Section of Odontology

President D Greer Walker MD FDS RCS

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Paper

Thermal and Electrical Stimulation of Teeth in the Diagnosis of Pulpal and Periapical Disease

by J M Mumford PhD FDS RCS
(*School of Dental Surgery, University of Liverpool*)

When dentine is already exposed, the pulp vitality can be tested by mechanical stimulation with a bur, probe or excavator. If dentine is not exposed a test cavity can be cut but, if a cavity would not otherwise be necessary, it is better to use a stimulus, such as heat or electricity, which will not damage the tooth; investigations have revealed problems in testing which should be understood; these are explained and the diagnostic value of the methods is evaluated.

Thermal Stimulation

Thermal stimulation may be applied in various ways: the most frequently used methods are the application of heat by heated gutta-percha or the removal of heat by cooling with ethyl chloride. In order to evaluate them (Mumford 1964*a*), sticks of gutta-percha were chosen so that they had approximately a constant diameter, selection being necessary because they vary greatly even in the same batch. A suitable length was held with about 5 mm in a flame for two seconds and then applied to the tooth on the middle of the labial surface. The subject graded the intensity of the sensation as mild, moderate or severe, these being just noticeable, clearly noticeable and unpleasant. Accurate assessment of pain is difficult but this system is acceptable in physiological investigations (Hardy *et al.* 1952; Armstrong *et al.* 1953). A fresh piece of gutta-percha was used each time because a previously used piece might have retained some heat or its shape been distorted, thus presenting a different area of contact to the tooth.

For testing with ethyl chloride a pledget of cotton wool with a diameter of a quarter inch was held in college tweezers and soaked in ethyl chloride; any excess was allowed to drain off and the pledget was applied to the middle of the labial surface. The intensity of sensation was noted as before.

The subjects returned at intervals of several days so that each tooth could be tested three times with each of the two stimuli. To reduce possible bias in recording, the previous results were never on view.

Of 74 normal teeth tested with gutta-percha only 10 gave a consistent response and 8 consistently failed to give any response. Using ethyl chloride on the same teeth 20 gave a consistent response and 2 consistently failed to respond. The results were similar for teeth which were carious or restored.

Discussion

When investigating pain experimentally the stimulus should be clearly defined and should be subject to quantitative measurement, but gutta-percha and ethyl chloride do not permit this, so it is not surprising that reproducible results were not obtained. Moreover, on the relatively crude level either of producing a response or of not producing a response, the methods were not satisfactory, sometimes repeatedly failing to produce a response even from normal teeth, an observation also made by Herbert (1945).

It could be argued that the stimuli chosen were not sufficiently strong but in a few cases, on apparently normal teeth, they caused pain which was not merely severe but so intense that the subject could not for a time allow the experiment to continue. To hurt a person in this way is undesirable but might also lead to an incorrect diagnosis of acute pulpitis. When using gutta-percha it is, therefore, advisable to heat the material for only a short time at first. If this does not produce a response the next piece of gutta-

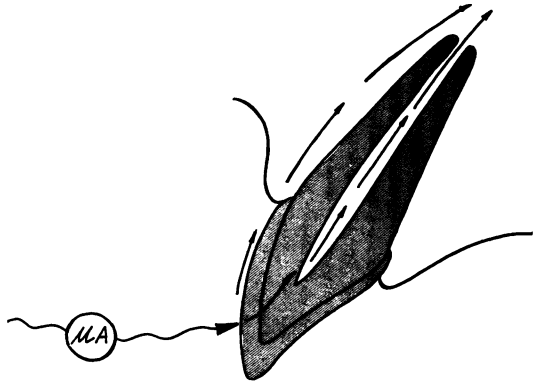

Fig 1 *The microammeter measures the total current flowing but an unknown part of this may pass through any moisture on the tooth surface, so the tooth must be isolated and surface moisture removed*

percha is heated for slightly longer and so on. However, the amount of heat that can be applied in this way is limited by the fact that the gutta-percha eventually wilts and goes on fire.

The disadvantages of these materials may be partly overcome by applying a stream of water at a monitored temperature (Sorenson *et al.* 1962), or by using a thermoelectric stimulator (Naylor 1961) which permits monitoring of the temperature by means of a thermocouple. However, it should be understood that it is the temperature at the place where excitation occurs that is important and only indirectly the temperature at the tooth surface. This explains why an incisor might respond to a stimulus whereas a canine might not, because its greater bulk takes up more of the heat, giving a smaller rise in temperature.

It takes some time for heat to be conducted through the tooth to reach the excitable zone; also, the heat is still there after the gutta-percha has been removed, so sensation may continue; indeed the pain may even become more intense during this period. This disadvantage is overcome by using an electrical stimulus which can be stopped immediately the patient signals, and for many cases this is the method of choice.

Electrical Stimulation

The following factors must be taken into account:

Voltage: In electric pulp testing the voltage has usually been measured but what matters is the current and this depends not only on the voltage but also on the electrical resistance (or, more strictly, impedance). The resistance of enamel is both high and variable; even with normal enamel its resistance depends upon the area of contact of the electrode; since the effective contact is altered by various amounts of saliva this must be controlled.

Resistance: The electrical resistance of enamel is also greatly affected by attrition, erosion, cracks, pits, fissures, caries and fillings so that for a given voltage the stimulating current may vary enormously and it is possible for the patient to receive an extremely painful shock. For this reason it is better to have a current-measuring instrument with a high impedance.

Surface conduction: There may be confusion if the current is allowed to pass along the tooth surface direct to the gingiva (Fig 1), in which case the microammeter accurately measures all the current but not the portion reaching the pulp. Similarly, wrong readings are obtained if the current is allowed to by-pass the pulp via caries or a metal filling. For these reasons the tooth must be well isolated, preferably by rubber dam.

Current path: The path taken by the current through the tooth is not fully understood, so an attempt was made to elucidate it (Mumford 1959). A small cylinder containing methylene blue was fixed to the labial surface of a freshly extracted tooth and a direct current was passed for several days to carry the coloured ion of methylene blue through the tooth to the cathode: about half the tooth was then ground away to reveal the distribution of dye, which was found to be along the lines of the enamel prisms, dentinal tubules and the pulp (Fig 2). From these experiments, and following general electrical principles, the current is presumably carried ionically through the electrolytes of the tooth. In multirooted teeth the current passes through each canal so it is not possible to test preferentially the pulp in one canal.

Fig 2 *Diagrammatic representation of the path taken by an electric current through a human tooth.* A *represents a small electrode area.* B *represents a large electrode area*

Duration of the electric stimulus: The shorter the duration the stronger is the current needed to produce excitation and the greater can be the variation in threshold value. To reduce this variable a stimulus duration of 10 milliseconds or more should be used (Mumford 1965), the current reading being then rheobasic.

Frequency of stimulation: For a given stimulus, the more times per second it is applied the higher is the average current flow per second. This means that the threshold reading is higher with greater frequencies but it is not suggested that this is a physiological feature; rather is it an electronic feature depending on the mark-space ratio.

Current direction: If the current enters the body via the tooth and leaves via the hand the threshold value is three and a half times higher than if the current passes through the body the other way (Mumford 1965). The electrode placed on the tooth should therefore be cathodal.

Adaptation: If the current is raised until the pain perception threshold is reached and held at that level the subject eventually signals that the pain has ceased. The current may be further raised until pain is again noted and if the current is held at that level the pain once more ceases. This can be repeated several times and demonstrates that adaptation occurs; in other words the pain perception threshold is not constant when measured in this way. The threshold value should therefore be determined expeditiously rather than slowly.

Sex: There does not seem to be a definite difference between the sexes in respect to the pain perception threshold (Schumacher *et al.* 1940, Mumford 1963, 1965).

Age: For 10 years of age and over the pain threshold values of teeth are in similar ranges, but below that age the results are variable. It was found that the young patients sometimes signalled when the current was not altered or when the instrument was not even connected to the mains. This was so even with intelligent children who apparently understood what was wanted of them, and it was not simply a matter of surface conduction because upper central incisors are easy to isolate from an early age. It seems possible that the state of innervation is the controlling factor; Fearnhead (1963) has stated that there may not be full innervation of teeth until they have been in function for four or five years.

Concussion: Electric pulp testing is, therefore, unreliable for children up to 10 years of age and this observation throws doubt on the idea of a tooth being concussed. It has been suggested that a tooth recently subjected to trauma may fail to respond but may subsequently recover its excitability. It is possible that it does not respond because innervation is not complete but responds later when innervation develops further. If this explanation is correct it is misleading to describe the tooth as being in a state of concussion.

Pain threshold and the pulp condition: The work of Lewis (1942) and others shows that inflamed skin will respond painfully to stimulation by a lighter pin-prick than would be needed for normal skin, so it seems reasonable to suppose that teeth with acute pulpitis including the early stage called hyperæmia may have thresholds which are lower than normal, whereas teeth with chronic pulpitis including degenerative pulp conditions may have higher thresholds than normal. To test this hypothesis a stimulator which allowed control of the variables already mentioned was used to determine the pain perception threshold values of teeth which were then extracted; decalcified sections were prepared and stained (Mumford 1964*b*). It was found that teeth with pain threshold values in the same range had pulps which were normal, pulps with calcifications, reticular degeneration, fibrous degeneration, mild chronic pulpitis, severe chronic pulpitis, acute pulpitis, acute abscess and even subtotal necrosis. From this result it is concluded that electric pulp testing by the method used does not in itself reveal the condition of the pulp.

Quality of the sensation: This has been said to give an indication of the pulp condition, a tingling sensation being regarded as indicating a degenerating pulp but, when testing normal teeth, it was found that more subjects described the sensation as tingling than by any other word (Mumford 1965) so this sensation is not of diagnostic value. Other sensations described were 'cold' and 'hot', so it is not accurate to say that pain is the only sensation elicited from a tooth (Brashear 1937). It seems worth relating this result to that of Lele & Weddell (1956) who found that all the nerves to the cornea end in fine filaments morphologically indistinguishable from one another but that sensations of cold, heat and touch as well as pain could be elicited.

Periapical lesions: Although electric pulp testing does not by itself give an indication of the state of health of a pulp it does indicate whether the pulp is alive or dead and therefore gives valuable aid in diagnosing periapical conditions. It is particularly useful for cases in which the lamina dura has been lost on one tooth because of disease spreading from a neighbouring periapical lesion.

Therefore one can conclude that pulp testing with heated gutta-percha or cooling ethyl chloride is crude; failure to obtain a response does not necessarily indicate a dead pulp but using both tests and repeating them decreases the chance of obtaining a false negative. A definite response generally means that the pulp is vital but a false positive response can sometimes occur when the pulp is dead. This is due to the application of heat causing thermal expansion of fluids in the pulp space thus causing pressure on sensitive tissue in the periapical area. Severe pain can occur with normal pulps and give a misleading impression of acute pulpitis, so it is advisable to heat the gutta-percha only a little at first and to increase the heat only if necessary.

Electric pulp testing should be by means of a current-measuring instrument which allows control of the stimulus in shape, duration, frequency and direction. The tooth should be adequately isolated and its surface dried to prevent surface conduction, but the tooth should not be desiccated. The quality of the sensation is variously described by different patients even in apparently normal teeth and is not useful for diagnostic purposes. The method is valuable for determining which teeth have vital pulps and which do not, which facilitates the diagnosis of periapical disease; there does not appear to be a correlation between the threshold value and the histological appearance of the pulp.

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Meeting March 21 1966
at the Royal College of Surgeons,
Lincoln's Inn Fields, London

Professor A E W Miles (*Honorary Curator of the Odontological Museum*) spoke about a new exhibit that was on display in the Museum on the subject of 'Animals in Experimental Dental Research'. The exhibit showed a wide variety of species that had been, and are being, used in the laboratory and included two newcomers: the gerbils, which are small desert-living rodents rather like hamsters, though with bushy tails, found in North Africa, the Near East and India, and the so-called miniature pig derived from strains of small pigs found in Vietnam, Corsica and Mexico.

Professor B Cohen (*Department of Dental Science, Royal College of Surgeons of England*) read a paper entitled **The New Dental Research Unit at Downe.**