method potentially overcoming the limitations of visual methods, such as the WTCI, associated with individual differences and unclear criteria. Our results indicate that there was no overlapping or omission of regions of tongue coating by the DTIS, and that this method could thus be useful, accurate and convenient in the clinical evaluation of tongue coating. An added advantage of the DTIS is the ability to use the monitor to show a patient their tongue coating status (or changes in this). All of these considerations suggest that the DTIS could be beneficially applied for accurate evaluations of tongue coating in clinical settings.

We found a higher level of inter-examiner agreement between Methods 1 and 2 (Table 2) than that reported for a previous study using a modified WTCI (r = 0.48, Lundgren *et al*, 2007). Interestingly, Lundgren *et al* (2007) also reported an improvement in the strength of correlation (r = 0.93) with the modified WTCI when score 1 (light coating) was excluded. However, we did not find any such improvement in the present study (r = 0.696 for *in vivo* scores). The differences between studies might reflect differences in the number of tongue surface sections analysed (Lundgren *et al*, 2007), and/or individual differences in how the examiners determined WTCI scores.

We investigated potential sources of disagreement between the WTCI scores of examiners by analysing the extent of correlation between Methods 1 and 3 for both the anterior and posterior sections of the dorsum of the tongue. There was a non-significant correlation found for the anterior tongue surface ratings of Examiner 1, potentially because of the WTCI criteria being applied broadly by this individual. There are some considerations regarding the application of the DTIS to clinical settings. First, a pale or whitish colour of the tongue body may make white tongue coating difficult to identify. Second, the DTIS can only calculate the area of tongue coating; it does not discriminate between light or heavy coating. Thus, further work is needed to improve the algorithm for evaluating tongue coating to ensure accurate results regardless of the colour of tongue coating or body. A higher correlation between tongue coating status and the percentage of tongue coating calculated by the DTIS algorithm will be evidence of improvement.

In conclusion, the present study was the first trial of the DTIS for evaluating tongue coating status. The method was found to be of relatively high reliability; thus, it might facilitate more accurate, and unbiased, clinical evaluations of tongue coating. However, problems associated with the white colour and thickness of tongue coating when using the DTIS remain to be solved.

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Author contribution

Jinsung Kim, Kyungmo Park and Jae-Woo Park contributed to the research design, the collection and analysis of data, and the drafting and critical revision of the paper. Yongjae Jung contributed to the collection and analysis of data.

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