©Operative Dentistry, 2006, **31-3,** 291-296

Clinical Research

DIAGNOdent Measurements and Correlation with the Depth and Volume of Minimally Invasive Cavity Preparations

JC Hamilton • WA Gregory • JB Valentine

Clinical Relevance

Measurements from DIAGNOdent were not strongly correlated with the depth or volume of cavity preparations that resulted from carious lesions in the pits and fissures of posterior teeth.

SUMMARY

In this clinical study, DIAGNOdent (KaVo) was used to assess previously diagnosed carious lesions in the pits and fissures of first and second molars. The measurements from this device were correlated with the depth and volume of the cavity preparations that resulted from minimal intervention to remove occlusal carious lesions. Twenty-five patients, 18 years of age and older, who were previously scheduled for an occlusal restoration due to caries, were recruited and enrolled in this clinical study. These patients had 48 qualifying teeth without previous restorations, sealants or other carious lesions. The occlusal surface of each study tooth was cleaned utilizing ProphyFlex2 (KaVo). Two dentists separately traced the pit and fissure system of each tooth using DIAGNOdent for two 15-second periods each. The peak reading of each of the four measurements was recorded. An impression of the occlusal surface of each tooth was recorded with a polyvinyl siloxane bite registration material. The carious lesions were removed with an air abrasion unit employing a 0.015-inch nozzle opening utilizing minimal operative intervention. A low viscosity polyvinyl siloxane was used to take an impression of the cavity preparation impression, using the bite registration impression to form the occlusal surface of the preparation impression. The preparation impression volume was calculated from its weight, using the known density of the impression material. The greatest depth of the preparation was measured. The Pearson correlation coefficient was used to investigate any relationship between depth or volume of the preparation impression and the DIAGNOdent measurements. The correlation for preparation volume and maximum DIAGNOdent measurement was 0.191 (p=0.189). Other logical

*James C Hamilton, BA, DDS, associate professor, Department of Cariology, Restorative Sciences and Endodontics, University of Michigan School of Dentistry, Ann Arbor, MI, USA

William A Gregory, DDS, MS, adjunct professor of dentistry, University of Michigan School of Dentistry, Department of Cariology, Restorative Sciences and Endodontics, Ann Arbor, MI, USA

John B Valentine, BS, DMD, MSD, clinical associate professor, Department of Dentistry, Faculty of Medicine and Dentistry, Alberta, Canada

*Reprint request: 1011 N University, Ann Arbor, MI 48109, USA; e-mail: jchamilt@umich.edu

DOI: 10.2341/05-47

subsets of cases also did not result in any statistically significant correlations between the DIAGNOdent readings and the depth or volume of the final cavity preparations.

INTRODUCTION

With the increased availability of fluoride in public water supplies, toothpaste and mouth rinses, there has been a significant reduction in dental caries (Brown, Wall & Lazar, 2000). However, this reduction, due to fluoride, has not affected all tooth surfaces equally (McDonald & Sheiham, 1992). Topical fluoride has been shown not to decrease pit and fissure caries (Zahran, 1976). Consequently, occlusal surfaces now represent more than 90% of caries in children (Zero, 1999).

Diagnosing caries in the pits and fissures of posterior teeth is challenging, and some feel it is becoming more difficult to diagnose due to the increased use of topical fluoride, which may mask the progression of dentinal carious lesions beneath the surface (Creanor & others, 1990; Lussi, 1993). Technologies developed to aid dentists in diagnosing pit and fissure caries include electrical resistance (Chalom, 1995; Lussi & others, 1995; Ricketts & others, 1996), quantitative laser fluorescence (Shi, Tranaeus & Angmar-Mansson, 2001), fiber-optic transillumination (Choksi & others, 1994) and digital imaging fiber-optic transillumination (DIFOTI) (Schneiderman & others, 1997).

DIAGNOdent (KaVo, Biberach, Germany), a quantitative laser fluorescence unit, is currently used as an aid in the diagnosis of carious lesions (Lussi & Reich, 2005). Various researchers and KaVo Clinical Guidelines have suggested that the greater the peak reading of this quantitative laser fluorescence-based system, the greater the depth of the occlusal lesion (Heinrich-Weltzien & others, 2003). It is felt that the greater the depth of a carious lesion, the greater its volume. Therefore, this study evaluated the degree of correlation between DIAGNOdent measurements and the depth or volume of the minimally invasive preparations needed to treat pit and fissure carious lesions.

METHODS AND MATERIALS

The protocol and consent forms used to treat human patients in a clinical research study were reviewed and approved by the Health Sciences Institutional Review Board of the University of Michigan. A HIPAA waiver was requested and granted to review patient charts at the University of Michigan School of Dentistry to aid in locating patients with the appropriate carious lesions for this study. Patients 18 and older who had been diagnosed with an occlusal carious lesion in the pits and fissure of at least one previously untreated maxillary and/or mandibular permanent first or second molar were contacted and asked to enroll in the study. The 25 enrolled patients had 48 eligible non-cavitated teeth when view clinically.

Just prior to the initial evaluation and treatment, a dentist cleaned each tooth enrolled in the study with ProphyFlex2 (KaVo, Biberach, Germany), utilizing the powder recommended by the manufacturer. That same dentist then photographed the occlusal surface, utilizing 35-millimeter slide film. The tooth was then scanned for 15 seconds with the just-calibrated DIAGNOdent. The peak reading was recorded. This scanning process was repeated, since it was noted in a previous clinical study that slight variations are to be expected (Hamilton & Dennison, 2003). A second dentist independently repeated the two 15-second scans. All four peak readings were recorded. The mean of the four peak measurements, along with the minimum peak and maximum peak measurements, were used to investigate correlations with the depth or volume of the preparations.

An impression of the occlusal surface of all teeth treated in the study was completed with a polyvinyl siloxane bite registration material. This occlusal impression would be utilized to construct a preparation impression later in the appointment.

After the preparation was completed, utilizing air abrasion and minimally invasive techniques to remove all caries, the preparation was photographed, utilizing 35-mm slide film. Visual and tactile feedback from an explorer were used to determine the end of caries removal. Due to the slower removal of tooth structure with air abrasion versus a high speed handpiece and bur and even slower cutting of the softer materials, such as carious dentin, air abrasion aided in the minimal removal of sound tooth structure.

A preparation impression was constructed from a low viscosity polyvinyl siloxane impression material that was injected through an intraoral syringe tip placed at the bottom of the preparation. The occlusal impression prepared prior to the cavity preparation formed the occlusal surface of the preparation impression. A water-soluble separator was placed on the occlusal impression to allow separation from the preparation impression. This process minimized voids in the impression. Experience has shown that, if voids are present, they are on the surface and can be easily seen, necessitating refabrication of the preparation impression. This technique for quantifying the size of the cavity preparation has been used successfully in a previous clinical study (Hamilton & others, 2002).

The preparations were etched with 37% gel acid etchant for 15 seconds followed by rinsing with water for 15 seconds. The preparations were restored utilizing Excite bonding agent, Tetric Flow and Tetric Ceram light-cured resin-based light-cured composite (Ivoclar Vivadent, Liechtenstein).

Table 1: *Pearson Correlation Coefficient (r) and Significance (2-tailed) for DIAGNOdent (DD) and Preparation Volume or Depth*

	All Cases			
	Preparation Volume		Preparation Depth	
	r	Sig	r	Sig
Mean DD Value	0.161	0.274	0.017	0.909
Maximum DD Value	0.193	0.189	-0.026	0.861
Minimum Peak DD Value	0.133	0.367	0.069	0.641

Table 2: *Pearson Correlation Coefficient (r) and Significance (2-tailed) for DIAGNOdent (DD) Measurements and Preparation Volume or Depth for Non-cavitated Pit and Fissure Carious Lesions*

	Non-cavitated Carious Lesions			
	Preparation Volume		Preparation Depth	
	R	Sig	r	Sig
Mean DD Reading	0.344	0.054	0.001	0.998
Maximum DD Reading	0.263	0.146	0.122	0.507
Minimum Peak DD Reading	0.339	0.058	0.138	0.451

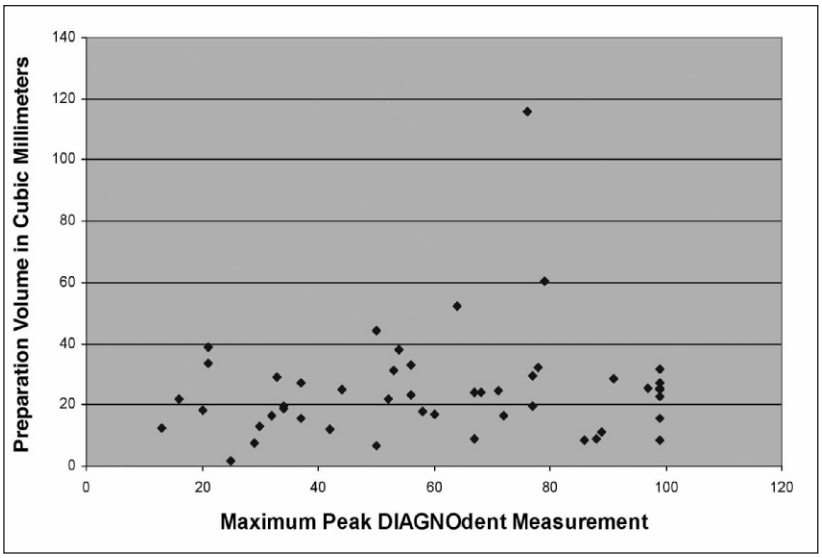

Figure 1. *Scatter plot of maximum peak DIAGNOdent measurement and preparation volume for all cases.*

After treating the 48 teeth, the preparation impressions were weighed on an analytic balance. Using the reported density of the impression material (1.32 gms/cm^3), which was confirmed by the investigators, the volumes of the preparations were calculated. Each impression was measured with calipers at its greatest thickness perpendicular to the occlusal surface to the closest 0.1 mm. All values were entered into SPSS version 10 to calculate the Pearson correlation coefficient between the preparation depth or volume and the DIAGNOdent measurements (minimum peak, mean peak and maximum peak). A *p*-value of less than 0.05 was considered statistically significant.

During viewing of the pre-operative 35-millimeter slides projected at approximately 10x, 16 of the 48 teeth appeared to have small, cavitated carious lesions, which were not noticed during the clinical evaluations. These cavitations were also not seen, due to their small size, in the occlusal impressions used to fabricate the preparation impressions. These small cavitations did not affect the volume or depth measurements obtained from the impressions, since they represented less than a fraction of one percent of the volume.

The clinical studies and guidelines cited in an article by Heinrich-Weltzien and others (2003) suggest an increasing DIAGNOdent value with an increasing depth of caries at least up to a value of 34. Therefore, the preceding correlations were also repeated for all teeth, with a mean peak DIAGNOdent measurement of less than 35. Since DIAGNOdent is often utilized as an aid in diagnosing caries in pit and fissures that had not cavitated, the above correlations were calculated for only those teeth with non-cavitated carious lesions.

RESULTS

The 48 teeth treated in this study included 14 maxillary second molars, 6 maxillary first molars, 4 mandibular first molars and 24 mandibular second molars. The 25 patients ranged in age from 18 to 39 years, with a mean age of 24. No significant correlation was found between preparation depth or volume and mean, maximum or minimum peak DIAGNOdent reading. The Pearson correlation coefficient and the significance of the above comparisons are shown in Table 1. A scatter plot of maximum peak DIAGNOdent measurements and preparation volume best illustrates the degree of correlation (Figure 1).

If only mean DIAGNOdent values of 34 or less are considered, there was no significant correlation between preparation volume (r=0.332, p=0.227) or thickness (r=0.324, p=0.239). The 15 teeth with values of 34 or less included three teeth with cavitated lesions, and these teeth had mean peak DIAGNOdent values of 12, 15 and 17. Scatter plots of these relationships are shown in Figures 2 and 3. Removal of the three cases with cavitated lesions reduced the correlation and increased the *p*-value.

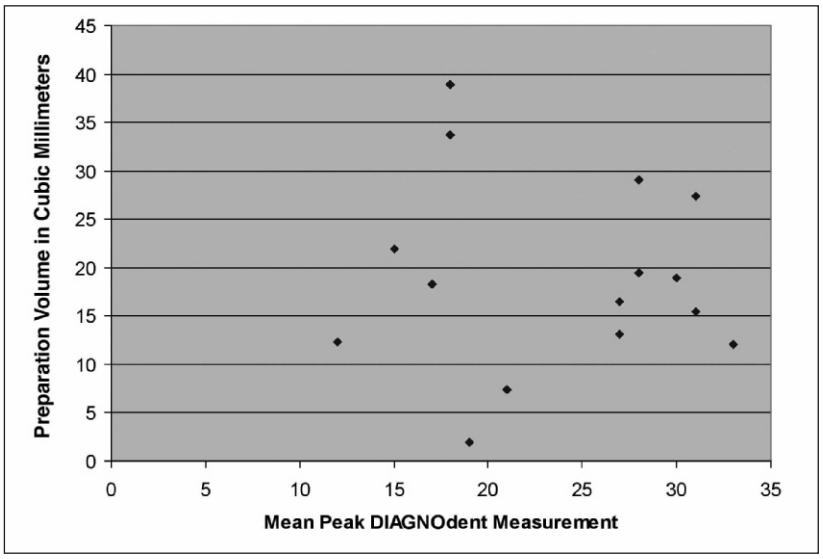

Figure 2. *Scatter plot of mean DIAGNOdent measurements < 35 and preparation volume.*

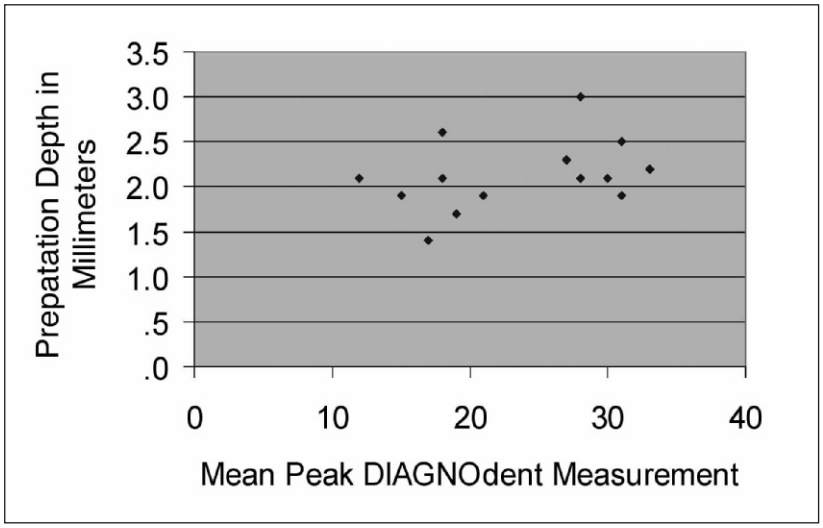

Figure 3. *Scatter plot of mean DIAGNOdent measurements <35 and preparation depth.*

If only non-cavitated lesions were considered, the highest correlation was found between the mean peak DIAGNOdent values and preparation volume, which was 0.344, with a *p*-value of 0.054 (Figure 4). Considering only the maximum or minimum peak DIAGNOdent measurement of the four values taken for each tooth, the correlations resulted in a lower correlation and larger *p*-value. Table 2 shows the Pearson correlation coefficient and significance considering only non-cavitated carious lesions.

DISCUSSION

The DIAGNOdent measures reflected laser fluorescence. A two-component fiber optic bundle transmits laser light into the tooth, while the other component transmits fluorescence from the tooth to a sensor that quantifies the amount of fluorescence. Healthy tooth structure exhibits little or no fluorescence at the wavelength of the incoming laser beam, while carious tooth structure exhibits fluorescence proportional to the amount of decay.

It was expected that a significant correlation would be found between DIAGNOdent measurements and preparation depth or volume. The clinical studies and guidelines noted in an article by Heinrich-Weltzien and others (2003) suggest an increasing DIAGNOdent value with an increasing depth of caries at least up to a reading of 34. The implication is that the deeper the carious lesion, the higher the peak reading.

This study could not demonstrate any significant correlation between preparation depth or volume and DIAGNOdent readings. There are many possible reasons for this. When the occlusal pits and fissures are repeatedly traced with the tip of the DIAGNOdent, the angulation of the tip with respect to the occlusal surface can affect the reading. It is not efficient to angle the tip in all possible positions when scanning a tooth, as this will lead to variations in readings even when used by the same operator on the same tooth. As noted later, stain can affect a DIAGNOdent reading. Many substances found in the oral cavity can fluoresce, including resin based composites and plaque. It has been reported that toothpaste and prophylaxis paste needs to be thoroughly rinsed from the surface of a tooth, since false DIAGNOdent readings are possible, especially in carious teeth (Lussi & Reich, 2005). All these factors will confound use of this quantitative laser fluorescent unit.

Although no correlation could be found in this clinical study, the question remains, does DIAGNOdent aid in diagnosing carious lesions? There was some indication that, with non-cavitated lesions, the correlation with preparation volume approached significance, although the correlation was only 0.334. This suggests that DIAGNOdent should be used only as an aid in diagnosing caries, as was originally suggested by the manufacturer. The concern remains that, due to all of the above factors, false positive readings can lead to unnecessary treatment of a sound tooth.

More than 90% of the teeth treated in this clinical study had darkly stained pits and fissures. Although these stained occlusal surfaces were cleaned utilizing a ProphyFlex2 with the powder recommended by the manufacturer, some stain remained in the pits and fis-

sures. It has been noted in one of the most widely read paid subscription dental newsletters that almost all stained pits and fissures of non-smokers are carious (Clinical Research Associates Newsletter, 1999).

Furthermore, Francescut and Lussi (2003) noted that discolored fissures lead to higher DIAGNOdent values compared to non-discolored or opaque fissures. Since more than 90% of the teeth in this study exhibited pit and fissure stain, it was expected that nearly all the teeth would have higher readings compared to those teeth without stain. This would not change the correlations of this study, if all teeth were equally stained, but this was not the case. When using DIAGNOdent, pit and fissure stain is an uncontrolled variable that the authors of this study did not try to quantify and which practicing dentists will need to consider along with other local factors when assessing carious lesions. Also, the staining of pits and fissures varies between teeth and within a single tooth; consequently, quantifying the affect of staining on DIAGNOdent readings would be difficult.

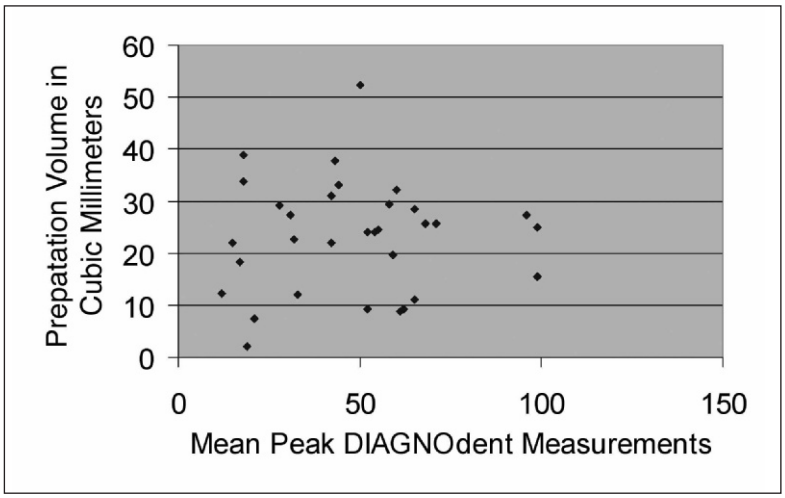

Figure 4. *Scatter plot of mean peak DIAGNOdent readings and preparation volume for non-cavitated lesions.*

In a previous randomized clinical trial involving teeth with questionable pit and fissure carious lesions, repeated DIAGNOdent measurements of the same tooth gave slight variations, with a correlation of 0.927, $p<0.0005$ (Hamilton & Dennison, 2003). In this study, the observed Pearson correlation coefficient between the first and second DIAGNOdent measurement for examiners one and two was 0.869 and 0.888, respectively, both with a $p<0.0005$. Differences between the two studies could be explained by differences in the extent of the carious lesions evaluated. The carious lesions in this clinical study were not questionable and, in some cases, were cavitated when viewed at approximately 10x. In the previous study at baseline, half the teeth had no caries into dentin and the other half had minimal caries into dentin. This created a narrower range of DIAGNOdent readings compared to the current study, in which nearly all the teeth had caries into dentin, and it was more likely that the carious lesions had progressed, creating a broader range of DIAGNOdent readings. Consequently, due to the larger range of readings, there was a greater chance for a lower correlation.

CONCLUSIONS

The results of this clinical study indicate no significant correlation between DIAGNOdent measurement and depth or volume of minimally invasive preparations that resulted from treating teeth diagnosed with occlusal caries. When subsets of these data were analyzed, no significant correlations were observed for non-cavitated lesions or DIAGNOdent readings less than 35.

(Received 2 April 2005)

Acknowledgements

The University of Michigan School of Dentistry Department of Cariology, Restorative Sciences and Endodontics supported this research study. The authors have no financial interest in the companies whose materials are discussed in this article.

References

Brown LJ, Wall TP & Lazar V (2000) Trends in total caries experience: Permanent and primary teeth *Journal of the American Dental Association* **131(2)** 223-31.

Chalom DE (1995) Electrical resistance measures for the diagnosis of occlusal caries *British Dental Journal* **178(6)** 205.

Choksi SK, Brady JM, Dang DH & Rao MS (1994) Detecting approximal dental caries with transillumination: A clinical evaluation *Journal of the American Dental Association* **125(8)** 1098-1102.

Clinical Research Associates (1999) The dilemma posed by stained pits & fissures *CRA Newsletter* **23(12)** 2.

Creanor SL, Russel JL, Strang DM, Stephen KW & Burchell CK (1990) The prevalence of clinically undetected occlusal dentin caries in Scottish adolescents *British Dental Journal* **169(5)** 126-129.

Francescut P & Lussi A (2003) Correlation between fissure discoloration, DIAGNOdent measurements, and caries depth: An *in vitro* study *Pediatric Dentistry* **25(6)** 559-64.

Hamilton JC, Dennison JB, Stoffers KW & Welch KB (2002) Early treatment of incipient carious lesions. A two-year clinical evaluation *Journal of the American Dental Association* **133(12)** 1643-1651.

Hamilton JC & Dennison JB (2003) Repeatability of DIAGNOdent measurements in a clinical study *Journal of Dental Research* **82(Special Issue B)** Abstract #3015.

Heinrich-Weltzien R, Kuhnisch J, Oehme T, Ziehe A, Stosser L & García-Godoy F (2003) Comparison of different DIAGNOdent cut-off limits for *in vivo* detection of occlusal caries *Operative Dentistry* **28(6)** 672-680.

Lussi A (1993) Comparison of different methods for the diagnosis of fissure caries without cavitation *Caries Research* **27(5)** 409-416.

Lussi A, Firestone A, Schoenberg V, Hotz P & Stich H (1995) *In vivo* diagnosis of fissure caries using a new electrical resistance monitor *Caries Research* **29(2)** 81-87.

Lussi A & Reich E (2005) The influence of toothpastes and prophylaxis pastes on fluorescence measurements for caries detection *in vitro European Journal of Oral Sciences* **113(2)** 39-48.

McDonald SP & Sheiham A (1992) The distribution of caries on different tooth surfaces at varying levels of caries—a compilation of data from 18 previous studies *Community Dental Health* **9(1)** 39-48.

Ricketts DN, Kidd EA, Liepins PJ & Wilson RF (1996) Histological validation of electrical resistance measurements in the diagnosis of occlusal caries *Caries Research* **30(2)** 148-155.

Schneiderman A, Elbaum M, Shultz T, Keem S, Greenebaum M & Driller J (1997) Assessment of dental caries with Digital Imaging Fiber-Optic TransIllumination (DIFOTI): *In vitro* study *Caries Research* **31(2)** 103-110.

Shi XQ, Tranaeus S & Angmar-Mansson B (2001) Comparison of QLF and DIAGNOdent for quantification of smooth surface caries *Caries Research* **35(1)** 21-26.

Zahran M (1976) Effect of topically applied acidulated phosphate fluoride on dental caries *Community Dentistry & Oral Epidemiology* **4(6)** 230-233.

Zero DT (1999) Dental caries process *Dental Clinics of North America* **43(3)** 635-664.