Published in final edited form as:

J Am Dent Assoc. 2012 April ; 143(4): 377–385.

Dentin caries activity in early occlusal lesions selected to receive operative treatment:

Findings from the Practitioners Engaged in Applied Research and Learning (PEARL) Network

Maryann Lehmann, DDS,

dentist in private practice in Darien, Conn., and a practitioner-investigator in the Practitioners Engaged in Applied Research and Learning (PEARL) Network

Analia Veitz-Keenan, DDS,

dentist in private practice in New York City; and clinical associate professor and the academic director, Oral & Maxillofacial Pathology, Radiology and Medicine, College of Dentistry, New York University, New York City; and a practitioner-investigator in the Practitioners Engaged in Applied Research and Learning (PEARL) Network

Abigail G. Matthews, PhD,

biostatistician, The EMMES Corporation, Rockville, Md

Donald Vena, BS,

statistician, The EMMES Corporation, Rockville, Md

Ashley Grill, RDH, MPH,

the administrative coordinator, Protocol Development and Training Core and Information Dissemination Core, Practitioners Engaged in Applied Research and Learning (PEARL) Network, New York College of Dentistry, New York University, New York City

Ronald G. Craig, DMD, PhD,

an associate professor, Basic Sciences and Craniofacial Biology, Department of Periodontology and Implant Dentistry, College of Dentistry, New York University, New York City; and the director of information dissemination, Practitioners Engaged in Applied Research and Learning (PEARL) Network, New York City

Frederick A. Curro, DMD, PhD, and

clinical professor, Oral & Maxillofacial Pathology, Radiology and Medicine, College of Dentistry, New York University, New York City; and the director of recruitment, retention and operations, Practitioners Engaged in Applied Research and Learning (PEARL) Network, New York City

Van P. Thompson, DDS, PhD

Copyright © 2012 American Dental Association. All rights reserved.

Address reprint requests to Dr. Thompson at College of Dentistry, New York University, 380 Second Ave. Suite 302, New York, N.Y. 10010, van.thompson@nyu.edu.

Disclosure. None of the authors reported any disclosures.

the director of protocol development and training, Practitioners Engaged in Applied Research and Learning (PEARL) Network; and a professor and the chairperson, Biomaterials, College of Dentistry, New York University, New York City

Abstract

Background—Members of the practice-based research network Practitioners Engaged in Applied Research and Learning (PEARL) Network investigated the dentin caries activity in early occlusal lesions and its relationship to patient age, preoperative tooth sensitivity and radio-graphic appearance, as well as its influence on preparation depth and volume.

Methods—PEARL Network practitioner-investigators (P-Is) (n = 45), general dentists who were trained but whose methods were not calibrated, conducted a study regarding postoperative hypersensitivity in resin-based composite restorations. The P-Is enrolled as study participants 613 patients with occlusal carious lesions that, in the P-Is' clinical judgment, required restoration. The P-Is used baseline radiographs to assess the depth and extent of the lesions. Data for 671 restorations included baseline sensitivity; ranking of dentin caries activity on the opening of the enamel; radiographic visibility (n = 652); and measurements of preparation depth, width and length.

Results—P-Is found rapidly progressing dentin caries in 38.5 percent (258 of 671) of lesions and slowly progressing (and potentially inactive dentin) caries in the remainder of the lesions. Rapidly progressing caries was not related to the participant's age or participant-reported preoperative hypersensitivity but was related to the lesion depth as seen radiographically ($P < .001$) and depth ($P < .001$) and volume ($P < .001$) of the preparation. Molars had slightly higher but not statistically significant levels of caries activity.

Conclusion—Rapidly progressing dentin caries, while present in only 38.5 percent of lesions, was related to the lesion's radiographic appearance but not to the participant's age or the study tooth's pre-operative sensitivity.

Clinical Implications—On the basis of the low level of rapidly progressing dentin caries in this study population and the fact that slowly progressing caries can be inactive or remineralizing, the authors advise sealing versus operative treatment of early or shallow occlusal lesions.

Keywords

Occlusal caries; dentin caries; hypersensitivity; radiographic appearance; resin-based composite restoration

The dentist faces a challenge when a patient has clinically diagnosed occlusal caries judged to extend into dentin but that may or may not be visible on radiographs. The dentist may consider several alternative treatments: observe the lesion across time, attempt to remineralize it, seal it to prevent caries progression, or remove the caries in enamel and dentin and place a restoration.^{1–3} A noninterventive approach is particularly problematic for molars, in which lesions must be advanced into dentin to be seen on radiographs.⁶ Supplemental diagnostic information may be provided by devices that attempt to monitor the bacterial byproducts in the dentin by use of laser fluorescence, light-emitting diode fluorescence, spectral difference and alternating current impedance spectroscopy. However,

neither visual inspection nor these alternative detection devices provide any valid indication as to whether dentin caries is active or inactive. If a patient has many restorations or has one or more additional carious lesions in the mouth, most dentists will assume that the caries is active and likely progressing, requiring restoration. Without such evidence, the dentist must decide whether to partner with the patient and attempt to remineralize the lesion, seal the tooth with caries present or restore the tooth.

When a dentist chooses to enter a tooth and remove the caries, he or she can classify the lesion in dentin as rapidly progressing or slowly progressing, according to the guidelines outlined by Fontana and colleagues.⁷ This categorization is an oversimplification, as noted by many of the same authors: the carious lesion in enamel

can, between 2 time points: (a) progress (exhibit net mineral loss), (b) arrest, i.e. remains unchanged (static/stable), or (c) regress (exhibit net mineral gain). At a further (third and/or subsequent) time point, the lesion can exhibit any of the above 3 changes, and hence can (d) undergo oscillations in status.⁸

Dentin caries is considered active and “rapidly progressing” when the dentin is soft and wet in appearance, with an anticipated high bacterial load,⁹ particularly of *Lactobacillus* species,¹⁰ whereas dentin with “slowly progressing” caries is described as leathery, or hard and discolored. However, the possibility that slowly progressing caries may alter at any given time and become inactive or arrested should be taken into consideration.¹¹

The majority of dentists believe, on the basis of Black’s principles,¹² that once the caries process is established in dentin it must be removed. These traditional dentists are under pressure to adopt minimally invasive techniques.¹³ This altered approach was proposed in the late 1960s with the advent of fluoride dentifrices but largely has gone ignored.³ However, dentists have almost no scientific information as to the time frame of the progress of occlusal carious lesions, and it has not been delineated clearly whether the caries process is continuous on a daily, weekly or monthly scale or episodic across long periods, particularly if the lesion is in dentin. Investigators in one Scandinavian study followed 14-year-olds for an average of 1.2 years and found that only 9 percent of occlusal dentin lesions visible radiographically progressed from outer dentin to inner dentin,¹⁴ which would be deemed rapidly progressing caries. The question remains: How often on the opening of a lesion is active, rapidly progressing dentin caries present?

The Practitioners Engaged in Applied Research and Learning (PEARL) Network is managed by the New York University College of Dentistry, New York City, in collaboration with a data coordinating center, The EMMES Corporation, Rockville, Md. PEARL is a practice-based research network supported by the National Institute of Dental and Craniofacial Research (NIDCR), Bethesda, Md. PEARL Network dentists are designated by NIDCR as practitioner-investigators (P-Is) on completion of training for conduct of clinical research in their offices. The PEARL Network recently completed a study regarding postoperative hypersensitivity in occlusal restorations, which included evaluation of dentin caries activity in Class I preparations. Interim results of this study have been published.^{4,5} In this article, we present an in-depth analysis of observations by participating dentists of dentin caries activity in the associated lesions. We set the study hypothesis arbitrarily and proposed that

60 percent or more of early occlusal lesions clinically judged to extend into dentin would have rapidly progressing caries.

METHODS

Study design

After undergoing training and technique calibration, PEARL Network P-Is and their staff members in 45 dental offices enrolled eligible study participants on an ongoing basis until 613 participants had been identified with Class I carious lesions that, in the P-Is' clinical judgment, extended into dentin and were amenable to restoration with resin-based composite (RBC). The study had been powered for a target enrollment of 610 participants, but, because of simultaneous enrollments, 613 participants were treated. The New York University School of Medicine Institutional Review Board approved the study protocol. The PIs recorded specific treatment data, including the following: participant demographics, including sex and age; participant-reported presence of hypersensitivity according to a zero-to-10-point anchored numeric pain assessment scale (NPAS) questionnaire regarding participants' dental sensitivity to cold, hot, sweet, clenching or chewing; type and location of the tooth with the lesion; radiographic visibility; ranking of dentin caries activity after enamel removal; appearance of the dentin after caries removal; and measured depth, width and length of the preparation, to the nearest 1 millimeter as determined with use of a marked periodontal probe. In addition, P-Is collected data according to lesion class and brand of cavity disinfectant and liner if used, bonding agent and manner of placement of the RBC. Before undergoing treatment, participants completed three questionnaires comprising the previously described NPAS regarding sensitivity; a separate questionnaire regarding analgesic use; and, finally, an Oral Health Impact Profile¹⁵ (OHIP-14), measuring quality of life, a tool validated by a number of researchers.^{16–18} Participants completed these same three surveys in person pre-operatively and either via mail or electronically at one week, four weeks and 13 weeks after treatment; they then transmitted these questionnaires to The EMMES Corporation, ensuring that they remained anonymous to the dentist and dental practice.

Inclusion criteria

Patients eligible to participate in the study were old enough to have a solely adult dentition but not older than 60 years; in addition, they had one or more permanent posterior teeth (in different quadrants, with third molars excluded) with clinical diagnoses of new occlusal caries assessed to extend into dentin with or without radiographic confirmation. We required that the lesion's radio-graphic depth be no more than 0.5 times the dentin depth—that is, one-half the distance or less from the dentoenamel junction to the pulp—and that the tooth be in occlusion with a natural tooth. Also, we required that the tooth be free of clinical evidence of either pulpitis or periodontal disease.

Exclusion criteria

We excluded from the study teeth that had existing restorations on the same tooth as the lesion, that had cracks, that were serving as removable partial denture abutments or that were undergoing active orthodontic treatment. We also excluded patients who had

undergone tooth bleaching within the previous three months or who were receiving desensitizing therapy. We excluded potential participants who were taking analgesic medications for pain. We also excluded those receiving treatment for medical disorders such as dementia, Parkinson disease, depression, severe anxiety or any other condition that, in the opinion of the P-I, would affect the patient's judgment of hypersensitivity or his or her ability to understand the informed consent process.

Bitewing radiography

Dentists received training in reading the initial radiograph by means of a PEARL Network Web-based training module that incorporated sample radiographs. P-Is also received for chairside use a laminated reference sheet on radiographic appearance that contained examples of lesion depth. Teeth that did not have radiographic evidence of caries were eligible for the study if the clinical appearance of the tooth led the P-I to deem the tooth in need of restoration.

Dentin caries activity

P-Is ranked the dentin caries activity in the study tooth by means of the following method, which was described in the study's manual of operations and presented in a chairside reference guide. If the enamel appeared intact, the P-I was to remove the enamel, attempting to limit the penetration into dentin. The P-I then was to stop the preparation process, irrigate the prepared cavity with water and dry it lightly with compressed air, and rank the dentin caries activity. If there was frank cavitation, the P-I was to remove the outer dentin layer to a depth of at least 1 mm, then irrigate and dry the tooth lightly. The P-I then was to score the dentin caries on a scale of 1 to 5 via a ranking (Box) that we constructed from dentin caries descriptions used by Kidd and colleagues¹⁹ and Zheng and colleagues²⁰ that consider tactile evaluation and appearance.

Preparation measurements

After preparing cavities, the P-Is measured lesion depth, width and length according to a standardized methodology used in another study.²¹ The P-I used a periodontal probe with 1-mm markings to determine the cavity depth from the enamel cavosurface margin to the deepest point in the preparation (at the enamel location providing the most axial orientation of the probe) to the nearest millimeter. The P-I also recorded the greatest and narrowest dimensions (designated as length and width) of the preparation at the enamel cavosurface margin.

The seven-member PEARL Network Practitioner Advisory Group (PAG) (which includes M.L. and A.K.-V.) conducted an evaluation of this measurement method involving the use of two natural mandibular and two natural maxillary second molars, with Class I cavity preparations of known dimensions (measured with a micrometer), mounted in a dental model in a phantom head. The PAG made periodontal probe measurements to the nearest 0.5 mm on these teeth in a dental operatory setting according to the prepared description and sample pictures. They determined variability in measurement techniques and, on the basis of this trial, rounded the measurements to be taken on the prepared cavity to the nearest millimeter.

Patient-reported hypersensitivity

Patients reported via questionnaire any hypersensitivity of the tooth to be prepared with regard to the following five stimuli: cold, heat, sweet, clenching and chewing. We considered a score of 3 or higher on any of the zero-to-10-point stimulus scales (here the NPAS) to represent “appreciable hypersensitivity.” Values for pain of 3 or higher on a zero-to-10-point scale were considered bothersome to patients and of clinical significance.²² We examined appreciable hypersensitivity for each stimulus for a relationship to the dentin caries activity.

Statistical analysis

We used descriptive statistics (for example, PROC FREQ and PROC UNIVARIATE in SAS 9.2, SAS Institute, Cary, N.C.) to evaluate the distribution of study variables. We used χ^2 tests to study the relationships between age intervals, radiographic lesion visibility, tooth type, appreciable hypersensitivity and caries activity. To study the relationships between caries activity and cavity depth and volume, we used logistic regression. Because these analyses reflect tooth-specific characteristics, we ignored the correlation between teeth within the same patient.

RESULTS

Although 613 participants were enrolled in this study, we determined subsequently that 609 participants each satisfied the inclusion criteria for at least one tooth. Thus, in these analyses, we consider only those 609 participants, of whom 543 contributed one study tooth each and 66 contributed two study teeth each, for a total of 675 eligible teeth. The majority of study teeth were molars (88 percent; 596 of 675), with the remainder being premolars (12 percent; 79 of 675), and all teeth were distributed fairly equally in the four posterior quadrants. Of the 596 molars, 63 percent (375 of 596) were second molars and 37 percent (221 of 596) were first molars. The female to male ratio was 1.46, and participants were distributed across age groups as shown in Table 1. Most patients were in the age groups of 16 through 20 years (22 percent) and 21 through 25 years (20 percent). The average number of teeth enrolled per practice was 15, with a range of one to 53. Of the 45 participating practices, 24 percent (11 of 45) enrolled more than 25 study teeth.

Because of missing data regarding dentin caries activity on four teeth, there were 671 evaluable teeth. Table 2 shows the distribution of dentin caries activity ranking, with scores ranging from 1 to 5. We considered caries to be rapidly progressing with scores of 1 or 2, according to our ranking approach—the dentin caries classification system modified from that of Kidd and colleagues¹⁹ and Zheng and colleagues²⁰—and slowly progressing if the score was 3 or more. Given this delineation, the P-Is scored dentin caries as rapidly progressing in 38.5 percent (258 of 671) of lesions (Table 2). There was no significant difference ($P = .117$) in dentin caries activity between premolars (30 percent [24 of 79] rapidly progressing) and molars (40 percent [234 of 592] rapidly progressing) or between first and second molars ($P = .248$).

An analysis of the relationship between rapidly progressing dentin caries and age group (Figure 1) revealed no association ($P = .47$) when we excluded participants 51 years and older. Figure 2 shows the distribution of caries activity rankings across the patient age intervals in a box-and-whisker plot. These results indicate that caries activity was distributed equivalently across age groups.

In each of 66 patients, two teeth in different quadrants were restored, and we found the dentin caries activity ranking for the 128 teeth with observed rankings to be consistent in most instances (88 percent; 56 of 64). The P-Is classified the majority of these matched rankings as slowly progressing caries (71 percent; 40 of 56), and within study participants whose rankings matched, this difference in caries activity was statistically significant ($P = .001$).

Radiographic assessment of the lesions indicated that almost one-half (44.8 percent; 292 of 652) were not visible (Table 3). Lesions were visible in 41.6 percent (271 of 652) of study teeth and equivocal in the remaining 13.7 percent (89 of 652). Because of incomplete radiographic data, the effective sample size for this analysis was 652. Results of χ^2 analysis indicated that rapidly progressing dentin caries was associated with lesion visibility on radiographs ($P < .001$).

Table 4 (page 383) indicates that lesion depth was related statistically significantly to dentin caries ranked as rapidly progressing ($P < .001$) and that the odds of rapidly progressing caries activity increased by 37 percent for each 1-mm increase in depth. Lesion volume recorded after preparation (shallow but extensive mesiodistal or buccolingual preparations are included) also was related statistically significantly to rapidly progressing caries ($P < .001$), although the effect per cubic millimeter increase in volume was small. We anticipated the relationship between preparation volume and rapidly progressing caries on the basis of the association between preoperative radiographic appearance and dentin caries activity.

We did not find baseline appreciable tooth hypersensitivity to any of the five stimuli, as reported by participants, to be related to dentin caries activity ($P = .21$). There was no evidence of an association between caries activity and any type of stimulus individually (all $P > .22$).

DISCUSSION

In this study of restoration of primary carious lesions in posterior teeth and postoperative hypersensitivity, we chose to use a modification of a scheme for dentin caries activity ranking used on the opening of the enamel.^{19,20} We depended on the clinical judgment of the PEARL Network dentists, and we were aware of the possible variability in diagnosis.²³ We chose to add an additional category—ranking 3, “soft, dry and granular” as determined by means of visual and tactile evaluation to describe a type of carious dentin that clinicians in the PEARL Network had observed. The inclusion of this ranking was affirmed by a group of cariologists and dental faculty members (E.A.M. Kidd, N.B. Pitts, A. Papas, J.D. Bader, D. Shugars, oral communication, March 25, 2011). We expected that this added ranking would be scored in a relatively low percentage of instances (estimated below 5 percent). The

fact that it was scored in 18.6 percent of instances came as a surprise and is being investigated further in a PEARL Network randomized controlled study of postoperative hypersensitivity in Class I RBC restorations.

In reviewing the literature, we can find no description of this combination of “soft, dry and granular” for carious dentin. In our opinion and that of others (E.A.M. Kidd, N.B. Pitts, A. Papas, J.D. Bader, D. Shugars, oral communication, March 25, 2011), this ranking represents lesions that were progressing rapidly and then became slowly progressing and potentially inactive or arrested. Generally, arrested dentin caries—as opposed to active dentin caries—is defined as pigmented (that is, dark), lacking viable bacteria in tubules, having greater hardness and being less permeable to isotopes and dyes.^{24–26} The arrested caries described and investigated in these three studies were from frankly cavitated lesions, whereas the lesions in our study may have been different in physical characteristics, as most had no visible evidence of exposed dentin. Arrested caries is described most often in Class V lesions,^{27,28} where it also has been designated as “stagnating” (as compared with progressing) dentin caries.²⁹ Researchers have investigated the pH of dentin in occlusal lesions and found it to be less acidic in lesions designated as arrested.³⁰ Although there has been active investigation of the caries zones in dentin involving the latest physical and mechanical characterization techniques,^{31–33} there is little information related to caries with respect to inactive and active stages as might be occurring in what now is designated as “slowly progressing caries.”

In our study, the majority of radiographically visible lesions (considered advanced on molars) were ranked as slowly progressing or “chronic”³⁴ but may have represented “inactive” caries.¹¹ Some lesions ranked as leathery in our study were readily visible on radiographs, suggesting some degree of remineralization. However, we cannot rule out the possibility of very slowly or intermittently progressing decalcification. The uncertainty of these findings emphasizes the lack of literature related to the progress or periodicity of occlusal caries in dentin, making it difficult to guide clinicians.

The finding that rapidly progressing caries rankings were distributed approximately equally across and within the age groups in our study (Figures 1 and 2) was unexpected and suggests an ongoing carious process. We believe most dentists would anticipate that rapidly progressing caries is found most often in teen age (here 32.6 percent [84 of 258] of lesions were from patients 20 years or younger, and 52.7 percent [136 of 258] from those 25 years or younger) and less so in middle age, which is contrary to our findings. Note that in all of the study participants except those aged 41 through 45 years, rapidly progressing carious lesions were less frequent than were slowly progressing carious lesions. Thus, dentists may have bias toward providing operative intervention in older patients rather than in those with more obvious dentin involvement, believing that caries is less likely rapidly progressing in this population. In our study, we did not investigate this possible bias. We have noted one investigation of postoperative hypersensitivity in occlusal RBC restorations that were either lined with glass ionomer or unlined, the findings of which were published while our study was in progress, in which the researchers classified caries as either slowly progressing or rapidly progressing.³⁵ In these patients, whose age averaged a mean (standard deviation) 22.8 (3.8) years, 11 percent (11 of 104) of the teeth treated (all molars) had caries ranked as

rapidly progressing, suggesting that our findings regarding rapidly progressing caries, although much greater, are plausible. In our study, we found rapidly progressing caries less often in premolars than in molars, but the difference was not statistically significant.

What is equivocal in our findings is whether the ranking of caries as “soft, dry and granular” can be considered to be slowly progressing caries, although experts agree with our designation (E.A.M. Kidd, N.B. Pitts, A. Papas, J.D. Bader, D. Shugars, oral communication, March 25, 2011). If we take this 18.6 percent (125 of 671) of lesions and consider them rapidly progressing, the percentage of active lesions becomes 57.1 percent—and even this number suggests a conservative approach to restoration. What is clear, however, is that if a lesion is visible radiographically, on the basis of our findings (Table 3), the likelihood of its being a rapidly progressing lesion increases (though still only 48 percent were ranked as such).

We should note that in our study, we found identical dentin caries activity rankings in 88 percent (56 of 64) of the instances in which two teeth were restored in the same patient. Both of these teeth were treated at the same appointment, so in this “slice of time” study, if caries was ranked as slowly progressing on the restoration of one of these teeth, it is likely that occlusal caries in the other tooth also would have been ranked similarly. Treatment of the second tooth could be approached by using more conservative methods.

We did not expect the lack of any relationship between caries activity and patient-reported appreciable hypersensitivity. Our anticipation was that rapidly progressing caries in teeth would make them more sensitive to cold and perhaps sweet. These were shallow lesions, many not visible radiographically, and this lack of depth in the dentin (0.5 times the dentin depth radiographically) may limit sensitivity.

In diagnosing occlusal caries, clinicians are at a disadvantage, because they have no reliable method to determine if caries is progressing rapidly or slowly or even is arrested. Enamel appearance can provide clues, but a validated methodology remains to be implemented.³⁶ Currently available diagnostic aids measure only demineralization or the presence of bacterial byproducts, neither of which can indicate enamel or dentin caries activity unless changes in readings are noted across time. Findings of a study by Iwami and colleagues³⁷ provided some indication that, with the use of a color measurement system and caries-detecting dyes (which indicate degree of demineralization), differences in the color values between active and arrested were apparent. Iwami and colleagues’ use of laser fluorescence to measure bacterial presence in active dentin lesions as opposed to arrested dentin lesions looks promising.³⁸ However, they conducted laser fluorescence tests in open, arrested dentin lesions, thus limiting the usefulness of this technology for detection of dentin caries activity in early lesions.

Clinicians may have noted some patients in their 40s, 50s and 60s who have radiographic evidence of proximal caries extending into dentin that can be identified on radiographs obtained many years earlier. These are instances of slowly progressing or inactive carious lesions that may never change or might become active if the patient’s salivary flow or

lifestyle changes. Monitoring remains the best approach in these instances, and this may be true for early occlusal lesions as well.

One limitation in our study is the patient base. The majority of the PEARL Network P-Is who enrolled patients in this study have well-established suburban practices, and their patients generally are perceived as having low or moderate risk of developing caries. Whether the findings from this study related to caries activity, patient age and radiographic lesion visibility will hold in a community clinic setting remains to be determined.

CONCLUSION

Our results and the literature cited suggest that dentists should take a cautious approach to restoration of early carious lesions in patients with low or moderate risk of developing caries. For those at moderate risk, lowering that risk should be a priority. Irrespective of the type of caries a patient has, the clinician should consider remineralization or sealing of the lesion. It now is well established in clinical studies that the sealing of occlusal caries leads to its becoming inactive, with evidence of remineralization of the lesion (in systematic reviews^{39,40} and a 2010 long-term clinical report⁴¹). The findings in these articles and our results suggest that sealant placement is a viable alternative for noncavitated lesions even when lesions are visible on radiographs.

Our hypothesis that more than 60 percent of noncavitated lesions would have rapidly progressing dentin caries was rejected, as only 38.5 percent were in this category, with the remainder having slowly progressing dentin caries. ■

Acknowledgments

The study described in this article was supported by the National Institute of Dental and Craniofacial Research grant U01-DE016755.

Some of the findings described in this article were presented at the Practitioners Engaged in Applied Research and Learning (PEARL) Network Annual Meeting, March 25, 2011, Palisades, N.Y.

ABBREVIATION KEY

NIDCR	National Institute of Dental and Craniofacial Research
NPAS	Numeric pain assessment scale
OHIP-14	Oral Health Impact Profile
PAG	Practitioner Advisory Group
PEARL	Practitioners Engaged in Applied Research and Learning
P-I	Practitioner-investigator
RBC	Resin-based composite

References

1. Massler M. Changing concepts in the treatment of carious lesions. *Br Dent J.* 1967; 123(11):547–548. [PubMed: 5234627]

2. Mount GJ, Ngo H. Minimal intervention: a new concept for operative dentistry. *Quintessence Int.* 2000; 31(8):527–533. [PubMed: 11203973]
3. Mount GJ, Ngo H. Minimal intervention: early lesions. *Quintessence Int.* 2000; 31(8):535–546. [PubMed: 11203974]
4. Berkowitz GS, Horowitz AJ, Curro FA, et al. Postoperative hypersensitivity in class I resin-based composite restorations in general practice: interim results. *Compend Contin Educ Dent.* 2009; 30(6):356–358. 360, 362–363. [PubMed: 19715013]
5. Curro FA, Craig RG, Vena D, Thompson VP. The role of interim analysis as a quality assurance function in practice-based research network clinical studies. *Compend Contin Educ Dent.* 2009; 30(6):352–354. [PubMed: 19715012]
6. Kidd EA, Ricketts DN, Pitts NB. Occlusal caries diagnosis: a changing challenge for clinicians and epidemiologists. *J Dent.* 1993; 21(6):323–331. [PubMed: 8258581]
7. Fontana M, Young DA, Wolff MS, Pitts NB, Longbottom C. Defining dental caries for 2010 and beyond. *Dent Clin North Am.* 2010; 54(3):423–440. [PubMed: 20630187]
8. Longbottom CL, Huysmans MC, Pitts NB, Fontana M. Glossary of key terms (published online ahead of print June 3, 2009). *Monogr Oral Sci.* 2009; 21:209–216. [PubMed: 19494688]
9. Massler M. Pulpal reactions to dental caries. *Int Dent J.* 1967; 17(2):441–460. [PubMed: 5233875]
10. Ricketts DN, Kidd EA, Beighton D. Operative and microbiological validation of visual, radiographic and electronic diagnosis of occlusal caries in non-cavitated teeth judged to be in need of operative care. *Br Dent J.* 1995; 179(6):214–220. [PubMed: 8541152]
11. Kidd, EAM. Clinical and histological features of carious lesions. In: Kidd, EAM., editor. *Essentials of Dental Caries*. 3rd ed. New York City: Oxford University Press; 2005. p. 21–40.
12. Mount GJ. A new paradigm for operative dentistry. *Aust Dent J.* 2007; 52(4):264–270. [PubMed: 18265680]
13. Tyas MJ, Anusavice KJ, Frencken JE, Mount GJ. Minimal intervention dentistry: a review. FDI Commission Project 1–97. *Int Dent J.* 2000; 50(1):1–12. [PubMed: 10945174]
14. Ridell K, Olsson H, Mejre I. Unrestored dentin caries and deep dentin restorations in Swedish adolescents (published online ahead of print April 29, 2008). *Caries Res.* 2008; 42(3):164–170. [PubMed: 18446024]
15. Slade GD, Spencer AJ. Development and evaluation of the Oral Health Impact Profile. *Community Dent Health.* 1994; 11(1):3–11. [PubMed: 8193981]
16. Bernab E, Marcenes W. Periodontal disease and quality of life in British adults (published online ahead of print Sept. 28, 2010). *J Clin Periodontol.* 2010; 37(11):968–972. [PubMed: 20880054]
17. McGrath C, Hegarty AM, Hodgson TA, Porter SR. Patient-centred outcome measures for oral mucosal disease are sensitive to treatment. *Int J Oral Maxillofac Surg.* 2003; 32(3):334–336. [PubMed: 12767883]
18. Soe KK, Gelbier S, Robinson PG. Reliability and validity of two oral health related quality of life measures in Myanmar adolescents. *Community Dent Health.* 2004; 21(4):306–311. [PubMed: 15617416]
19. Kidd EA, Joyston-Bechal S, Beighton D. Microbiological validation of assessments of caries activity during cavity preparation. *Caries Res.* 1993; 27(5):402–408. [PubMed: 8242678]
20. Zheng L, Hilton JF, Habelitz S, Marshall SJ, Marshall GW. Dentin caries activity status related to hardness and elasticity. *Eur J Oral Sci.* 2003; 111(3):243–252. [PubMed: 12786956]
21. Yip KH, Poon BK, Chu FC, Poon EC, Kong FY, Smales RJ. Clinical evaluation of packable and conventional hybrid resin-based composites for posterior restorations in permanent teeth: results at 12 months. *JADA.* 2003; 134(12):1581–1589. [PubMed: 14719754]
22. Curro, FA.; Friedman, M.; Leight, RS. Design and conduct of clinical trails on dentine hypersensitivity. In: Addy, M.; Embrey, G.; Edgar, WM.; Orchardson, R., editors. *Tooth Wear and Sensitivity: Clinical Advances in Restorative Dentistry*. London: Martin Dunitz; 2000. p. 299–314.
23. Swenson E, Hennessy B. Detection of occlusal carious lesions: an in vitro comparison of clinicians' diagnostic abilities at varying levels of experience. *Gen Dent.* 2009; 57(1):60–66. [PubMed: 19146144]

24. Barber D, Massler M. Permeability of active and arrested carious lesions to dyes and radioactive isotopes. *J Dent Child*. 1964; 31:26–33.
25. Miller WA, Massler M. Permeability and staining of active and arrested lesions in dentine. *Br Dent J*. 1962; 112:187–197.
26. Young MA, Massler M. Some physical and chemical characteristics of carious dentine. *Br Dent J*. 1964; 115:406–412.
27. Schüpbach P, Lutz F, Guggenheim B. Human root caries: histopathology of arrested lesions. *Caries Res*. 1992; 26(3):153–164. [PubMed: 1628289]
28. Schüpbach P, Osterwalder V, Guggenheim B. Human root caries: microbiota in plaque covering sound, carious and arrested carious root surfaces. *Caries Res*. 1995; 29(5):382–395. [PubMed: 8521441]
29. Arnold WH, Bietau V, Renner PO, Gaengler P. Micromorphological and micronanalytical characterization of stagnating and progressing root caries lesions (published online ahead of print Dec. 19, 2006). *Arch Oral Biol*. 2007; 52(6):591–597. [PubMed: 17181998]
30. Murakami K, Kitasako Y, Burrow MF, Tagami J. In vitro pH analysis of active and arrested dentinal caries in extracted human teeth using a micro pH sensor. *Dent Mater J*. 2006; 25(3):423–429. [PubMed: 17076310]
31. Angker L, Nijhof N, Swain MV, Kilpatrick NM. Influence of hydration and mechanical characterization of carious primary dentine using an ultra-micro indentation system (UMIS). *Eur J Oral Sci*. 2004; 112(3):231–236. [PubMed: 15154920]
32. Pugach MK, Strother J, Darling CL, et al. Dentin caries zones: mineral, structure, and properties. *J Dent Res*. 2009; 88(1):71–76. [PubMed: 19131321]
33. Zavgorodniy AV, Rohanizadeh R, Swain MV. Ultrastructure of dentine carious lesions (published online ahead of print Oct. 29, 2007). *Arch Oral Biol*. 2008; 53(2):124–132. [PubMed: 17915189]
34. Roberson, TM. Cariology: the lesion, etiology, prevention and control. In: Roberson, TM.; Heymann, HO.; Swift, EJ.; Sturdevant, CM., editors. *Sturdevant's Art and Science of Operative Dentistry*. 5th ed.. St. Louis: Mosby; 2006. p. 62-129.
35. Burrow MF, Banomyong D, Harnirattisai C, Messer HH. Effect of glass-ionomer cement lining on postoperative sensitivity in occlusal cavities restored with resin composite: a randomized clinical trial. *Oper Dent*. 2009; 34(6):648–655. [PubMed: 19953773]
36. Ekstrand KR, Martignon S, Ricketts DJ, Qvist V. Detection and activity assessment of primary coronal caries lesions: a methodologic study. *Oper Dent*. 2007; 32(3):225–235. [PubMed: 17555173]
37. Iwami Y, Hayashi N, Takeshige F, Ebisu S. Relationship between the color of carious dentin with varying lesion activity, and bacterial detection (published online ahead of print Jan. 8, 2008). *J Dent*. 2008; 36(2):143–151. [PubMed: 18191886]
38. Iwami Y, Yamamoto H, Hayashi M, Ebisu S. Relationship between laser fluorescence and bacterial invasion in arrested dentinal carious lesions (published online ahead of print June 20, 2010). *Lasers Med Sci*. 2011; 26(4):439–444. [PubMed: 20535516]
39. Ricketts DN, Kidd EAM, Innes N, Clarkson J. Complete or ultraconservative removal of decayed tissue in unfilled teeth. *Cochrane Database Syst Rev*. 2006; 3 CD003808.
40. Thompson V, Craig RG, Curro FA, Green WS, Ship JA. Treatment of deep carious lesions by complete excavation or partial removal: a critical review. *JADA*. 2008; 139(6):705–712. [PubMed: 18519994]
41. Alves LS, Fontanella V, Damo AC, Ferreira de Oliveira E, Maltz M. Qualitative and quantitative radiographic assessment of sealed carious dentin: a 10-year prospective study. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2010; 109(1):135–141. [PubMed: 20123388]

Box

Visual and tactile dentin caries activity ranking as
evaluated by means of explorer or spoon excavator.*

1 = Soft and serous

2 = Soft and dry

3 = Soft, dry and granular[†]

4 = Leathery

5 = Firm but discolored

* Sources: Kidd and colleagues¹⁹ and Zheng and colleagues.²⁰

[†] New description added for this study.

Figure 1.

Percentages and 95 percent confidence intervals (CIs) (error bars) of lesions ranked as rapidly progressing in relation to the participant's age at enrollment. For participants 51 years and older, the results showed an insufficient number of lesions ranked as rapidly progressing ($n = 4$) for computation of a 95 percent CI.

Figure 2.

Box-and-whisker plot of the distribution of participants' ages at enrollment, according to dentin caries activity ranking. The upper end of the box is the 75th percentile, the bottom of the box is the 25th percentile and the difference between the two is the interquartile range (IQR). The line in the middle of each box represents the median. The bottom of the lower whisker represents the 25th percentile $- 1.5 \times \text{IQR}$, and the upper whisker extends to the 75th percentile $+ 1.5 \times \text{IQR}$. The open circles denote outliers. The diamonds represent mean values.

TABLE 1

Distribution of participants' ages at enrollment (N = 609).

AGE (YEARS)	NO. OF PARTICIPANTS	PERCENTAGE
10 to 15	72	12
16 to 20	132	22
21 to 25	121	20
26 to 30	86	14
31 to 35	66	11
36 to 40	53	9
41 to 45	35	6
46 to 50	26	4
51 or Older	18	3

TABLE 2

Distribution of dentin caries activity rankings (N = 671).

DENTIN CARIES ACTIVITY	RANKING	NO. OF LESIONS	PERCENTAGE [†]
Soft and Serous	1	92	13.7
Soft and Dry	2	166	24.7
Soft, Dry and Granular	3	125	18.6
Leathery	4	124	18.5
Firm but Discolored	5	164	24.4
Progression Rapid Slow	1–2	258	38.5
	3–5	413	61.5

* Sources: Kidd and colleagues¹⁹ and Zheng and colleagues.²⁰

[†] Ranking percentages neither add to 100 percent nor always sum to activity percentages solely because of rounding.

TABLE 3

Dentin caries activity and radiographic assessment of lesion visibility (n = 652^{*}).

RADIOGRAPHIC LESION VISIBILITY	NO. OF TEETH (%[†])	RAPIDLY PROGRESSING CARIES, NO. OF TEETH (%)	SLOWLY PROGRESSING CARIES, NO. OF TEETH (%)
Lesion Visible and Less Than or Equal to 0.5 Times the Dentin Depth	271 (41.6)	129 (47.6)	142 (52.4)
Radiograph Equivocal	89 (13.7)	26 (29.2)	63 (70.8)
Lesion Not Visible on Radiograph	292 (44.8)	101 (34.6)	191 (65.4)

^{*} Because of incomplete radiographic data, the effective sample size for this analysis was 652 lesions.

[†] Percentages do not sum to 100 percent solely because of rounding.

TABLE 4

Preparation depth and cavity volume.

CARIES ACTIVITY RANKING ACCORDING TO PREPARATION CHARACTERISTIC	MEAN (SD[*])	MEDIAN (MINIMUM- MAXIMUM)	ODDS RATIO (95% CI[†])	P VALUE
Preparation Depth (Millimeters)			1.37 (1.20–1.56)	< .001
Rapid caries progression	4 (1.3)	4 (1–8)		
Slow caries progression	3 (1.2)	3 (1–7)		
Preparation Volume (Cubic Millimeters)			1.01 (1.01–1.02)	< .001
Rapid caries progression	55 (47.8)	41 (4–312)		
Slow caries progression	38 (34.6)	26 (2–286)		

* SD: Standard deviation.

† CI: Confidence interval.