Plaque Assessment via Computer Aided Digital Image Analysis (DPIA)

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ABSTRACT

Indices previously used for the measurement of dental plaque have included computer assisted image analysis of digitized photographs (Sunberg et al., 1996 *IADR meeting*). The present development is a fully automated technique for measuring *in-vivo* plaque coverage on teeth based on digital photography of fluorescein disclosed plaque under UV light. Digitally captured images are fed directly to a Macintosh Power PC 8100/100 (96Mb RAM, 1Gb HD) for immediate analysis of plaque coverage. Each image pixel is classified as teeth, tooth plaque, gingival plaque, gingiva or lip retractors using a least squared distance discriminant classification model based on Red, Green and Blue values (0-255 scale). The model parameters are established based on pre-measures of the average RGB values and covariance between RGB for each of the five classes. A Fuji HC-1000 camera is used to capture the images and provide subject repositioning on the chin rest. The subject is repositioned by aligning themselves to a stored baseline image. A live image is superimposed on the stored image and subjects adjust their position accordingly. In addition to the HC-1000 camera, the repositioning system includes RGB monitors and a NuVista+ video card. Capture, storage and analysis of images is accomplished with customized software. **Repeated measures of plaque coverage (including re-disclosing and re-positioning on multiple subjects) show an average RSD less than 2.0% on plaque amount. In addition, the discriminant model correctly classifies pixels at a rate of 99.1%. The Digital Plaque Image Analysis technique is a useful tool for measuring anti-plaque efficacy, as only 5 subjects are required to observe a significant 20% reduction in plaque.**

INTRODUCTION

Prior to the development of Digital Plaque Image Analysis, the primary technique for assessing plaque levels *in-vivo* was a dentist's subjective grading using the modified Turesky plaque scale. Many problems exist with traditional plaque grading scales such as the large number of subjects required and variation in grading techniques between dentists. As a result, measuring modest plaque efficacy between chemotherapeutic agents and devices becomes difficult and cumbersome.

Thus, the need existed for an automated technique to measure plaque coverage on teeth.

The technical basis for successful automated image analysis of dental plaque coverage is the wide color separation of plaque, gingiva, gingival plaque and teeth when disclosed with fluorescein and photographed under U.V. light. Under these conditions, plaque on teeth fluoresces yellow, teeth fluoresce light blue, gingiva are black and plaque on the gingiva is green. Previous attempts to automate the measurement of plaque coverage have failed due to the inability to distinguish plaque on teeth from plaque on the gingiva due to similarity in color. The fluorescein based disclosing technique developed as a part of this invention eliminates this problem.

An initial prototype image analysis system was developed by R. Sunberg (1996 *IADR Abstract*) based on film photography. While the accuracy and precision of the technique was superior to subjective grading scales, the technique was cumbersome and did not allow immediate review of the images captured. Image errors were not detected until studies were complete.

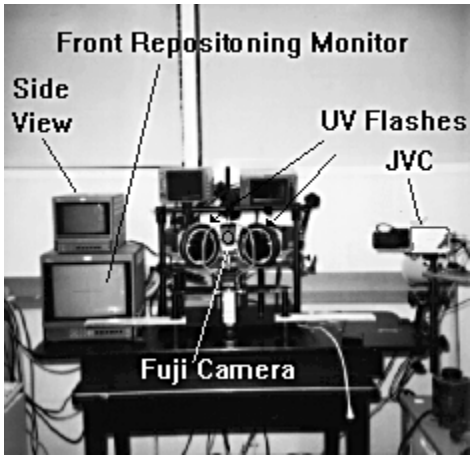
OBJECTIVE

The objective of the present development is to design a fully automated plaque imaging technique to measure the amount of plaque on teeth. The plaque will be disclosed with fluorescein and imaged under U.V. light to maximize the color separation between plaque, gingival plaque, teeth, gingiva and lip retractors.

MATERIALS AND METHODS

A Fuji HC-1000 camera was used to capture the U.V. images of fluorescein disclosed plaque. The camera, which was permanently mounted between two Balcar 2400 UV Starflashes, is focused on the plane of the chin rest which is located 24 inches from the lens. The physical setup of the system is shown below in figure 1:

Figure 1.



Subjects are repositioned by aligning themselves to a stored baseline image. A live image and the stored are superimposed using a NuVista+ video card. The system operator then instructs the panelists on how to properly align themselves (Fig. 2).

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Figure 2.

Once repositioning is established, a 1280 x 960 pixel image is captured under U.V. light. The image is automatically transferred to a Macintosh power PC 8100 where it is automatically saved according to subject number.

The images are color corrected for small variations in lighting conditions based on daily imaged color standards. In addition, the images are reduced to 640 x 480 pixel for hard disk space considerations.

A custom Oncor Image application coupled with a Hypercard file management stack is used to analyze the images. Each pixel of an image is classified as plaque, teeth, gingiva, gingival plaque or lip retractors using a least squared distance discriminant model. The distance in RGB color space for each pixel to defined classes is calculated according to the model below. Pixels are classified into the class with the smallest least square distance.

$$D_t^2(x) = (x-m_t)'*S_t^{-1}*(x-m_t) + \log|S_t|$$

x = 1x3 RGB matrix of the pixel to be classified.
t = class number (1=plaque, 2=gingiva, 3=teeth, 4=gingival plaque, 5=lip retractors)
m_t = 1x3 RGB matrix containing average RGB values of class t
S_t=3x3 covariance matrix of RGB values for class t.

The model parameters (average RGB's, RGB covariance) are established by sampling pixels across 10 random images with 2000 total pixels sampled - 400 pixels in each of the five classes.

Plaque coverage is calculated as (# plaque pixels)/(# plaque pixels + teeth pixels)

To measure repeatability of the technique, 5 subjects were imaged 3 consecutive times in a 10 minute period with re-disclosing between images.

RESULTS

The average RGB values for the five classes are shown below. (Note the color separation between the classes especially between plaque on teeth and gingival plaque.)

Class	Red	Green	Blue
Plaque	96	218	53
Gum Plaque	53	145	30
Teeth	49	144	122
Gums	13	56	23
Retractors	12	80	130

Using the discriminant model to reclassify the data set used to establish the model parameters shows that the model correctly classifies 99.1% of the plaque pixels correctly and 100% of tooth pixels correctly.

The table below shows the results of the repeated analysis of plaque coverage:

Measurement	Subject 1	Subject 2	Subject 3
1	21.73	24.50	47.44
2	22.46	24.57	48.31
3	22.20	24.85	48.36
Average	22.13	24.64	48.04
Std Dev	0.37	0.185	0.517
RSD	1.67	0.750	1.08
Measurement	**Subject 4**	**Subject 5**	
1	15.50	12.57	
2	15.36	13.34	
3	16.00	12.44	
Average	15.62	12.78	
Std Dev	0.336	0.486	
RSD	2.15	3.81	

CONCLUSION

-The fully automated Digital Plaque Image Analysis (DPIA) technique is able to objectively measure in-vivo plaque levels with a high degree of precision (RSD<2%). The precision of the technique allows rapid and accurate *in-vivo* evaluation of plaque agents and devices with a minimal number of subjects required.

-Based on repeated measure analysis and day to day plaque variation within subject (Sagel and White, 1997 *IADR Abstract* #2075), 20% plaque reductions can be observed in a cross over design with five subjects.

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