Evaluation of a laser Doppler flowmeter to assess blood flow in human primary incisor teeth

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The purpose of this investigation was to evaluate the suitability of a laser Doppler flowmeter for the assessment of blood flow in primary incisor teeth that are commonly affected by luxation and subluxation injuries.

Methods

Thirty-two children, aged 14 months to 7 years, who were scheduled for restorative treatment under general anesthesia at The Hospital for Sick Children in Toronto, Canada, were randomly selected over a four-month period. The number of incisors tested per child ranged from one to four; all had pre-existing dental caries. For inclusion in the study, all children were required to be healthy and to have maxillary primary incisors that had radiographic evidence of at least two-thirds of
their roots. The incisors were scheduled for either extraction or root canal treatment. At this hospital, carious exposures of primary teeth with vital pulps are managed by a zinc oxide/eugenol root canal treatment rather than the aldehyde-based vital pulpotomy that is the norm in North America.

Teeth were classified into one or more of three categories according to the patient’s treatment plan: Category I, measurement of the labial and lingual surfaces of each tooth; Category II, measurement before and after extraction of each tooth; and Category III, measurement before and after pulp extirpation and obturation (root canal treatment). Not all teeth could be included in Category I since some teeth did not have sufficient surface area on both the labial and lingual surfaces to ensure that there would not be any false positive readings from gingival blood vessels (>2 mm).10

The teeth were measured with the flowmeter and the electrocardiograph described below under two different conditions (with and without blood flow) for one of the following variables: before and after extraction, or before and after root canal treatment.

The pulpal blood flow of each primary incisor was measured with an Advance Laser Flowmeter Model 21® (ALF 21; Transonic Systems, Ithaca, NY) and a hand-held DN-J (Transonic Systems) fiberoptic probe. In addition, cardiac electrical activity was monitored with a Hewlett-Packard Electrocardiograph (ECG) Model 78315A (Hewlett-Packard, Camas, WA) and four 3M ECG leads (3M, St Paul, MN) placed on the patients’ right and left arms and legs. The displays of both the flowmeter and the ECG were recorded and printed with an eight-channel Graphtec Thermal Arraycorder (Graphtec, Tokyo, Japan).

All teeth were tested and radiographed intraoperatively. The following procedure was completed for teeth in Category I and for all teeth in Categories II and III before treatment. The end of the DN-J probe was placed on the cingulum (and also on the labial surface in the case of teeth in Category I) and directed toward the pulp chamber of the tooth. The fiberoptic probe was placed at least 2 mm from the gingiva to avoid soft-tissue interference.10 Once the flowmeter output stabilized, tooth and patient identification data, probe surface, and flowmeter values were noted on the tracing. Once the pulpal blood flow was measured and recorded, treatment was completed and the incisors were remeasured. For teeth in Category I, both labial and lingual measurements were completed during the initial testing. For those in Category II, the extracted tooth was cleaned and held securely while the probe was placed on the lingual surface as before. For those in Category III, after completion of pulp extirpation and obturation, and before placement of the final resin restoration, the tooth was retested on the lingual surface.

To verify that the recordings were a measure of blood flow through the dental pulp, the analog display of the flowmeter was recorded and compared with the ECG tracings.11,12 Two values were obtained for each tooth. Each value consisted of a two-channel tracing and the value of the laser Doppler flowmeter. The only alteration during the measurements of the teeth in Categories II and III was the severed connection of the blood vascular system.

The tracings were analyzed in two ways. A random sample of 54 recordings from vital teeth taken before pulp extirpation or extraction was used. First, it was necessary to test for the time linkage of the flowmeter recording of pulpal blood flow pulse with that of the ECG. The number of peaks in the ECG recording representing the R-point of the wave and the pulsatile peaks recorded by the flowmeter were counted over a 10- or 15-sec period.

Since the ability of an observer to determine the presence of vascular integrity from the flowmeter display is essential if the equipment is to be used to make valid diagnoses, we determined whether outside observers could differentiate between readings taken before and after pulp extirpation or extraction. Forty sections of randomly selected recordings were duplicated and coded. Two independent observers, one dentist and one lay person who was not a health care provider, were asked to state whether the reading was taken from a vital pulp or a nonvital (pulp extirpation and obturation or extraction) pulp.

The Shapiro-Wilk test was used to measure the normality of values obtained for teeth in Category I; these values were plotted against normal probability scores. Linear correlation coefficients were computed for the normal probability plots. A two-tailed paired t-test was done to test for significance at a confidence level of P<0.05. A 95% confidence interval for the difference in means was calculated for samples in Category I. For those in Categories II and III, a paired t-test for a difference of means was used to test for significance at a value of P<0.05. To evaluate entrainment, a t-test for the difference in means was used to test the differences between the number of peaks on each of the pairs of strip charts and a 95% confidence interval was calculated.

To adjust for the number of t-tests used in this study, the Bonferroni correction was applied. For a difference to be significant at P<0.05, a critical value of P<0.01 was used to allow for significant differences between individual t-tests. Statistical analysis was done on an Apple Macintosh PowerBook 160 (Apple Computer, Cupertino, CA) computer with StatView 1.03 (Abacus Concepts, Berkeley, CA).

Results

A total of 119 teeth were tested in the 32 children enrolled in the study. The number of subjects used in each test, their mean age, and the number of teeth tested by category are summarized in the Table 1. For Category I (19 teeth measured from 9 children), the evidence of approximation of the data to a lin-

| Category  | No. of Teeth | Age Range (yr) | Mean Age (yr) | No. of Subjects
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<tbody>
<tr>
<td>I (Surface)</td>
<td>19</td>
<td>2.0–5.2</td>
<td>3.6</td>
<td>9</td>
</tr>
<tr>
<td>II (Extraction)</td>
<td>22</td>
<td>2.0–7.0</td>
<td>4.4</td>
<td>7</td>
</tr>
<tr>
<td>III (RCT)</td>
<td>78</td>
<td>1.2–4.3</td>
<td>3.2</td>
<td>25</td>
</tr>
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*Surface = measurement of the labial and lingual surfaces of the tooth, Extraction = measurement before and after extraction of the tooth, RCT = root canal treatment (pulp extirpation and obturation). †Some subjects were tested in more than one category.
We found that the laser Doppler flowmeter could reliably measure both the presence and absence of pulpal blood flow. When we measured the same teeth under two conditions (with and without blood flow), we found statistically significant differences between blood flow before and after either extraction or pulp extirpation and obturation.

When the analog record of the flowmeter was compared with that of an ECG, linkage of the analog record of the ECG signal to pulsatile variations in the flowmeter record was verified. This demonstrated the instrument’s ability to measure changes in blood flow that were entrained in a 1:1 ratio with the ECG (Fig 1). The ECG is the most common measure of cardioelectric activity and has been used in other studies.6, 7 We have shown that the laser Doppler flowmeter is reliable and may be used without ECG verification.

Finally, a comparison of tracings from the flowmeter for incisors with and without vital pulps verified that differences between the two conditions were visually recognizable. Based on the evidence of this study, therefore, the laser Doppler flowmeter provides a valid means of measuring blood flow in primary incisors.

Measurement of the vascular integrity of traumatized primary teeth is superior to the secondary evidence of neural conduc tion and radiographic signs. This and similar laser Doppler flowmeters may allow clinicians to manage care rather than continue to rely on their observation of the late signs of pulpal necrosis.

Conclusion

Although several methods of testing pulpal vitality exist, the laser Doppler flowmeter is the only one that is objective, noninvasive, nonpainful, direct, and acceptable to young children. This investigation shows that it also has the characteristics of reliability, reproducibility, standardization, and ease of use. It has immediate clinical applications in the assessment of the vascular status of the pulp of primary teeth.

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References


This article by Drs. Fratkin, Kenny, and Johnston is a preview of the new journal format that will be fully implemented in the March/April 1999 issue of Pediatric Dentistry.

An Invitation to Participate

Readers have asked how they can become involved with Pediatric Dentistry. The most obvious way is to prepare and submit a manuscript to be considered for publication. However, there is also a great need for dedicated individuals to volunteer the hours needed to referee articles, to prepare abstracts of the scientific literature, or to serve on the Editorial Board. If you are interested in any of these activities, please contact Editor-in-Chief Milton I. Houpt through the Headquarters Office or by e-mail (houpt@umdnj.edu) indicating your particular interest and/or area of expertise. There is no financial remuneration for these activities, but great personal satisfaction comes from contributing to the production of our highly respected journal.