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Concordance Between Preoperative and Postoperative Assessments of Primary Caries Lesion Depth: Results From The Dental PBRN

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Clinical Relevance

Accuracy of dentists' preoperative estimates of caries lesion depth is a major determinant in appropriate restorative treatment decisions. Dentists may benefit from a personal review of their accuracy on assessing lesion depth by considering the results from this study.

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SUMMARY

This study investigated the concordance between pre- and postoperative assessments of primary caries lesion depths by dentists from The Dental Practice-Based Research Network

(DPBRN; www.DentalPBRN.org). A total of 229 DPBRN dentists collected data on 8,351 consecutive restorations inserted due to primary caries in 5,810 patients. Dentists estimated the preoperative depth of caries lesions based on the diagnostic methods they typically used. The preoperative depth was then compared to the postoperative depth, which dentists determined using actual clinical observation. Both estimated and observed depths were recorded as being in the outer half (E1) or inner half (E2) of enamel, or in the outer third (D1), middle third (D2) or inner third (D3) of dentin. Most restorations were placed to treat lesions that were preoperatively assessed as extending to the D1 (53%) and D2 (25%) depths. Of the restored caries lesions, 10% were preoperatively assessed as being limited to E2 depth and 3% to E1 depth. The majority of the restored enamel lesions were located on occlusal surfaces. Preoperative estimates of caries lesion depth were more concordant with postoperative depths when the lesion was at an advanced stage: 88% concordance at the D3 depth, compared to 54% concordance at the E1 depth. DPBRN dentists can discriminate caries lesions at different depths, but the accuracy of their depth assessments was higher for dentin than for enamel lesions. In general, DPBRN dentists were more likely to underestimate than overestimate the depth of caries lesions, and the extent of underestimation was greater for enamel than for dentin lesions.

INTRODUCTION

The variation among dentists in diagnosing and managing dental caries represents a noteworthy problem in dentistry.[1-10] Of particular concern, dentists disagree in their treatment decisions regarding whether operative intervention is required following the detection of a caries lesion.[1-2,4-5,8,10-14] This well-recognized variation in the management of caries, from offering no treatment to intervening operatively, implies that some patients will not receive appropriate treatment;[11] that is, caries lesions that could be arrested and remineralized by preventive measures may be restored, while others requiring restorations may remain untreated. Part of the variation in operative decisions occurs because dentists differ greatly in their assessment of how advanced the caries process is.[4-5,11] Clinical dentistry could benefit significantly from reducing this variation and thereby reducing the amount of inappropriate care provided to dental patients.

Current knowledge of the caries process indicates that efforts to arrest disease activity and progression using remineralization measures must occur prior to enamel cavitation,[15-17] while cavitated and active lesions progressing into dentin most often require operative intervention.[18] It has been shown that, when an occlusal lesion has become cavitated, the dentin is always involved in the process.[19-21] Although cavitation status may be a better indicator for restorative needs than lesion depth, cavitation is not always easily assessed on proximal lesions. As a result, the lesion depth or whether the lesion has progressed into the dentin has become the main criterion for decisions to intervene operatively. The problem arises when estimating the depth of lesions near the dentino-enamel junction (DEJ), at a point where depth and cavitation status are not strongly correlated and treatment decisions may be inappropriate. Given that lesion depth remains the main criterion for operative decisions in many clinical cases, dentists' capacity to distinguish the various depths of the caries process—from the first discernable signs at the superficial level to an advanced stage of dentin caries—may play a critical role in the management of dental caries. Accurate clinical assessment of caries lesion depth will facilitate appropriate treatment decisions; conversely, inaccurate depth estimates may result in incorrect treatment decisions, particularly with respect to operative intervention.

To begin addressing the existing variation in treatment decisions encountered in daily clinical practice, it appears necessary to determine the accuracy with which dentists can estimate the depth of caries lesions. A limited number of studies have queried dentists' accuracy of depth assessments by radiographs,[3,7-8,22-23] but little information is available from general dental practice about the accuracy with which dentists clinically estimate the depth of caries lesions.[10] The current study is a component of a broader research program being undertaken by The Dental Practice-Based Research Network (DPBRN) to investigate the way dentists diagnose and treat dental caries.[24-27] The DPBRN is a consortium of dental practices with a broad representation of practice types and treatment philosophies that conducts research across geographically dispersed regions. The goals of this study were to provide information on: 1) the preoperative and 2) the postoperative assessments of caries lesion depths by DPBRN dentists and on 3) the concordance between their pre- and postoperative assessments of lesion depth in relation to caries lesion location and other factors.

METHODS AND MATERIALS

The DPBRN Dentists—Practitioner-investigators from The DPBRN who perform restorative dentistry in their practices were eligible for this study. The DPBRN comprises outpatient dental practices from five regions: AL/MS: Alabama/Mississippi, USA; FL/GA: Florida/Georgia, USA; MN: dentists employed by

Table 1: *Registration of Pre- and Postoperative Depth of Caries Lesions*

Preoperative Assessment	**Postoperative Assessment**
How deep did you estimate that the deepest part of the primary caries lesion was preoperatively?	How deep did you estimate that the deepest part of the primary caries lesion was postoperatively?
(Please mark one category only.)	(Please mark one category only.)
1 E1 (Outer half of Enamel)	1 E1 (Outer half of Enamel)
2 E2 (Inner half of Enamel)	2 E2 (Inner half of Enamel)
3 D1 (Outer one-third of Dentin)	3 D1 (Outer one-third of Dentin)
4 D2 (Middle one-third of Dentin)	4 D2 (Middle one-third of Dentin)
5 D3 (Inner one-third of Dentin)	5 D3 (Inner one-third of Dentin)
6 Uncertain	

HealthPartners and private practitioners in Minnesota, USA; PDA: Permanente Dental Associates in cooperation with Kaiser Permanente Center for Health Research, Portland, Oregon, USA and SK: Denmark, Norway and Sweden.[24] DPBRN dentists can also be characterized by type of practice as being in either: 1) a solo or small group private practice (<4 dentists) (SGP); 2) a large group practice (≥4 dentists) (LGP) or 3) a public health practice (PHP). Public health practices were defined as those that receive the majority of their funding from public sources. The current study was approved by the respective Institutional Review Boards of the participating regions.[28]

DPBRN dentists were recruited through continuing education courses and/or mass mailings to licensed dentists within the participating regions. As part of the eligibility criteria, all dentists completed an enrollment questionnaire describing their demographic and practice characteristics. Additional information about dentists' demographics and practice characteristics are provided at: http://www.DentalPBRN.org and elsewhere.[25,29] For the current study, dentists also attended an orientation session with the DPBRN regional coordinator; the orientation session explained in detail how to complete the study form using a training manual.[25,29] These questionnaires, study forms and further details about the training sessions are available at: http://www.dentalpbrn.org/users/publications/Supplement.aspx.

Assessment of Caries Lesion Depth—DPBRN dentists provided responses to questions regarding the depth of consecutive primary caries lesions being restored in their practices. The data collection form was pilot-tested to assess feasibility and item clarity.[25] The data collection form requested (i) the tooth type and carious tooth surfaces being restored; (ii) the method of diagnosis (clinical assessment by means of visual-tactile examination and/or radiographs, and/or transillumination and optical techniques); (iii) the preoperative estimate of the depth of the deepest part of the caries lesion (Table 1) and (iv) the postoperative depth of the deepest part of the caries lesion based on actual clinical observation (Table 1). Lesion depths were categorized as either being in the outer half (E1) or inner half (E2) of enamel, or in the outer third (D1), middle third (D2) or inner third (D3) of dentin. Practitioner-investigators were instructed to record the depth of the dental tissue affected by caries, not the final depth of the cavity preparation.

Statistical Analysis—Data were analyzed using SAS software version 9.2 (Cary, NC, USA). Descriptive statistics are presented as counts and percentages for categorical variables and as means and standard deviations for continuous variables. Multiple logistic regression modeling implemented using generalized estimating equations (GEE) was used to identify predictors of agreement, underestimation and overestimation of postoperative depth based on preoperative assessment of lesion depth, accounting for multiple restorations conducted by individual dentists. Independent variables included: 1) DPBRN regions: AL/MS, FL/GA, MN, PDA and SK; 2) tooth type: posterior and anterior; 3) tooth surfaces: mesial/distal, buccal/lingual and occlusal surfaces (tooth surfaces were represented by indicator variables and were not mutually exclusive); 3) number of tooth surfaces involved; 4) patient age by quartiles of the sample distribution; 5) dentist's graduation year classified as: before 1974, 1975-1983, 1984-1993 and 1994 or after and 6) methods of diagnosis: clinical assessment, radiographs, transillumination and optical techniques and combinations of these methods. A p-value of 0.05 or less was considered statistically significant.

RESULTS

A total of 229 DPBRN dentists recorded information on 8,351 restorations inserted due to primary caries lesions in 5,810 patients. However, 45 observations (0.5%) had to be excluded because of uncertain preoperative assessment of lesion depth and 211 (2%) observations were excluded due to missing preoperative and/or postoperative assessments of lesion depth. With respect to the 8,095 restorations with complete data on tooth type and tooth surfaces restored as well as on

Table 2: *Distribution of Total One-surface and Multi-surface Caries Lesions of Posterior and Anterior Teeth by Preoperative Depth Assessments*

Lesion Depth	Posterior One-surface			Posterior Multi-surface	Anterior One-surface			Anterior Multi-surface	Total
	O	M or D	B or L	M/O/ D/ B/ L	M or D	B or L	I	M/ D/ B/ L/ I	
E1 [N (%)]	123 (6%)	12 (1%)	45 (5%)	42 (2%)	5 (1%)	17 (5%)	2 (6%)	13 (2%)	259 (3%)
E2 [N (%)]	347 (16%)	66 (4%)	123 (13%)	140 (7%)	25 (6%)	66 (19%)	5 (16%)	47 (8%)	819 (10%)
D1 [N (%)]	1165 (54%)	825 (56%)	550 (58%)	1003 (48%)	261 (63%)	195 (56%)	17 (55%)	288 (47%)	4304 (53%)
D2 [N (%)]	461 (21%)	434 (29%)	202 (21%)	633 (30%)	98 (24%)	54 (16%)	4 (13%)	182 (30%)	2068 (26%)
D3 [N (%)]	78 (4%)	138 (9%)	28 (3%)	275 (13%)	24 (6%)	16 (5%)	3 (10%)	83 (14%)	645 (8%)
Total [N (%)]	2174 (100%)	1475 (100%)	948 (100%)	2093 (100%)	413 (100%)	348 (100%)	31 (100%)	613 (100%)	8095 (100%)

O: occlusal; M: mesial; D: distal; B: buccal/facial; L: lingual/palatal and I: incisal tooth surfaces. Percentages are within columns for each type of caries lesion.

Table 3: *Distribution of Caries Lesions Showing Concordance Between Pre- and Postoperative Depth Assessments*

Lesion Depth	Posterior One-surface			Posterior Multi-surface	Anterior One-surface			Anterior Multi-surface	Total
	O	M or D	B or L	M/O/ D/ B/ L	M or D	B or L	I	M/ D/ B/ L/ I	
E1 [N (%)]	53 (4%)	1 (0%)	27 (4%)	25 (2%)	3 (1%)	15 (6%)	1 (5%)	10 (2%)	135 (2%)
E2 [N (%)]	178 (13%)	35 (3%)	75 (11%)	67 (5%)	18 (6%)	41 (15%)	2 (11%)	29 (7%)	445 (8%)
D1 [N (%)]	731 (55%)	597 (55%)	424 (61%)	658 (45%)	208 (65%)	154 (58%)	11 (58%)	211 (47%)	2994 (53%)
D2 [N (%)]	291 (22%)	332 (30%)	142 (21%)	461 (32%)	68 (21%)	43 (16%)	3 (16%)	134 (30%)	1474 (26%)
D3 [N (%)]	70 (5%)	128 (12%)	23 (3%)	246 (17%)	23 (7%)	14 (5%)	2 (11%)	61 (14%)	567 (10%)
Total [N (%)]	1323 (100%)	1093 (100%)	691 (100%)	1457 (100%)	320 (100%)	267 (100%)	19 (100%)	445 (100%)	5615 (100%)

O: occlusal; M: mesial; D: distal; B: buccal/facial; L: lingual/palatal and I: incisal tooth surfaces. Percentages are within columns for each type of caries lesion.

Table 4: *Concordance, Underestimation and Overestimation of Depth Assessments of One-surface Caries Lesions*

	Posterior									Anterior								
	O (N=2174)			M or D (N=1475)			B or L (N=948)			M or D (N=413)			B or L (N=348)			I (N=31)		
Lesion Depth	Pre< Post	Pre= Post	Pre> Post	Pre< Post	Pre= Post	Pre> Post	Pre< Post	Pre= Post	Pre> Post	Pre< Post	Pre= Post	Pre> Post	Pre< Post	Pre= Post	Pre> Post	Pre< Post	Pre= Post	Pre> Post
E1 (%)	57	43	0	92	8	0	40	60	0	40	60	0	12	88	0	50	50	0
E2 (%)	48	51	1	44	53	3	34	61	5	16	72	12	30	62	8	60	40	0
D1 (%)	34	63	3	25	72	2	21	77	2	17	80	3	18	79	3	35	65	0
D2 (%)	31	63	6	16	77	7	18	70	11	17	69	13	15	80	6	0	75	25
D3 (%)	0	90	10	0	93	7	0	82	18	0	96	4	0	88	12	0	67	33
Mean (%)	34	62	4	35	61	4	23	70	7	18	75	6	15	79	6	29	59	12

Pre<Post: percentage of preoperative assessments that underestimated depth; Pre=Post: percentage in which the preoperative and postoperative assessments were the same; Pre>Post: percentage of preoperative assessments that overestimated depth. O: occlusal; M: mesial; D: distal; B: buccal/facial; L: lingual/palatal and I: incisal tooth surfaces. Percentages are within rows for each caries lesion depth.

pre- and postoperative depth estimates, 83% were placed on posterior teeth and 17% on anterior teeth.

Table 2 presents the distribution of one-surface and multi-surface (≥2 surfaces) caries lesions of posterior and anterior teeth according to their preoperative depth estimates. One-surface caries lesions of posterior teeth comprised 57% of total caries lesions restored in this study, with about half being occlusal caries. Multi-surface caries lesions of posterior teeth comprised 26% of total caries lesions restored in this study. The remaining 17% of lesions were in anterior teeth.

Dentists estimated the preoperative depth of caries lesions on the basis of the diagnostic methods they typically used, which consisted mainly of visual-tactile and radiographic examinations (Rindal & others, submitted 2009). Irrespective of tooth type and tooth surfaces restored, most restorations were placed to treat lesions that were pre-assessed as extending to a D1 depth (53% of total caries lesions), followed by D2 (26%), E2 (10%), D3 (8%) and E1 (3%) depths. Consistent with the preoperative estimates, caries lesions that extended to a D1 (43% of total caries lesions) and D2 (33%) final depth were generally the most commonly restored lesions in the current study.

Of the 8,095 caries lesions reported in this study, 5,615 (69%) showed agreement between pre- and postoperative estimates of lesion depths as shown in Table 3. In general, preoperative estimate of caries lesion

Table 5: *Concordance, Underestimation and Overestimation of Depth Assessments of Multi-surface Caries Lesions*

	Posterior			Anterior		
	M/O/D/B/L(N=2093)			M/D/B/L/I(N=613)		
	Pre<Post	Pre=Post	Pre>Post	Pre<Post	Pre=Post	Pre>Post
E1 (%)	40	60	0	23	77	0
E2 (%)	52	48	0	36	62	2
D1 (%)	34	66	0	25	73	2
D2 (%)	20	73	7	19	74	8
D3 (%)	0	89	11	0	73	26
Mean (%)	40	60	0	23	77	0

Pre<Post: percentage of preoperative assessments that underestimated depth; Pre=Post: percentage in which the preoperative and postoperative assessments were the same; Pre>Post: percentage of preoperative assessments that overestimated depth. O: occlusal; M: mesial; D: distal; B: buccal/ facial; L: lingual/palatal and I: incisal tooth surfaces. Percentages are within rows for each caries lesion depth.

depth was more concordant with its postoperative depth when the lesion was at an advanced stage: 88% concordance between preoperative and postoperative estimates at D3 depth (567 lesions [shown in Table 3] of 645 lesions [shown in Table 2]); compared to 71% at D2 (1,474 lesions of 2,068); 70% at D1 (2,994 lesions of 4,304); 54% at E2 (445 lesions of 819) and 52% at the E1 depths (135 lesions of 259). Concordance, underestimation and overestimation of lesion depth are detailed in Table 4 for the 5,389 one-surface lesions and in Table 5 for the 2,706 multi-surface lesions. Overall, concordance of pre- and post-assessments of lesion depth was greater for dentin than for enamel caries lesions. The preoperative estimates of E1 and E2 depths frequently underestimated their final depths.

Logistic regression analysis revealed that DPBRN region (p=0.0009), mesial/distal surface [p=0.015; OR (odds ratio) = 1.28] and occlusal surface (p=0.0008; OR = 0.76) significantly predicted agreement between preoperative and postoperative estimates of lesion depths. DPBRN regions (p=0.0009), mesial/distal surface (p=0.013; OR = 0.76), buccal/lingual surface (p=0.015; OR = 0.80) and occlusal surface (p=0.0001; OR = 1.42) were significant predictors of underestimation of lesion depth. Pairwise comparisons among DPBRN regions indicated that the MN region differed significantly from the others with a higher mean rate of agreement (p<0.0001) and lower mean rate of underestimation (p<0.0001) of lesion depth. The dentists' graduation year was the only variable that significantly predicted overestimation of lesion depth assessments by DPBRN dentists; that is, increasing years since graduation was associated with lower overestimation (p=0.005).

DISCUSSION

In the current study, DPBRN dentists were asked to determine clinically the depth of caries lesions before and after operative intervention. Caries lesions that were pre-assessed as extending to D1 and D2 depths were predominant but not exclusive among the diagnosed and restored lesions of the current study. Restoration of enamel lesions was also a relatively common event among the DPBRN dental practices. The capacity of dentists to correctly characterize dentin lesions was evident, regardless of lesion location; however, their depth estimation was less concordant for enamel lesions. Notably, the depth assessment of each caries lesion was performed by the same dentist, which may suggest that the postoperative assessment would be influenced by the preoperative assessment. However, the most relevant findings of this study are that dentists often underestimated the depth of caries lesions and that underestimation was largely found among enamel lesions. The high rate of underestimated enamel lesions suggests that the clinical decision to operatively intervene on enamel lesions is often made in the presence of inaccurate or uncertain estimation of caries lesion depth by DPBRN dentists; yet, the rate of concordance for enamel depth estimation indicates that some dentists did restore enamel lesions based on accurate assessments. It should also be noted that the depth estimates reported in the current study represented only lesions that required restorative treatment as judged clinically by DPBRN dentists. The depth estimates reported here are biased samples of all depth estimates made by dentists in their practices. Nothing is known about the depth of lesions in which restorative treatment was not recommended, likely because the evaluation of factors other than or in addition to depth did not support such a treatment decision.

The preoperative depth assessments of posterior one-surface D1 and D2 lesions were mostly accurate: being higher for lesions located on the mesial or distal and buccal or lingual surfaces, with depth being correctly estimated for about three-fourths of lesions and lower for occlusal lesions where depth was correctly estimated for about two-thirds of lesions. Overestimation of

lesion depth occurred at approximately the same rate for all one-surface types of posterior lesions, 2%-3% for D1 depth estimates and somewhat higher with 6%-11% for D2 depth estimates, although almost none of the lesions overestimated to be at D2 depth was found to be limited to enamel. Of note, dentists' professional experience was significantly associated with lower levels of overestimation of lesion depths. About one-third of the occlusal D1 depth estimates and one-fourth of the mesial or distal and buccal or lingual depth estimates were underestimated. Underestimation was also commonly observed for D2 lesions, where one-third of occlusal lesions were underestimated as were one-fifth of mesial or distal and buccal or lingual lesions. These patterns were similar for posterior multi-surface lesions, although the underestimation rates were slightly lower and overestimation rates were slightly higher. Of importance is that disagreement between depth assessments occurred for one-third of all lesions located near the DEJ, at the crucial E2 and D1 depths, with underestimation being approximately 10 times more frequent than overestimation. Because caries lesions extending into dentin are commonly used as the main criterion for operative intervention, it would seem that a substantial proportion of restorations were placed under inaccurate or uncertain estimations of E2 and D1 depths.

Underestimation of E1 and E2 depths was most frequent on one-surface lesions located on the occlusal and proximal surfaces of posterior teeth. The great majority (84%) of these lesions were examined by bitewing radiographs (Rindal & others, submitted 2009), which are well-known to underestimate the lesion depths.[30] The training material used for the current study emphasized that depth estimation should be determined by the depth of the dental tissue affected by caries and not dictated by the restorative material used for the restoration. While underestimation may have occurred due to dentists reporting preparation depth rather than lesion depth, the general underestimation of enamel lesion depth in DPBRN practices suggests that many clinically detectable "enamel lesions" may have already reached the dentin. The interpretation of this statement should be taken with caution, owing to the variations and limitations of diagnostic methods used in dental practice and the fact that caries activity or monitoring of caries activity were not reported in this study. The rate of lesion progression throughout the enamel is slow for most patients,[19-20,31] and that has significant implications for detecting early lesions, predicting caries risk and managing the disease.

Dental practice structures and dentists' characteristics clearly affect treatment decisions in the management of dental caries. In the current study, the rates of agreement between preoperative and postoperative estimates were not equal among the DPBRN regions, possibly because practice structures differed by DPBRN region. Dentists from the AL/MS and FL/GA regions were primarily in independent or small group practices, MN and PDA dentists were primarily in large group practices and SK dentists were in public or private health care settings. The MN region, which, for this study, was composed mainly of dentists associated with the HealthPartners Dental Group (HP), showed the highest rate of agreement and lowest rate of underestimation of lesion depth. HP and PDA are multi-specialty dental groups that employ evidence-based guidelines with a focus on management of the caries disease process through risk assessment, risk reduction and preservation of hard and soft tissue.[25] These guidelines include specific recommendations for caries diagnosis and remineralization of early caries.[32] This level of organization might have enabled MN dentists to most accurately assess lesion depth in this study and delay restorative interventions until lesions have clearly progressed into the dentin. An equivalent notion of caries management directed to preventive dentistry and updated knowledge in cariology has been adopted by dentists from the SK region, where restrictive criteria for placement of restorations exists and positive outcomes of caries and restoration prevention have prevailed.[33]

Accuracy of dentists' preoperative estimates of caries lesion depth is a major determinant in appropriate restorative treatment decisions. The extent of discrepancies on depth estimation of enamel lesions indicates that the decision to intervene operatively was often based on inaccurate assessments. Evidence-based guidelines for general practitioners regarding outcomes of preventive intervention for enamel, and mostly suspicious lesions, are rather limited.[15,32] This lack of clinical guidelines may explain to a certain degree the decision to restore enamel lesions.[11] Even so, it is critical that dentists recognize that restorations require replacement over time, usually accompanied by loss of tooth tissues; thus, optimal management of caries demands early detection and preventive therapy of enamel lesions in order to achieve long-term health of tooth tissues.[15-17]

CONCLUSIONS

Evidence from this investigation suggests that DPBRN dentists can identify and discriminate depths of caries lesions into the dentin but the accuracy of their enamel lesions assessments is rather weak. The current study should prompt research into more refined diagnostic tools that can detect the depth of caries lesions more accurately and provide a more precise discrimination between enamel and dentin caries lesions. The current study also supports the imperative need for the transfer of information from research to daily dental

practice through continuing education programs on the management of dental caries that pursue clinically oriented and scientifically supported evidence-based guidelines to general practitioners.

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