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The sources of laser Doppler blood-flow signals recorded from vital and root canal treated teeth

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Summary *Objectives*: The aim was to determine the strength of signals derived from the dental pulp and those from the surrounding tissues in human teeth using the laser Doppler flowmetry (LDF). *Methods*: Twenty-six vital teeth (13 experimental and 13 controls) from 12 patients were used. Experimental teeth had root canal treatment in a single visit and their healthy antimeres were controls. Blood flow measurements were made before and after local anaesthesia, after root canal preparation, following root canal filling and coronal restoration. *Results*: Perfusion unit (PU) values recorded from empty pulp chamber were determined to be only 30% lower than the values recorded before anaesthesia from the experimental intact teeth. When the measurements in the group were compared with each other the values of variation in the both groups were not statistically significant. The variation between the groups when the measurement values before anaesthesia, 10 min after anaesthesia and after coronal restoration were compared, it was not statistically significant ($P > 0.05$). The variation between the groups after preparation and root canal filling in their values of measurements was important statistically ($P < 0.05$). The measurement values of the study group were lower than that of the control group. *Conclusions*: In pulpal, LDF a major portion of the signal comes from tissues other than pulp. Without taking precautions (such as rubber-dam application) in pulp blood flow measurements, the results may be inconsistent.
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Introduction

Laser Doppler flowmetry (LDF) is a non-invasive method of recording blood flow in intact microvascular systems, and its use in human teeth was first described by Gazelius et al.[1] The technique has found application in monitoring dynamic changes in pulpal blood flow (PBF).[2–4]

It is reported that the LDF technique is reliable for measuring human pulpal blood flow to determine pulp vitality.[2,4] However, it has also been claimed that signals obtained from human teeth did not necessarily indicate pulpal blood flow.[5]

Transmission of light through LDF is capable of measuring pulp blood flow by enamel and dentine.[6] However, work involved extracted teeth and there was no information about the quantity of the signal coming from the pulp and that from other sources in living subjects. It has been reported that laser light applied to teeth can reach the periodontal tissues and return back to the probe again.[5] Aim was to study the degree of reliability of pulp blood flow measurements taken in vital teeth with LDF.

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Materials and methods

The study was performed at Cumhuriyet University, School of Dentistry Hospital. The protocol was approved by the Ethics Committee of Cumhuriyet University, School of Medicine. Patients were included in the study after giving their informed consent.

The following were excluded from the study:

(1) non-vital teeth,
(2) restored teeth,
(3) gingivitis or periodontitis,
(4) smokers,
(5) cardiovascular diseases.

Tooth vitality was checked by conventional electrical and thermal tests. Radiographs were taken to determine that the pulp chamber of the tooth to be examined was visible and that the periapical status of the tooth was normal. For each vital tooth recorded the tip of the pulp was above the bone level.

Twenty-six upper anterior teeth from 12 patients (nine female and three males) determined to be vital were included into the study. Thirteen teeth (which interfere with the construction of stabile prosthesis and will extract prosthetically) were root treated in a single visit (study group) and 13 teeth were used as symmetric controls.

A Periflux 4001 Master Laser Doppler Flowmeter (Perimed, Stockholm, Sweden) was used to measure pulpal blood flow. The LDF emitted light with a 780 nm wavelength. Band width was 20 Hz—20 kHz and sampling frequency was 32 Hz. The diameter of the probe was 1 mm (415—159, Perimed, Sweden). Calibration (zeroing was done automatically at calibration) was made with the ''PF 1000 Calibration Device'' (Perimed, Sweden) before each measurement.

To stabilise the probe, a laboratory made acrylic splint was made to position the probe labially on the cervical third of the tooth crown.

The patients rested for at least 10 min in the dental chair before recordings were made.

LDF measurements were taken:

(1) before anaesthesia,
(2) 10th min after anaesthesia,
(3) after root canal preparation,
(4) after root canal filling,
(5) after coronal restoration.

Citanest® Octapressin® (Eczacıbaşı, Turkey) was used as anaesthetic with 1 ml placed as a buccal infiltration.

Root canal access was made and the working length established 0.5 mm short of the apical foramen radiographically. The canal was instrumented with stainless steel K-files and reamers (Mani Inc., Japan) to size 40 using a step-back instrumentation technique, dried with sterile paper points and obturated with AH Plus (Dentsply, Germany) and laterally condensed gutta-percha points (Sure-Endo, Sure Dent Corp., Korea). Radiographs were taken to confirm the quality of obturation. The teeth were then restored with using zinc phosphate cement (as a base layer material) (Adhesor®, Spofa Dental, Germany) and composite (Charisma, Heraeus Kulzer, Germany).

Perfusion units (PU); concentration of moving blood cells (CMBC); velocity and total backscatter (TB) were recorded using the flowmeter and monitored using the Perisoft software (Version 5.1,

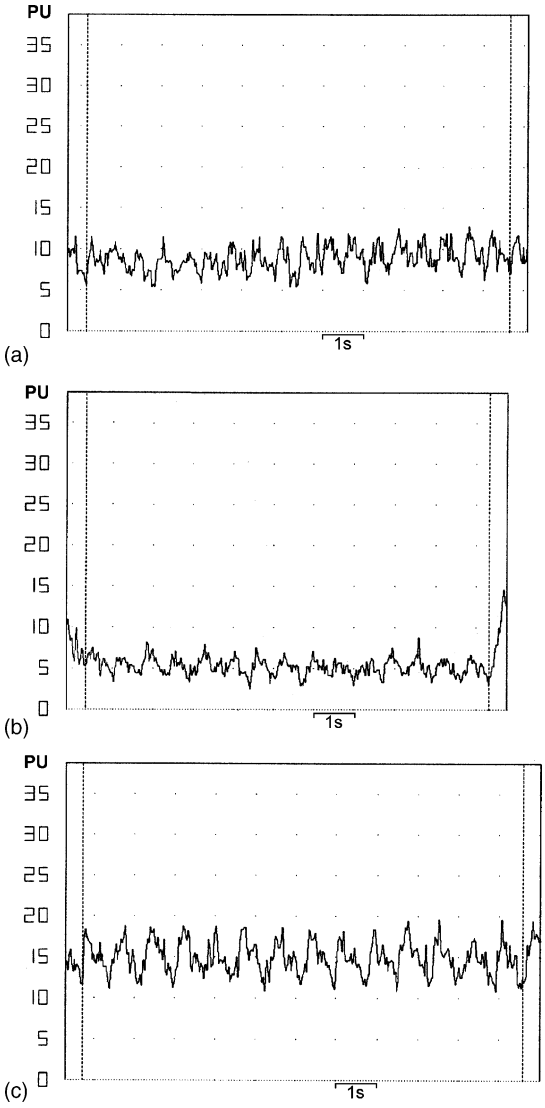


Figure 1 (a) Signal obtained from tooth before anaesthesia; (b) signal obtained from same tooth after root canal preparation; (c) signal obtained from same tooth after coronal restoration.

Table 1 Mean pulpal blood flow values in perfusion unit.

	Study group, $n = 13$ (mean ± S.E.)	Control group, $n = 13$ (mean ± S.E.)	P-value
Before anaesthesia	7.04 ± 1.02	7.76 ± 0.93	0.663
10th min. after anaesthesia	5.73 ± 1.08	8.19 ± 0.78	0.086
After root canal preparation	4.94 ± 0.93	7.45 ± 0.88	0.029
After root canal filling	5.55 ± 0.97	7.69 ± 0.67	0.029
After coronal restoration	7.45 ± 1.45[a]	8.11 ± 0.77[b]	0.457

S.E.: standard error.
[a] $F = 1.83$, $P > 0.05$.
[b] $F = 0.59$, $P > 0.05$.

Gastrosoft Inc.). The mean PU values (PU is arbitrary measurement unit) are determined using at least 10 s of recording (Fig. 1).

Statistical tests were performed using SPSS (Version 9.0, SPSS Inc., Chicago, IL, USA). Mann–Whitney U-test was used during the comparison of the measurement phases of the groups with each other. Repeated measures analysis of variance was used while assessing the variation within the group. The level of statistical significance was set at $P = 0.05$.

Results

The average of the patients was 32.83 years.

When the measurements in the group were compared with each other the values of variation in the both groups were not statistically significant ($P > 0.05$) (Table 1).

The variation between the groups when the measurement values before anaesthesia, 10 min after anaesthesia and after coronal restoration were compared, it was not statistically significant ($P > 0.05$). The variation between the groups after preparation and root canal filling in their values of measurements was important statistically ($P < 0.05$). The measurement values of the study group were lower than that of the control group (Table 1) (Fig. 2).

Discussion

Reliability of recordings should have been enhanced by the single visit nature of the experiment.

Since it has been shown that it does not have an effect on pulpal blood flow we used the Citanest® Octapressin® for local anaesthesia.[7]

Repeated measures analysis of variance test indicates that there is a non-significant overall difference among the groups. Pairwise comparisons are not requested. For this reason, we did not perform post-hoc test (Tukey) for paired comparison in groups.

Several studies have reported placing the LDF probe as 1–1.5,[8] 2,[9] 2–3,[10,11] ~3[12] and 4–5 mm[11,13] coronal to the gingival margin. In our study, we placed the probe on the cervical third of tooth crown, taking the crown sizes of the teeth into account.[14] One reason for this sampling site is that the output signal for transmitted laser light is

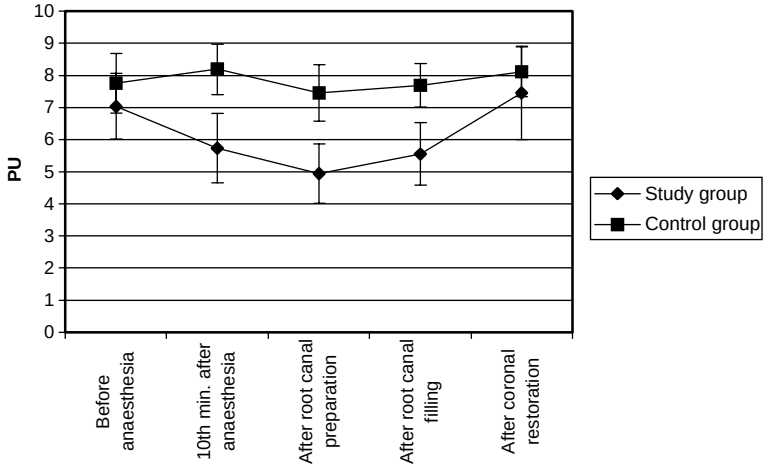


Figure 2 Mean pulpal blood flow values in perfusion unit.

minimal due to the thickness of the tooth in this region,[15] or to pulpal backscattering. Likewise, Ikawa et al.[5] showed that laser light could reach even to the 6 mm depth of the root.

Measurements made after preparation of the root canal showed a decrease in PU value of 30%. This finding seems justifying the previous literature[11,16] that tissues other than pulp contribute to measurement values. Tissue measured other than pulp can be oral tissues (such as lips and tongue), periodontal ligament or gingiva. Roebuck et al.[11] have stated that rather than oral tissues like lips and tongue periodontium is more effective. Hartmann et al.[17] showed that the measurement value decreases 69% when rubber dam was used during the measurement of pulpal blood flow. Akpınar et al.[18] reported that periodontal paste application to labial and palatinal gingiva caused a 63% decrease in pulpal blood flow measurements. Akpınar's study revealed that in the pulpal blood flow measurements, the contribution of labial gingiva to signal is more than that of palatinal gingiva. The increase of the signal after canal filling and coronal restoration made us consider that the beams reflected from canal filling materials and the coronal restoration may arrive at gingiva (especially labial) and turn back to probe. That the value measured after canal preparation is at statistically significant degree lower than the value measured from the antimere tooth puts forward the importance of the reflecting beams. Especially, the value measured after coronal restoration is almost the same as the value measured before anaesthesia and the value measured from antimere intact tooth shows that the gingival contribution to signal is at a degree which can affect the measurement reliability.

Vongsavan and Matthews[19] attributed the LDF technique capable of making measurements in skin and mucosa up to an approximate depth of 1–2 mm and passing over the 2–3.5 mm thick enamel and dentine of teeth and measuring blood flow to dental tissues being more transparent and tubular of dentine acting like light guides. They speculated that the periodontium and other neighbouring tissues could contribute to the signal.

Odor et al.[20] subsequently, showed that enamel prisms and dentine tubules could transmit light rays coming from the tooth surface and distribute them in teeth.

Olgart et al.[2] had observed that there was no change in pulse style in almost all of the cases with respect to signals received from non-vital teeth. In our study, even after complete emptying of root canal in pulsatile measurements could be obtained (Fig. 1b).

Vongsavan and Matthews[6] studying pig teeth claimed that the effect of tissues other than the pulp is very small (7–14.9%). It may be that the discrepancy between these results is due to species differences in the optical properties of the dentine and enamel which cause a greater proportion of the incident light to be transmitted to the tooth supporting tissues in man.

Some recent studies suggest that between 45 and 60%, depending on the recording conditions,[21] or even 82%[16] of the signal recorded from an intact human incisor may not be from the pulp.

Hartmann et al.,[17] investigating vital teeth using a polyurethane splint/rubber-dam combination, showed that blood flow measurement values decreased by 69% as compared to control in which only polyurethane splint is used. It is estimated that the remaining 31% of the signal is coming from pulp. Because, in the same study, when polyurethane splint/rubber-dam combination is used in teeth with a necrotic pulp values close to zero were attained.

Ramsay et al.[3] demonstrated that when the probe position approaches the gingival aspect of the crown, there is an increase in blood flow values. This may represent the light from the flowmeter sampling a larger volume of pulp tissues but contributions from tissues other than the pulp my also be increasing.

Conclusions

Without taking precautions (such as rubber-dam application) in pulp blood flow measurements, the results may be inconsistent. The contributions of tissues other than the pulp should be considered, and this is worthy of further consideration.

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