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CLINICAL USE OF ULTRASONIC CW DOPPLER TECHNIQUE IN STOMATOLOGY

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All methods used in stomatological practice for assessment of blood supply to the pulp require sensitivity testing. This, however, is not a reliable diagnostic method. Blood movement in the pulp can be detected directly by means of CW Doppler ultrasound. This technique, consequently, is an objective method which seems to be suitable for the above purpose, The author's approach to the problem has been theoretical, with the view to examining the suitability of the method and to establishing technical parameters of a stomatological Doppler device. Preliminary results so far obtained from the use of the ultrasonic Doppler technique in testing blood supply to the tooth are presented in this paper. Both advantages and disadvantages of the method are discussed.

Introduction

Determination of tooth vitality is essential to any planning of suitable dental therapy. Vitality depends on sufficient blood supply to the pulp and intact nervous function (HOFFMANN-AXTHELM [1]). Clinical detection of blood movement in the tooth and prediction, in this manner, of intact pulp function have not been possible, as yet. Thermal, electrical, and mechanical stimulation tests as well as exploratory trepanation are used by the authors to check "tooth vitality". However, such tooth sensitivity testing does not provide accurate information on pulp condition proper (cf. THIERFELDER et al. [4]). Different methods were used by THIERFELDER [5] to assess blood supply to the tooth (intravital arteriography, micro-angiography, fluorescence angiography, nuclear diagnostic blood volume measurement, ultrasound Doppler method). The conclusion he drew from his results was that the ultrasonic Doppler technique was the best applicable under practice conditions.

Measurements

While measurement of the cross-section averaged flow velocity in arterial and venous vessels is a well-known procedure, some difficulty has to be overcome for blood flow measurement in small vessels. The dental structures have grossly different acoustic properties, such differences being sources of sizeable problems in the determination of blood supply to the pulp. Most of the commercially available Doppler blood flowmeters, therefore, are not adapted to stomatological applications.

The authors assumed the prevalence of unfavourable conditions in their attempt to figure out the parameters an ultrasonic Doppler device should have for stomatological use. Velocities of about 0.28 $cm \cdot s^{-1}$ may be expected to occur in pulp vessels, just as in arterioles [3]. The operating frequency required for the detection of such low velocities should be some 100 MHz which, however, could not be used because of extremely high absorption in tissue. The highest operating frequency is 10 MHz. In such a case, velocity components of 1.5 $cm \cdot s^{-1}$ in the direction of sound propagation are detectable, with the Doppler frequency being about 200 Hz. Good acoustic contact or coupling between ultrasonic probe and tooth cannot be achieved unless the probe is positioned at the dental neck. The difference between the mean sound velocities in the pulp ($1.54 \cdot 10^3$ $m \cdot s^{-1}$) and tooth ($4.45 \cdot 10^3$ $m \cdot s^{-1}$) is of sizeable magnitude, and so the angle obtainable between sound beam and vessel in the pulp is 80 degrees only, as may be seen from Fig. 1. Hence, blood flow velocities beyond

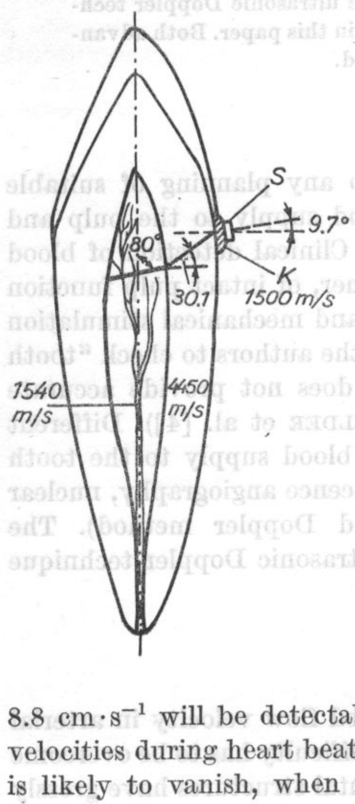

Fig. 1. Propagation of ultrasound beam in canine tooth diagram representation

S – ultrasonic probe; *K* – coupling gel

8.8 $cm \cdot s^{-1}$ will be detectable, and measurability will be reduced to the peak velocities during heart beat. Therefore, as shown in Fig. 2.2, the Doppler signal is likely to vanish, when marked change occurs to the blood vessels in the pulp or to their elastic properties. Estimated losses along the pathway between transmitter and receiver are given in the level diagram.

Level diagram

Loss	dB
Transmitter crystal coupling	~ − 10
Reflections at tooth interfaces	~ − 20
Absorption	~ − 65
Backscattering	~ − 60
Receiver crystal coupling	~ − 10
total	~ −165

The estimated high-frequency transmitting power will be about 1 W, taking into account this special condition [4]. Preliminary experiments have shown that this value might be somewhat lower.

The potential benefits and shortcomings of the method should be summarised against the background of technical and clinical aspects.

Benefits

1. Convenient applicability to clinical practice, with no extraordinary preparations required.
2. No damage (observation of course of the disease).
3. Direct detection of movements due to blood stream in pulp.
4. With presence of fillings (amalgam, precious metal), no interference with or distortion of signal detection.
5. Objective nature of findings, no time-consuming evaluation.

Shortcomings

1. Very high sensitivity of device necessary.
2. Signal qualities so far obtainable are low.
3. Only peak velocities detectable in teeth.

Preliminary results

An ultrasonic Doppler device, Parks Model 806, has been used in preliminary clinical tests. Its power output is high and its operating frequency 9.5 MHz. The Doppler signals were received by earphone. The output voltages of the internal frequency-voltage converter were recorded on a signal-channel ECG recorder whereat the ds-components were lost. The dental status of a test person

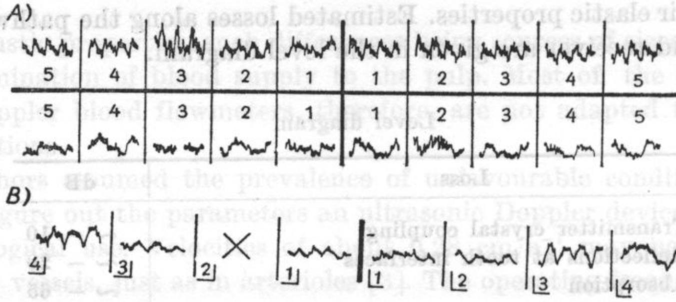

Fig. 2. Recordings of ultrasonic Doppler signals from tooth vessels

A – dental status of patient aged 20; B – dental status of patient between 14 and 24, following loss of twelve after orthodontic treatment

aged 20 is shown in Fig. 2A. Signal curves are reproducible and typical of each of the teeth. The curves obtained from the sides of the upper and lower jaws are comparable with each other, if none of the teeth is pathologically changed. It should be noted that the premolars in the upper jaw have two peaks (two root canals), while the intact canine teeth have high signal amplitudes. An

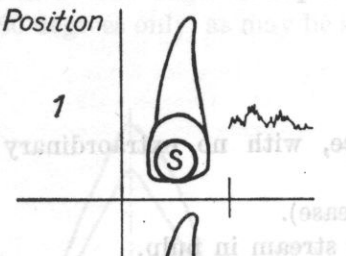

Fig. 3. Positions of ultrasonic probe relative to tooth

S – ultrasonic probe

atlas giving the curves of vessels in the pulp may be readily drawn. Figure 3 shows the positions of the ultrasonic probe relative to the tooth, with position 3 being preferred. An improved Doppler signal curve will be obtainable, if the

ultrasonic probe is used to compress without troubling the patient's gingiva (see Fig. 4).

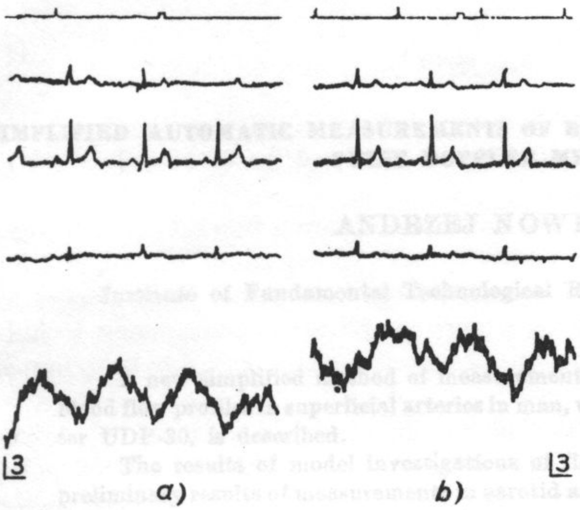

Fig. 4. Improvement of Doppler tracings with gingiva compressed by ultrasonic probe
a – gingiva compressed; *b* – gingiva not compressed

Conclusions

The CW ultrasonic Doppler method can be used to test dental vitality. Being applicable to clinical practice and provided some technical improvement, it can replace all sensitivity tests used in the past. Only qualitative results so far have been obtainable to this date. However, quantitative results may be expected, following technical improvement. A stomatological CW Doppler unit is now being developed and ultrasonic probes designed for the purpose by the authors in cooperation with "Manfred von Ardenne" Research Institute, Dresden, GDR.

References

[1] W. Hoffmann-Axthelm, *Zahnärztliches Lexicon*, 4th edition, Johann Ambrosius Barth Verlag, Leipzig 1964.

[2] S. Lees, F.E. Barbar, *Looking into teeth with ultrasound*, Science **161**, 477-478 (1968).

[3] H. Rein, M. Schneider, *Physiologie des Menschen*, 13th/14th editions, Springer Verlag, Berlin-Göttingen-Heidelberg 1960.

[4] Ch. Thierfelder, S. Magnus, G. Pardemann, S. Vogel, *Gefässfunktionsdiagnostik der Pulpa dentis – ein neues Anwendungsfeld des Ultraschall-Doppler-Verfahrens*, das Deutsche Gesundheitswesen, **33**, 24, 1105-1109 (1978).

[5] Ch. Thierfelder, *Die Blutversorgung des Zahnes – eine experimentelle Studie*, Medical dissertation "B", Humboldt Universität, Berlin 1978.

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