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A Novel Instrument to Determine Pulp Proximity

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Abstract - *The aim was to determine whether extracted teeth could be used to test the Prepometer™ instrument, which indicates pulp proximity with green/amber/red light emitting diodes. Third molars were reduced to a plane in dentine and Prepometer™ readings made. Dentine was removed in 0.5 mm increments and readings made until only lights 9 or 10 (red) showed. The teeth were sectioned and the dentine thickness measured. Analysis permitted construction of a highly significant predictor-model ($p < 0.01$), the red/amber light boundary coinciding with a dentine thickness of 2.4 mm. The Prepometer™ was consistent in predicting pulp proximity but was more sensitive than specified.*

KEY WORDS: Pulp proximity; tooth preparation; alternating current; instrument; LED display

INTRODUCTION

The preparation of teeth for restorations can be hazardous to the dental pulp. The evidence is that a significant proportion of vital teeth prepared to retain fixed prostheses will become non-vital over succeeding years. In a study of abutments supporting crowns or fixed partial dentures, 18-23 years after placement, 15% of remaining abutments that had originally been classified as vital, were either endodontically treated or had periapical radiolucencies[1]. In an evaluation of fixed partial dentures 10 years following insertion, abutment teeth presumed to be vital had a 10% prevalence of radiographically visible periapical lesions[2]. From a systematic review of the literature over 50 years, Goodacre et al.[3] concluded that the single most common complication for abutments with single crowns was the need for endodontic treatment, with an incidence of 3% after an average period of 6 years. For fixed partial dentures the need for endodontic treatment was the second most common complication, with 11% of abutments affected after an average of 8 years.

During tooth preparation, as the distance from the pulp decreases, the permeability of the remaining dentine increases. This effect is most marked in cervical areas of the tooth, over pulp horns and on dentine that has had its smear layer removed [4,5]. It a reasonable to assume that over time, as cements and smear layers are lost beneath restorations, deep preparations place the pulp at greater risk from the diffusion of noxious agents from the external environment, than shallow preparations.

To date dentists have had to use clinical experience, knowledge of dental anatomy, and dental radiographs, to keep their preparations as far as practicable away from the dental pulp, while still accommodating the mechanical requirements of the restoration. Patients and dentists would welcome any device that could help avoid the biological cost, the financial cost and the inconvenience of endodontic treatment following restorative procedures.

The Prepometer™ (Fig 1) is an instrument that purports to indicate the thickness of dentine overlying a vital pulp. An electrode supplies an alternating electrical current through the dentine and pulp and completes a circuit via a lip clip electrode in the style familiar to users of electrontic apex locators. An array of light emitting diodes (LEDs) in traffic light colours, informs the operator of the proximity of the pulp. According to the manufacturer a red light indicates a dentine thickness of less than 1.4 mm over the pulp.

In vitro studies have shown that the electrical resistance of dentine is affected by the age of the teeth, the thickness of dentine over the pulp[6], the orientation of tubules[7] and the electrolyte concentration in which the teeth are stored[8]. The current path follows the orientation of the tubules[9].

The objectives of this pilot study were to:

1. investigate whether extracted teeth could serve as a model for testing the Prepometer™.
2. assess the consistency of the Prepometer™ in determining pulp proximity.
3. determine if the sensitivity of the instrument in detecting pulp proximity matched the claims made for it by the manufacturer.

MATERIALS AND METHODS

Ten disease-free third molars were placed in isotonic saline (0.9% w/v NaCl) and frozen immediately after extraction. When needed for the experiment, a tooth was removed from the freezer and high-speed diamonds and 400 grit carborundum paper were used with water coolant to remove all of the enamel from the occlusal surface, creating a flat plane at a level just deeper than the deepest enamel fissure. The reduced tooth was mounted in the centre of an acrylic disc using composite resin. The disc fitted in the test apparatus shown (Fig 2). This consisted

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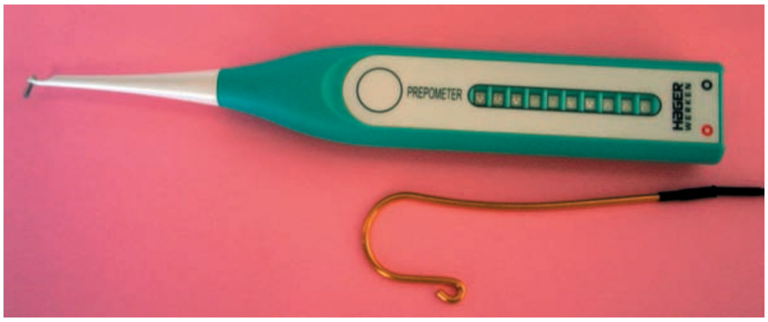


Figure 1. *The Prepometer™ instrument*

Figure 2. *The molar in the test apparatus.The occlusal surface is ground and the roots are in isotonic saline.*

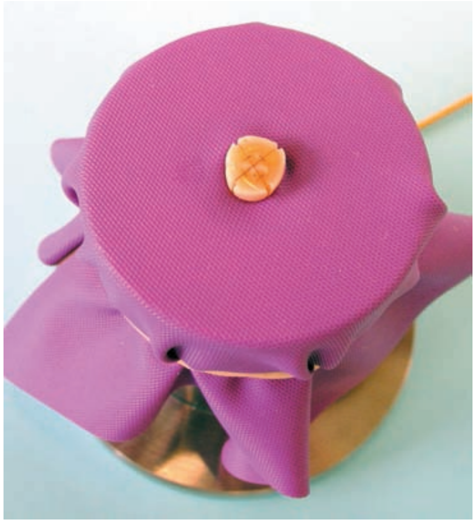


Figure 3. *The molar isolated, marked and ready for Prepometer™ readings.*

of a cylindrical steel pot with a brass screw top sealing down onto a rubber O-ring. A hole in the centre of the top allowed the third molar in the acrylic disc to have its roots in isotonic saline in the pot and its crown exposed for testing. The lip electrode was placed in contact with the cylinder base.

A sheet of rubber dam was applied over the tooth crown. Two lines were drawn across the ground occlusal plane, connecting points of maximum convexity – mesiobuccal to distolingual, and mesiolingual to distobuccal. On these two axes four points were marked, each 2.5 mm peripherally from the intersection (Fig 3). The four points and the intersection point were labelled a, b, c, d, e. Prepometer™ recordings were made at each point in the sequence a to e, and the sequence was repeated twice. For convenience the 10 point LED display of the instrument, (which runs from green through amber to red) was numbered 1 to 10. Recordings were made at each of the five points with the display of the instrument turned away from the operator towards the person making the recording. The mean of three recordings was calculated for each point.

The stylus of a Digimatic Indicator™ digital measuring gauge was placed on the centre point, e, and zeroed. The tooth in its mounting disc was then removed from the test cylinder and approximately 0.5 mm was removed from the cut surface using a depth gauge diamond and 400 grit carborundum paper. The apparatus was reassembled, the axes re-drawn and the measuring gauge used to precisely measure the amount of dentine removed at point e. Three Prepometer™ recordings were made again at each point in the sequence a to e. Tooth reductions and Prepometer™ recordings were continued until the instrument displayed 9 or 10 (red LEDs) at all five points on the surface. At each level of reduction the means of the three Prepometer™ readings for each point were calculated. The teeth were removed from the acrylic disc and sectioned across the a-c axis using a diamond-tipped saw. The cut halves of the prepared teeth were placed under a measuring microscope and the distance from the dentine surface to the pulp chamber was measured along a line perpendicular to the surface, at points a, c and e. The cut halves were glued together using cyanoacrylate adhesive and the tooth sectioned across the b-d axis. The cut halves were returned to the measuring microscope and the distance from the dentine surface to the pulp chamber was measured at points b and d. The dentine thickness corresponding to each mean Prepometer reading was calculated by adding the final dentine thickness to the measured increments removed.

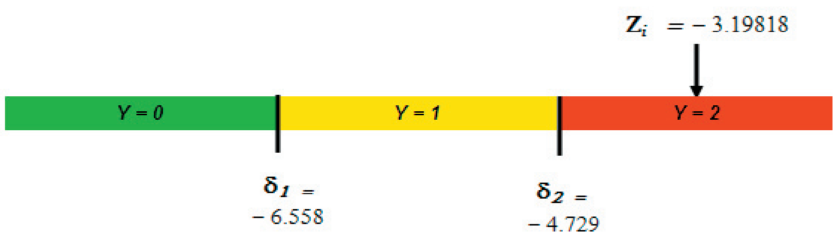
STATISTICAL ANALYSIS

Ordinal regression statistical techniques were used to analyse the data. Ordinal regression extends logistic regression beyond its binary predictive limitation by making provision for three or more ordered categories into which a predicted dependent variable might be calculated to fall. The categories of interest in the present case represent the three Prepometer diode colour domains of green (coded 0), amber (coded 1) and red (coded 2). Ordinal regression posits an underlying 'latent' continuous scale that is divided into a series of contiguous numeric bands, or domains, one for each of the ordinal diode colour categories under investigation. The values of δ_1 and δ_2 in the uppermost rows of the 'Estimate' column of Table 1 represent calculated numeric points of demarcation that separate the domains. Thus, the value for "diode category = 0" (δ_1) marks the threshold between colour domains 0 and 1, and that for "diode category = 1" (δ_2) the threshold between colour domains 1 and 2. As in other species of regression, a parameter Z_i is calculated by multiplying an estimated slope coefficient β by an explanatory variable X_i - which in the present application is the thickness of the dentine (measured in millimetres) that separates cavity surface and pulp space. SPSS's 'PLUM' application computes coefficient β and presents it at the foot of the 'Estimate' column of Table 1 as 'Location (slope)'; while Z_i - its product with the dentine thickness measurement - can be regarded as a sliding marker that can take up a point anywhere along the posited latent scale. The position it assumes relative to the ordinal domains that are ranged along the scale provides an indication of the colour category that will have the highest probability of occurrence. The illustrative example provided (Fig 4) demonstrates the extended logit equations that are used by 'PLUM' to calculate the respective probabilities $P(Y=0)$, $P(Y=1)$ and $P(Y=2)$ for categories 0, 1 and 2 when the dentine thickness measures 1.51 mm. The values for P derived in this way always summate to 1, with the highest P value taken to be the most likely ordinal diode response category in any particular instance.

Table 1. *Ordinal equation parameter estimates*

		Estimate	*Standard Error (SE)*	*Wald*	*df*	*Sig*	*95% confidence interval*	
							lower	*upper*
Threshold	σ_1 [diode category=0]	-6.558	0.613	114.300	1	*0.000	-7.760	-5.356
	σ_2 [diode category=1]	-4.729	0.532	79.001	1	*0.000	-5.772	-3.686
Location (slope)	β	-2.118	0.207	105.146	1	*0.000	-2.523	-1.713

Wald statistic is ratio: Estimate / Standard Error (SE) of Estimate, squared.
*Sig value <0.01 indicates that parameter is useful to model



Z_i = (X_i x β) = (1.51 x - 2.118) = - 3.19818

$$P(Y=0)=\frac{1}{1+\exp(Z_i-\delta_1)} \quad = \frac{1}{1+\exp(-3.19818+6.558)} \quad = \mathbf{0.034}$$

$$P(Y=1)=\frac{1}{1+\exp(Z_i-\delta_2)}-\frac{1}{1+\exp(Z_i-\delta_1)}$$

$$=\frac{1}{1+\exp(-3.19818+4.729)}-\frac{1}{1+\exp(-3.19818+6.558)} \quad = \mathbf{0.144}$$

$$P(Y=2)=1-\frac{1}{1+\exp(Z_i-\delta_2)} \quad =1-\frac{1}{1+\exp(-3.19818+4.729)} \quad = \mathbf{0.822}$$

With a dentine overburden of 1.51 mm, there is an 82% probability that the light the Prepometer displays will be red

Figure 4. Illustrative example assuming a dentine thickness (Xi) of 1.51 mm. Multiplying this figure by the β coefficient (slope) from Table 1 provides a value of Z_i that is shown to fall within the 'red' domain of the underlying 'latent' scale (Y = 2). The associated probabilities are reflected by the logit calculations, confirming the probability that P (Y = 2) is pre-eminent.

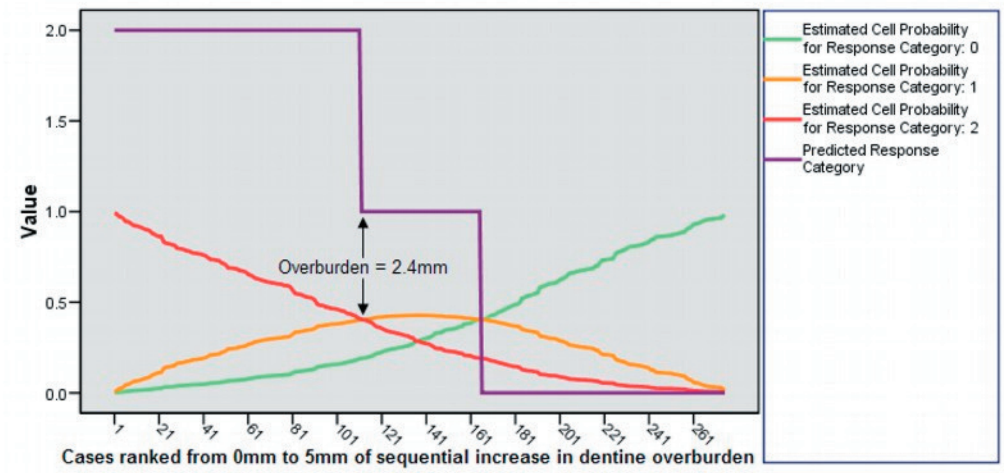


Figure 5. *The changing proportions (of unity) that the three colour domains assumed when the 275 dentine thickness measurements were linearly ranged on the x axis. The purple line represents the category codes at which the respective colours assume pre-eminence, a step-down occurring at the crossing points between the response category plots.*

RESULTS

Figure 5 illustrates the changing proportions (of unity) that the three colour domains assumed when the 275 measured dentine thickness readings were linearly ranged on the x axis, in increasing order, from zero at left to 5 mm at right.

The purple line represents the category codes at which the various colours have pre-eminence, a step-down occurring at the crossing points between the various response category plots. It is worth noting that the point of equal probability (i.e. the crossing point) of the red and amber response plots coincides with a dentine thickness of 2.416 mm which can be verified by applying this value to the regression equations, where equal probability values of 0.404 emerge for red and amber, with that of green (0.192). The dentine thickness of 2.4 mm that triggered a red light response from the Prepometer™ is significantly more than the value of 1.4 mm that is cited in the Prepometer™ literature.

DISCUSSION

Freezing the teeth immediately after extraction would have preserved the pulpal tissue in situ. Thawing them at the time of use and maintaining them in isotonic saline is probably the most practical way to simulate the electrical conductivity of vital teeth. Using freshly extracted teeth would have been an alternative but less practical way of conducting the experiment. An in vivo experiment would require the use of premolars or third molars destined for extraction with its attendant ethical issues.

The teeth used in the present experiment were caries-free third molars from young adults. The dentinal tubules would have been large and electrical resistance would be expected to be low as the dentinal fluid is the conducting medium. Furthermore cellular disruption after extraction may possibly have altered the conductivity of the dentine by releasing electrolytes into tubules. This may account for the red light output from the Prepometer™ when the pulp was on average still 2.4 mm away. However if the instrument were to be clinically useful in operative dentistry a more sensitive indication of the proximity of the pulp would be important.

The output of the machine would be expected to vary from site to site within individual teeth as the tubule orientation, density and structure vary within the dentine. Further studies will test the applicability of the instrument to axial preparations.

In this study, a substantial smear layer, produced by the diamond and carborundum abrasives, would have covered the ground dentinal surface. The effect of removing or modifying the smear layer will be tested in future experiments.

The ease of use and consistency of the Prepometer™ in this study suggest it has the potential to be a useful clinical instrument, however a clinical study of 12 anterior teeth in two patients found no clear correlation between Prepometer™ measurements and dentine thickness[10]. The patients were 45 and 62 years of age and suffered from advanced periodontal disease. Although the teeth were vital they were not representative of the healthy teeth that the Prepometer™ would be applied to clinically. The present study attempted to control some of the many variables that exist in clinical practice by its systematic dentine reduction and repeated measurements of only molar teeth. The instrument was a consistent predictor of pulp proximity. However, its sensitivity (red light at 2.4 mm of dentine thickness) would not be applicable clinically. The machine may have to be recalibrated for clinical use. If the operator had to learn to interpret the lights in the context of the age of the tooth, the condition of the cut surface and the history of restorations or caries that may have rendered the dentinal tubules less than pristine, then the instrument would provide little value over normal clinical judgement.

CONCLUSIONS

The method described, freezing newly extracted teeth and testing them in isotonic saline, proved to be a suitable model for examining the operation of the Prepometer™ instrument. The instrument proved to be a consistent predictor of pulp proximity. In this laboratory test it was rather more sensitive to pulp proximity than described in the manufacturer's specifications.

MANUFACTURERS' DETAILS

- Prepometer, Hager and Werken, Duisburg, Germany
- Digimatic Indicator, Mitutoyo Mfg Co Ltd, Japan

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