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Quantification of dental plaque on lingual tooth surfaces using image analysis: reliability and validation

R. N. Smith[1], A. Rawlinson[2], D. Lath[3], C. Elcock[1], T. F. Walsh[2] and A. H. Brook[1]

[1]Department of Oral Health and Development, School of Clinical Dentistry, University of Sheffield, Claremont Crescent, Sheffield, UK; [2]Department of Adult Dental Care, School of Clinical Dentistry, University of Sheffield, Claremont Crescent, Sheffield, UK; [3]University of Sheffield and Boots National Centre for Applied Research into Oral Health, School of Clinical Dentistry, Claremont Crescent, Sheffield, UK

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Abstract

Aim: The aim of this study was to increase the versatility and further validate the method reported by Smith et al. (2001) by testing the reliability of plaque measurement against two well-known dental plaque quantification methodologies using image analysis in a clinical trial.

Method: The teeth of 40 subjects were disclosed before digital images of the labial and lingual surfaces of their upper and lower incisors were acquired. The amount of plaque present was quantified using a modification of the method described by Smith et al. (2001). The method was modified for obtaining images of the lingual surfaces by incorporating the use of orthodontic occlusal mirrors and 5-mm pieces of moistened blue articulating paper used to enable calibration. Plaque measurements were made from 320 upper and lower anterior teeth from the 40 subjects by two operators. Fliess' coefficient of reliability was used to assess intra- and inter-operator reliability and the independent sample *t* test was used to assess statistical significance between test and control groups after checking the data for normality. For validation, measurements were recorded using the Turesky et al. (1970) (modification of the Quigley & Hein (1962) plaque index and the Addy et al. (1983) plaque area index. The results were compared with the image analysis method using Pearson's correlation coefficient.

Results: The results for reliability were within Fliess' range of ''excellent'' for both intra-operator repeatability and inter-operator reproducibility. Pearson's correlation coefficients showed highly significant values indicating the close similarity between all three methods.

Conclusions: This method for the measurement of dental plaque on lingual surfaces of anterior teeth proved reliable. The combined results from the labial and lingual surfaces of anterior teeth using image analysis produced trial conclusions comparable with the alternate plaque quantification methods used, with less clinician time and further producing a permanent database of images for future use.

Key words: dental plaque; image analysis; quantification

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Many reports have been made regarding the discriminatory power of area measurement against standard indices for plaque measurement. Addy et al. (1999) noted that Turesky's plaque index had better discriminating power than the Addy et al. (1983) plaque area index. Others, such as Ainamo et al. (1993) discovered that area planimetry methods were least discriminating. On the other hand Quirynen et al. (1991) found his 24-h planimetric method (Quirynen et al. 1985) had greater discriminating power than the Quigley & Hein (1962) method, the Harrap (1974) GMP1I index and the Elliot et al. (1972) navy index, especially over short durations. Söder et al. (1993) compared computerised planimetry with the Quigley & Hein (1962) method and found the planimetry area measurement more discriminating when very small changes were likely. Shaloub & Addy (2000) showed that reliable results could be obtained from operators with varying experience when using area measurement methods, suggesting the area measurement methods were easier to perform and therefore less likely to produce operator errors and thus provided greater accuracy.

Comparisons of area measurement and conventional index systems agree

that area measurements are more discriminating for short-term trials where plaque changes are small. This suggests an overall greater discriminating power.

A computerised image analysis system, first described by Smith et al. (2001), does not utilise planimetry or other manual area tracing, but accurately calculates areas of complex scattered and broken up plaque regions from calibrated digital images. In agreement with the previously mentioned authors, results so far have shown greater discriminating power that is more noticeable in the early stages of a clinical trial and when there are small changes in plaque level expected. This method also shows more significant results at intermediate periods, compared with other methods.

As most clinical indices used to measure dental plaque incorporate assessment of both the buccal and lingual surfaces of upper and lower teeth, it was decided that the image analysis system described by Smith et al. (2001) should be developed so that lingual dental plaque area measurement of the anterior teeth could be performed. This would give the method more scope for use in trials where site-specific data are required, such as the effectiveness of oral hygiene products on the plaque levels on lingual surfaces, or any trial where the level of change of plaque on the labial and lingual surfaces should be taken into account.

Thus, the aim of the present study was to test the reliability of the dental plaque area measurements on the lingual surface of anterior teeth and validate the results by comparing with two well-known dental plaque indices.

Material and Methods

Study design

This image analysis method was used in a single centre, double-blind, parallel-group study designed to compare the effectiveness of toothpastes at inhibiting the re-growth of dental plaque. The study received ethical approval from the South Sheffield Research Ethics Committee.

The study involved 40 subjects that were allocated to the two different treatments according to a predetermined randomisation scheme. All subjects received information regarding the procedures and experimental protocol and gave their written consent. The inclusion criteria were that the patients must be aged between 18 and 65 years, in good general health, able to complete a 2-week study, have a minimum of 18 natural teeth (excluding second and third molars) and have previously demonstrated at screening the formation of measurable amounts of plaque having suspended cleaning for 2 days.

Subjects used a washout toothpaste (standard fluoride toothpaste) for 7 days and were then disclosed and prophylaxis was carried out to reduce the plaque scores to zero at baseline by scaling and polishing if necessary. A predetermined weight of the test toothpaste, a dentifrice with a novel anti-adherent block copolymer or control (this was a standard currently marketed fluoride toothpaste containing sodium lauryl sulphate) toothpaste equalling 3 g in weight was then mixed with 10 ml of water to produce the slurries used throughout the trial. The subjects rinsed twice a day with their particular slurry from time zero, day 1 until the fourth day at 96 h. Plaque levels were scored at 24 and 96 h thus giving all indices a reasonable chance to be discriminative (control and test toothpastes were developed and provided by Boot Contract Manufacturing, Beeston, UK).

Plaque measurement procedure

An identical patient management, image capture and data analysis method were used as described by Smith et al. (2001) with the inclusion of orthodontic occlusal mirrors (D B Orthodontics, Skipton, UK) to facilitate intra-oral imaging of the lingual surfaces of the anterior teeth.

Table 1. Fliess' coefficient of reliability (R) and Pearson's correlation coefficient for intra- and inter-operator reliability results for the lingual tooth surface plaque measurements on the anterior teeth for two operators

	Upper lateral incisors		Upper central incisors		Lower incisors	
	Fliess (R)	Pearson	Fliess (R)	Pearson	Fliess (R)	Pearson
intra-operator (1) error	0.956	0.967*	0.966	0.964*	0.975	0.982*
intra-operator (2) error	0.900	0.896*	0.990	0.994*	0.984	0.984*
inter-operator error	0.895	0.967*	0.946	0.970*	0.958	0.983*

R of 0.81–1.00 = excellent reliability.
*$p \leqslant 0.01$

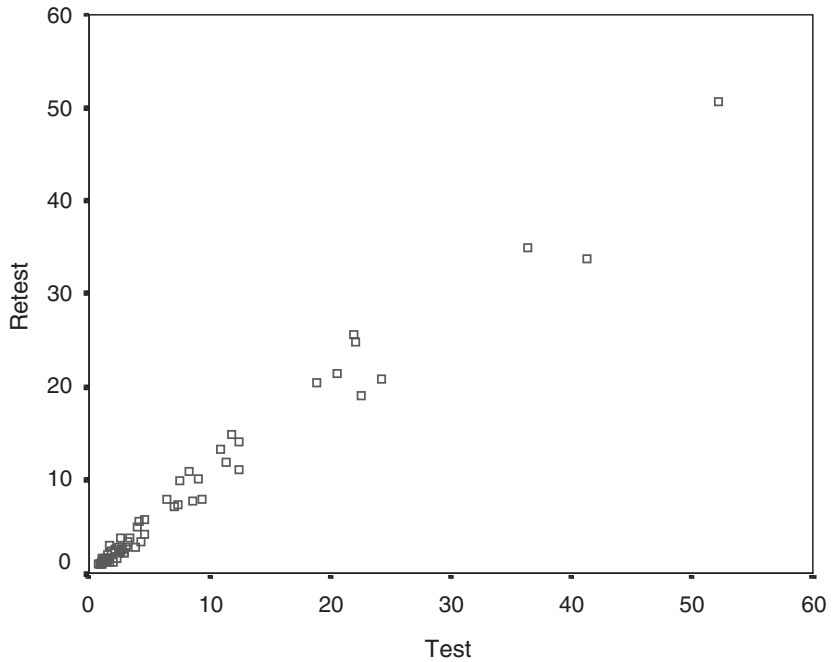

Fig. 1. Inter-operator reproducibility (lower incisors, lingual surfaces) (operator 1, first measurement against operator 2, first measurement in mm^2).

The mirrors were prewarmed over a water bath before use, to help prevent steaming up when used. Precisely cut pieces of blue articulating paper 5 mm × 2 mm (H Schein, Kent, UK) were very slightly moistened with the subject's saliva to help secure them in position and placed with tweezers towards the incisal tooth edge on the lingual surfaces of anterior teeth. Two separate images were grabbed of the upper and lower lingual surfaces and likewise for the labial surfaces. The images of the labial surface were then calibrated using the calibration scale bite (Smith et al. 2001) and the piece of articulating paper was used as a 5-mm standard for the lingual surface images. The plaque levels were then measured for all images using the methodology described by Smith et al. (2001).

Evaluation

Images were obtained from the 40 subjects after disclosure with Erythrosin FDC Red 3 (GMBH and Co., Duifberg, Germany). For reliability calculations, including imaging for total system error, the patients were imaged and then asked to stand away from the apparatus for subsequent re-positioning and re-imaging. This allowed replicate images to be taken of the same plaque pattern for the lingual surface images. Two trained operators each took a set of replicate images and later measured the replicate images of the lingual surfaces on separate occasions, while the labial images were as described by Smith et al. (2001).

Fliess' coefficient of reliability (Fliess 1986) was used to calculate the difference between the first and second occasion measurements for the intra- and inter-operator reliability determination. There was no statistical difference between measuring plaque levels on teeth from the left and right sides so a mean of the two sides was used, and similarly the lower central and lateral incisors were assessed collectively (Smith et al. 2001).

Validation

After disclosing with erythrosin, all patients had their dental plaque levels scored using the Turesky et al. (1970) modification of the Quigley & Hein (1962) plaque index and the Addy et al. (1983) plaque area index. Two trained clinicians undertook the clinical observations.

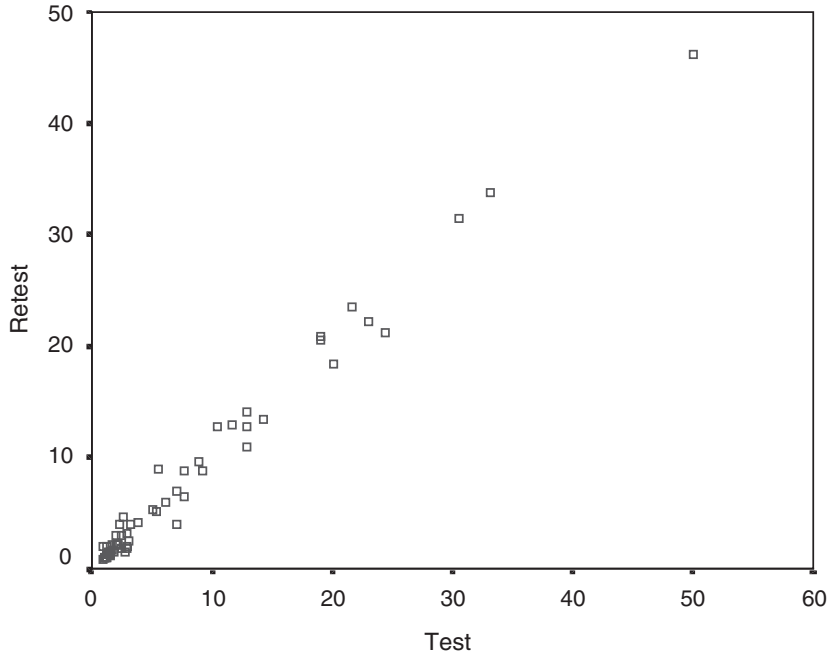

Fig. 2. Inter-operator reproducibility (upper lateral incisors, lingual surfaces) (operator 1, first measurement against operator 2, first measurement in mm^2).

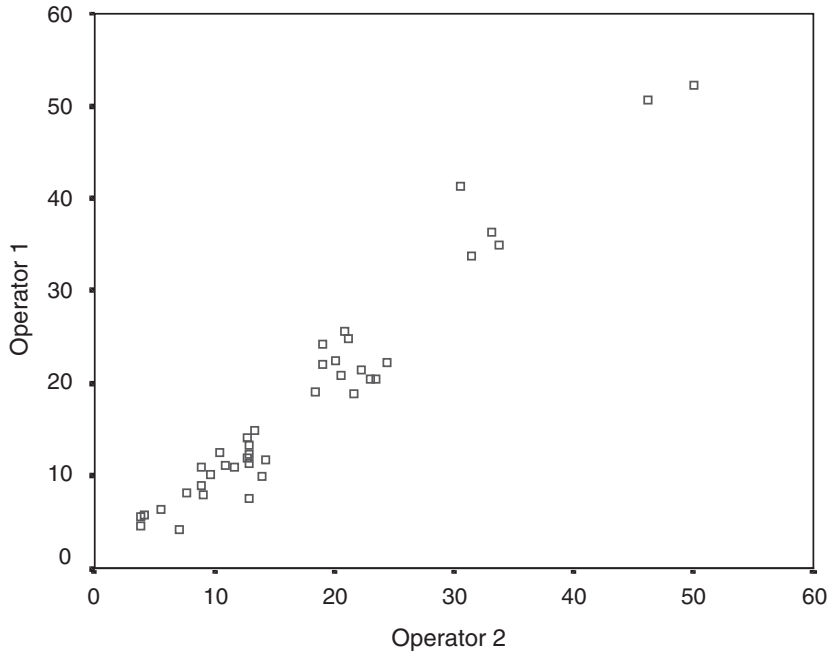

Fig. 3. Inter-operator reproducibility (upper central incisors, lingual surfaces) (operator 1, first measurement against operator 2, first measurement in mm^2).

After checking for normality, the difference between the mean control plaque levels and test plaque levels were calculated using the independent sample *t* test, as baseline scores were all the same at time zero. The results showed no significant difference between test and control groups. To give a measure of validation, Pearson's correlation coefficient was used to calculate the similarity between the data sets (Silberman et al. 1998).

Results

Reliability

Table 1 shows intra-operator repeatability and inter-operator reproducibility for

two operators. The upper central incisors were measured separately from the upper lateral incisors and lower incisors were also measured separately as these three groups of teeth had obvious differences in the difficulty in measurement. All the results were similar and within Fliess' coefficient range of 0.82–0.99. Figs 1–3 and the inter-operator results from Table 1 display a high degree of reproducibility between operators and non-bias results.

Pearson's correlation coefficient was used to give evidence of validation. Table 2 demonstrates the similarity in the data between the image analysis method and Turesky et al. (1970), and image analysis and Addy et al. (1983) method. The results show a strong correlation significant at the 0.01 level.

Table 2. Pearson's correlation coefficient comparing image analysis with the Turesky method and image analysis with the Addy method

image analysis compared with Turesky	0.766*
image analysis compared with Addy	0.771*

*$p \leqslant 0.01$

Discussion

The tables and figures of the lingual tooth surface plaque measurements show that the image analysis technique is as repeatable and reproducible a method for anterior lingual tooth surfaces as for the labial surfaces (Smith et al. 2001). Figs 4 and 5 show all scores from the lingual surfaces, and there was no bias in readings, as the points follow the diagonal central line very closely. These results demonstrate the technique's high level of standardisation as previously detailed (Smith et al. 2001).

The Pearson's correlation coefficient results in Table 2 indicate the technique produces comparable results when compared with two well-known indices, giving evidence of validation. In general, the Turesky et al. (1970) method produced consistently higher scores than the image analysis method, and the Addy et al. (1983) method produced slightly higher scores than the image analysis method. This can be explained by the fact that both the Turesky et al. (1970) and Addy et al. (1983) methods are approximations of the actual areas, with the Turesky et al. (1970) method having the larger experimental error due to areas that have been allocated scores.

The results of this experiment showed that the addition of the lingual surface measurements to the labial ones did not increase the system's sensitivity, so lingual measurements need only be included where lingual plaque data were specifically required. It is admitted that this technique is not a chair side method that can be adopted by all clinicians, but the method was intended for use in pilot studies and clinical trials required to show a higher degree of discriminatory power (Smith et al. 2001). Therefore, an accurate indication may be obtained using this method to determine if a full scale and, therefore, more costly trial

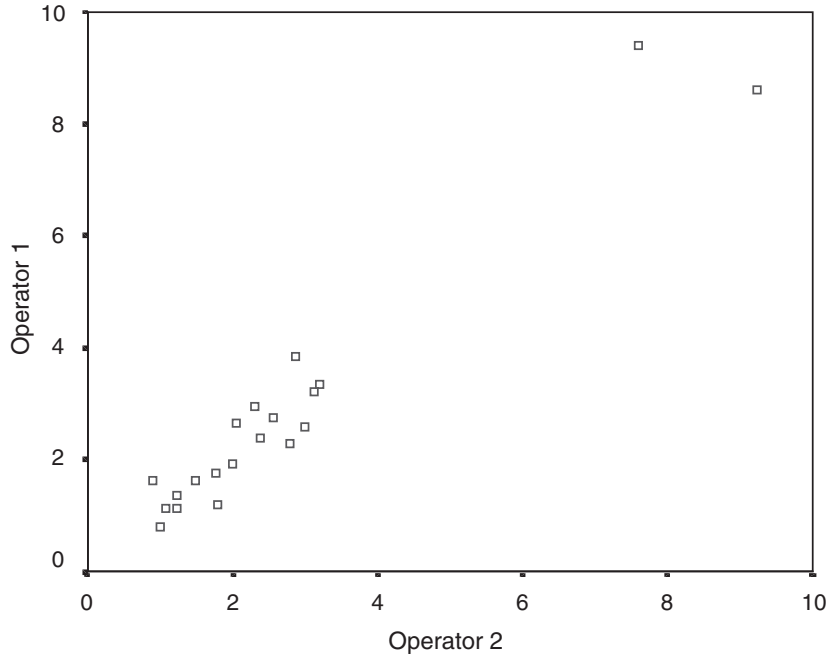

Fig. 4. Intra-operator repeatability (all measurements) operator 1 (test = measure mm^2 from first set of images, retest = measure mm^2 from second set of images).

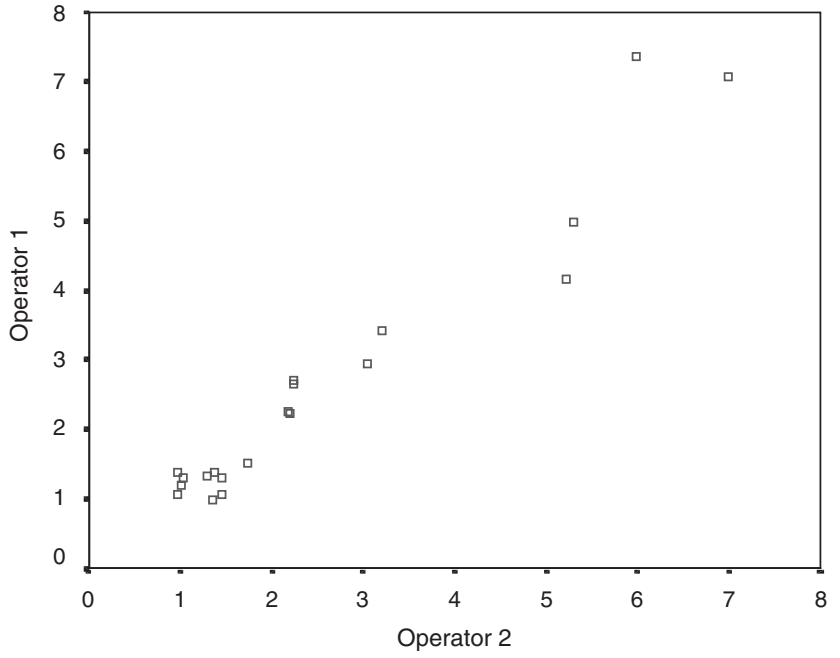

Fig. 5. Intra-operator repeatability (all measurements) operator 2 (test = measure mm^2 from first set of images, retest = measure mm^2 from second set of images).

containing this and other methods should be performed. However, this plaque measurement system has many general benefits over existing techniques. These include: a shorter chair time for the patient as the imaging with quantification carried out later, the clinician is not required at all to perform any measurement, fewer measurements are needed as less surfaces are assessed without loss of sensitivity, a permanent database of images is created and can be used for patient information and motivation as well as further studies.

The system is undergoing constant modification and improvement to facilitate capturing images illuminated with ultraviolet light and to permit the imaging of posterior teeth, currently a limiting factor for trials requiring site-specific data. This method has proved its value in several trials regarding dental plaque levels and is portable.

In conclusion, the results have shown that where necessary the system can provide lingual plaque level scores as well as labial, with little clinical time. Its increased level of sensitivity over existing methods can give a greater indication of the validity of undertaking large expensive clinical trials when testing new dental hygiene products.

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Address:
Richard N. Smith
Department of Oral Health and Development
University of Sheffield
School of Clinical Dentistry
Claremont Crescent
Sheffield S10 2TA
UK
Fax: +44 114 271 7843
E-mail: R.Smith@Sheffield.ac.uk