HYPERSPECTRAL IMAGING OF THE ORAL CAVITY

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INTRODUCTION

HYPERSPECTRAL IMAGING

Hyperspectral Imaging (HSI) is a spectral imaging technique that is gaining increasing interest for clinical applications. Already routinely used in geographical remote sensing, HSI combines photography and spectroscopy. The compact and robust nature of the instrumentation makes it an appealing portable clinical tool (Figure 1).

Figure 1. The Hyperspectral imaging instrumentation used in this study: 1) Lens; 2) Spectrograph; 3) Camera
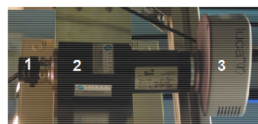
Data is collected in hundreds of narrow, contiguous bands, building up the spatial information in 'layers' to produce the image. The image can be viewed at each of these bands individually (Figure 2), or, for the complete image, the full spectrum for a selected area can be obtained. Nuances that could not be detected visually, can be detected this way.
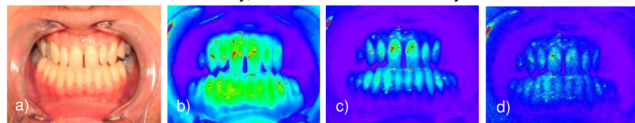

Figure 2. a) Digital image of teeth and gums, and false–color hyperspectral images at b) 750 nm; c) 587 nm, and d) 460 nm.

POTENTIAL FOR PERIODONTAL APPLICATIONS

Current methods of diagnosing inflammatory diseases of the gums, are inherently limited by the qualitative and subjective nature of assessment. For early detection or to monitor progression, it is necessary to develop imaging techniques that will enable quantitative assessment of disease progression over time.

The aim of this proof of concept study was to investigate the feasibility of hyperspectral imaging as a technique for detecting inflammatory changes in the gums that cannot be detected visually. The was done by imaging the gums of healthy volunteers before and after induced increase of blood flow.

EXPERIMENTAL METHODS

This was a single centre, single arm study in six healthy volunteers with good general dental health. Subjects were fitted with oral retractors for image acquisition. Digital and hyperspectral images were acquired before and after brushing the anterior teeth and gums for 30 s with a wetted toothbrush. The instrument used was a Luca-R EMCCD camera, with a Specim V8E spectrograph (272-870 nm). Hyperspectral images were corrected using calibration images (recorded using a white calibration tile and the lens cap for light and dark respectively). Data was extracted using Image J software.

RESULTS AND DISCUSSION

Digital photographic images showed slight changes in illumination pre- and post-brushing. The spectral data was corrected for this by using the right central incisor as an internal standard for each subject. The spectrum obtained for subject 006 after this correction (both pre- and post-brushing) is shown in Figure 3. It can be seen that this spectrum exhibits the features observed in the absorption coefficient plots of hemoglobin (Hb) and oxygenated hemoglobin (HbO$_2$) (Figure 4). Figure 3 shows the double minima at 541/576 nm, characteristic of reflectance by HbO$_2$, (seen as a double maxima in Figure 4).

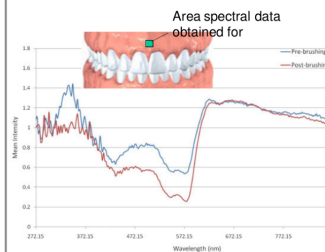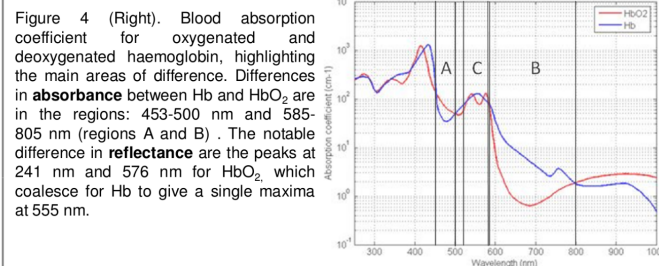Area spectral data obtained for

Figure 3 (Left). Reflectance intensity, corrected by calculating the ratio against a reference spectrum (obtained from the right central incisor) for Subject 006, plotted against wavelength, for the area above the papilla between the central incisors.

Figure 4 (Right). Blood absorption coefficient for oxygenated and deoxygenated haemoglobin, highlighting the main areas of difference. Differences in **absorbance** between Hb and HbO$_2$ are in the regions: 453-500 nm and 585-805 nm (regions A and B) . The notable difference in **reflectance** are the peaks at 241 nm and 576 nm for HbO$_2$, which coalesce for Hb to give a single maxima at 555 nm.

In order to determine whether there was any notable change in spectral profiles in regions A, B and C (Figure 4) it was necessary to correct the baseline of the spectra so that the expected isosbestic points were observed. The range over which meaningful data can be obtained for the hyperspectral system used in this study is 420 nm – 750 nm, which explains the increased noise below 400 nm in Figure 3.

After baseline correction (using the isosbestic point of 500 nm), significant changes in spectral profiles were observed pre- and post-brush. Figure 5 shows the pre- and post-brushing spectra obtained for Subjects 002, 003, 004 and 006, who gave evaluable data.

It can be seen that the spectra for Subject 004 are almost identical pre- and post-brushing, suggesting that this subject did not apply significant pressure to the gums during brushing. For subjects 002, 003 and 006, the post-brushing spectrum shows greater reflectance intensity (and therefore reduced absorbance) in region B post-brushing.

Comparing this to the reference absorption spectrum (Figure 4) this suggests that there is more HbO$_2$ present in the surface capillaries post-brushing.
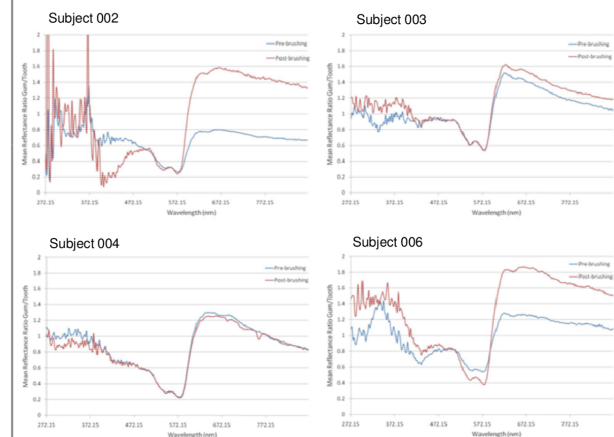

Figure 5. Baseline-corrected plots of measured intensity against wavelength pre- and post-brushing.

For each subject, the characteristic double minima, corresponding to reflectance by HbO$_2$ can be observed. Subjects 003 and 004 show little to no change in this region. However, Subjects 002 and 006 display a noticeable sharpening of the second minima (576 nm). These are also the two subjects who exhibited the greatest difference in the 585-750 nm spectral region pre- and post-brush. The reduction in the minimum at 576 nm indicates reduced reflectance, hence increased absorbance by HbO$_2$. Again, this suggests increased levels of HbO$_2$ post-brushing, corroborating the information from the 585-750 nm region. Although the 541/576 nm double minima is a useful identifying characteristic of the 'spectral fingerprint' of the gums, the region from 585-750 nm shows a greater change over a larger range and thus would be a more useful region for future studies on quantifying spectral changes.

CONCLUSION

Hyperspectral imaging has been used to detect changes in blood flow in the gums of healthy volunteers. The spectral changes following increased blood flow are, as expected, observed in the red region of the visible spectrum, where Hb and HbO$_2$ have the greatest difference in absorption coefficients. Spectroscopic means of monitoring the relative quantities of Hb and HbO$_2$ could prove to be a powerful tool in the quantification of disease progression.