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A comparison between red and infrared light for recording pulpal blood flow from human anterior teeth with a laser Doppler flow meter

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ABSTRACT

Objective: To compare red (635 nm) and infrared (780 nm) light for recording pulpal blood flow from human anterior teeth with a laser Doppler flow meter.
Design: Recordings were made from 7 healthy teeth in 5 subjects (aged 22–55 years) using a laser Doppler flow meter (Periflux 4001) equipped with both red and infrared lasers. Average blood flow signals were obtained with both light sources alternately from each tooth under five conditions: intact tooth without opaque rubber dam, intact tooth with dam, after injecting local anaesthetic (3% Mepivacaine) (LA) over the apex of the tooth and cavity preparation to almost expose the pulp, after removal and replacement of the pulp, and with the root canal empty.
Results: With infrared light, because of technical limitations, data were obtained for the first three conditions only. The dam significantly decreased the mean blood flow by 82%. Injecting LA and cavity preparation had no significant effect. With red light, dam produced a decrease of 56%, and the resulting signal was reduced by 33% after LA and cavity preparation. The remaining signal fell by 46% after pulp removal and replacement. This contribution of the pulp is similar to that recorded previously with infrared light. There was no significant further change when the pulp was finally removed.
Conclusions: The importance of using opaque rubber dam is confirmed. With dam, there is no advantage to using red rather than infrared light, and in each case the pulp contributes less than 50% to the blood flow signal.

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1. Introduction

Laser Doppler flow meters have been used in many studies in an attempt to record blood flow in teeth.[1] This is potentially a valuable technique both for research on pulpal blood flow and for clinical diagnosis, but a limitation of the technique is that the records obtained are derived from tissues outside the tooth, such as the gingiva and periodontal ligament, as well as the pulp. The contamination of the records from non-pulpal tissues can be reduced by covering the adjacent gingiva with rubber dam[2,3] or periodontal paste.[4] Soo-ampon et al.[3] found that opaque rubber dam reduced the blood flow signal recorded from an intact, anterior tooth in man by an average of 73%. They also showed that the signal remaining after applying the rubber dam was further reduced by 57% when the pulp was removed and replaced in the root canal. Thus only approximately 10% of the signal recorded from a tooth without

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dam, and 43% of that recorded with dam can be attributed to blood flow in the pulp.

The laser Doppler record obtained from a tooth will depend on the wavelength of the light employed. Infrared light (780 nm) penetrates deeper into tissues than red light (635 nm),[5] thus a record obtained with infrared might be expected to include a greater contribution from tissues outside the pulp than one obtained with red light. Soo-ampon et al.[3] used infrared light. The present experiments were carried using a similar protocol to the one they used but with red light to determine if this resulted in a significantly smaller contribution from tissues outside the pulp. To estimate the contribution of these tissues, recordings were made from the tooth crown before and after applying opaque rubber dam, after removing the pulp and replacing it in the root canal, and with the root canal empty. The extirpated pulp was initially replaced in an attempt to reproduce the distribution of laser light in the intact tooth.[3]

2. Materials and methods

The experiments were done on 7 healthy, anterior teeth (4 upper and 1 lower central incisors, 1 upper lateral incisor and 1 upper canine) in 5 subjects (aged 22–55 years). These teeth were to have root canal treatment before the construction of a fixed prosthesis. All the teeth were free from periodontal disease and caries and were either intact or had only a small restoration. Radiographic examination and electrical pulp stimulation confirmed that they were vital and healthy. The study was approved by the Ethics Committee on Human Rights Related to Human Experimentation of Mahidol University, and complied with the principles of the Declaration of Helsinki. Informed consent was obtained from each subject.

Recordings were made using a Periflux system 4001 two-channel, laser Doppler flow meter (Perimed AB, Järfälla, Sweden). One channel was equipped with an infrared (780 nm) laser and the other, a red (635 nm) laser. The probe (type 407: ext. diam. 1.0 mm; optical fibre diam. 0.125 mm, fibre separation 0.25 mm) was supported in a mini probe holder (type PH 07-5) that was incorporated into a removable acrylic splint. The probe holder was positioned so that the probe was perpendicular to the labial enamel surface on the labial surface of the tooth, with its tip over the central long axis of the crown, and with its centre 2 mm from the gingival margin (Fig. 1). The rotation of the probe around its long axis was kept constant between trials by aligning marks on the probe and the probe holder. Recordings were made with the probe connected alternately to each of the two channels of the flow meter.

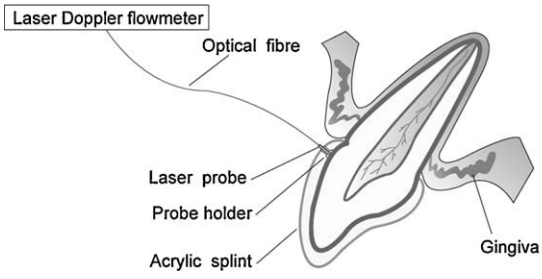

Fig. 1 – Diagram of the experimental set up (not to scale).

The probe was zeroed separately with infrared and red light and calibrated according the manufacturer's instructions so that the Brownian motion of a standard suspension of latex particles[6] gave a reading of 250 arbitrary perfusion units (P.U.). An upper bandwidth setting of 12 kHz and a time constant of 0.2 s were used throughout. The data were recorded from the digital output of the flow meter with a computer running the PeriSoft (version 1.13) software program.

Recordings were made from each tooth under five conditions: (1) the intact tooth without rubber dam, (2) after applying opaque black rubber dam (Four D Rubber Co. Ltd., Heanor, England), (3) after local anaesthetic (1 ml, Mepivacaine 3%) had been injected near the apex of the root and a cavity cut in the incisal third of the labial surface until the pulp was nearly exposed, (4) after removal of the pulp with a broach, arrest of bleeding with paper points and replacement of the pulp in the root canal, and (5) with the canal empty after removal of the pulp. At each stage, the blood flow signal was allowed to stabilize for several minutes before measurements were made. These conditions are the same as those used for the Series 2 experiments of Soo-ampon et al.[3], except that the rubber dam remained in place after its initial application at stage 2. The additional time required to make measurements with both infrared and red light in the present study meant that measurements could not be made under all conditions both with and without the dam.

After each experiment, recordings were also made at different light intensities from a stationary reflector (white card). These data were used to calculate the offset of the blood flow signal that would have been present while recording from the teeth due to noise in the detection system.[6] For each set of blood flow values recorded from a tooth during the experiment, the mean and standard deviation were calculated and the offset, determined as described above, appropriate for the intensity of backscattered light present was subtracted from the mean.

Comparisons between the overall mean blood flow values recorded under each of the different conditions were made using one-way, repeated measures analysis of variance. Where this showed that there were significant differences between the means, the Tukey test was used to make multiple comparisons between them. Student's paired *t*-test was used to compare % changes in mean blood flow with the two light sources under otherwise the same conditions. p values of less than 0.05 were considered significant.

3. Results

Examples of records obtained with infrared and red light under the different conditions of the experiment are shown in Fig. 2. The records with infrared light illustrate a limitation of the Periflux system 4001. Under conditions when the blood flow signal was very low, when the pulp was cut and replaced (Pulp cut) and when it was removed (Pulp removed), the record was clipped when it fell to zero, that is the value estimated to be equivalent to zero blood flow during the calibration procedure. As the records obtained under these conditions

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