Clinical Decision-Making for Caries Management in Root Surfaces

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Abstract: This report presents the results of an evidence-based approach to obtaining the best available information on the natural history, prevalence, incidence, diagnosis, and treatment of root caries. Searches of electronic databases produced 807 references; from these and from citations in the selected articles, a final 161 references were used. We found that the information on the natural history of the disease does not provide practitioners with probabilities of, or time estimates for, progression of the disease through stages. For patients aged thirty and older, the prevalence of root caries is roughly 20 to 22 percent less than a person’s age. Severity reaches over one lesion by age fifty, two lesions by age seventy, and just over three lesions for those seventy-five and older. About 8 percent (odds of 1:11) of the population would be expected to acquire one or more new root caries lesions in one year. The accuracy of current systems of diagnosis is unknown, although color has been shown to have little validity. Using the criteria of “softness” to define active lesions has been validated by the presence of microbes in the lesion. One strong study and other studies with weaker design or shorter duration add consistent support for the use of fluorides in the remineralization of root caries. Every three-month application of chlorhexidine varnish was shown to be efficacious in one arm of one study. Evidence for restoration of root caries is tentative since the studies were of limited design and duration.

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Key words: root caries, diagnosis, therapy, natural history, incidence, prevalence

This paper is an abridged version of a full report that was prepared for the NIDCR Consensus Development Conference, Diagnosis and Management of Dental Caries Throughout Life.1 The purpose of both papers is to present the evidence for diagnosing and intervening in the disease known as root caries, so that clinicians can communicate to their patients the best information for their joint decisions on care.

The report is based on a model of disease management, slightly expanded from that presented at the conference.2 Both models hold that clinicians first need to understand the natural history, risks, and predictors of the disease. For decisions on patient care, they then need to diagnose or, more specifically, estimate the probability that their client does or does not have the condition of interest. For results that indicate the probability of disease is above the treatment threshold, clinicians need to communicate information on the efficacy and the relative efficiencies of the potential interventions and then, based on patient preferences, jointly select the care that is appropriate.

Other reviewers were assigned the responsibility of reviewing aspects of diagnosis,3 risk assessment,4 and prevention.5,6 Thus, this review addressed the following questions:

1. Among North American populations, what is the natural history of root caries?
   For root caries, understanding the natural history would require clear case definitions of lesions at different stages of activity of lesions (active, inactive); rates of progression from stage to stage; reversibility, under natural conditions, of lesions by stages; and outcomes of untreated root caries.

2. How accurate and reliable are the methods we have to diagnose active and inactive root caries?

3. For persons with root caries, are there differences in outcomes between subjects randomly assigned to receive therapeutic care and those not receiving such interventions (by stage of lesion)?

Methods

The electronic search strategy is available in Appendix I. The searches resulted in 292 references from Embase and 535 from Medline that were imported into EndNote4.7 Twelve duplicates and eight that were incomplete were deleted, resulting in an initial database of 807 references. The annotated references were printed then read independently by at least two people to achieve consensus on ninety-four that were selected for retrieval and copying. In reading the copied articles, the reference lists were checked, and citations that appeared to relate to our questions were added back into the EndNote4 database and also retrieved and copied. The final database consists of 161 references.

The copied articles were then scanned and identifying keywords (natural history, prevalence/incidence,
diagnosis, treatment) were manually edited into the “keywords” section of the EndNote4 database. In this way, articles that could be used to address more than one question (for example, both incidence and natural history) were marked for later retrieval to address each question.

Using the “keyword in any field” searching capacity of the EndNote4 program, articles relevant to each question were identified, selected, and read more completely. Generally articles were included if they addressed the question and arrayed the data so that it could be abstracted. Articles were excluded if upon closer reading they did not address the question or we could not abstract the data. For example, fifty-seven studies were tagged with the label “diagnosis” in our database, but fifty-two were eliminated on critical appraisal. Detail on the numbers and reasons for the exclusion of studies is contained in Table 6 of the full report.1 Specific inclusion and exclusion criteria and the numbers of studies retrieved and included are identified at the start of each of the relevant sections.

Ideally the evidence should have been selected from several studies with strong design and high scores when critically appraised. However, other than for studies on prevalence and incidence, many studies were both weak in design and, upon careful appraisal, limited in execution. Recommendations derived from articles on therapy were classified, according to the system used by the Agency for Healthcare Research and Quality8 (AHRQ): from good (A) or fair (B) evidence to support; to insufficient evidence to support (C); to fair (D) to good (E) evidence to not support a particular maneuver.

Findings

We examined more than forty articles labeled with “natural history” in our database. Only one article6 was found that explicitly claimed to address the natural history of root surface caries, but the investigators did not observe the same teeth in the same individuals over time. Others10 observed the same teeth in the same subjects in a longitudinal study; they found it difficult to separate true changes from scoring inconsistencies. Billings11 has provided a staging classification, termed a severity index, of the disease. The stages range from Incipient; Shallow, Cavitation, to Pulpal. Overall, the state of the science does not now allow practitioners to provide probabilities of, or time estimates for, progression of the disease through stages.

Active and inactive lesions have been described by several investigators.12-15 The prime distinguishing feature is claimed to be that active root caries feels softened or leathery on probing with moderate pressure and is frequently covered by visible plaque. Inactive caries is stated to have dark brownish or black discoloration and a typically smooth and shiny surface, which is hard on probing with moderate pressure. Using “softness” criteria to define active lesions has been validated by the presence of microbes that are assumed to be actively advancing the lesion.16 The extent of true remission and relapses, or the changing between active and inactive lesions, can not be described clearly, but overall the impression is that the net advance of lesions is slow.

As the authors of a text in clinical epidemiology17 state, diagnosis is imperfect, resulting in the odds, or a probability, of being right. Those odds are the product of the likelihood ratio of the diagnostic test and the prior probability of the disease being present. Thus, an evidence-based model of decision-making requires estimating the prior probabilities of disease—both for new patients, which we might base on the background population prevalence, and for recall patients, which we could base on the background incidence of the disease.

Figure 1 shows the prevalence of root caries by age group in the United States according to the NHANES III study.19 The prevalence among persons is shown on the left scale (taller bars) and the severity, mean root decayed or filled surfaces (RDFS) per person, is shown on the right scale in the shorter bars. From these findings, for patients aged thirty and older, the prevalence of root caries is roughly 20 to 22 percent less than a person’s age. For example, a person aged fifty would have a probability of 30 percent of having had one or more RDFS. Severity reaches over one lesion by age fifty, two lesions by age seventy, and just over three lesions for those seventy-five and older.

Annual Incidence

Seven articles20-25 representing five separate studies met the inclusion criteria of representative, community-dwelling residents in North America. Incidence in studies spanning sixteen to eighteen months showed much higher incidence rates than did the studies lasting three years or more.

Eight studies20-26 provided data on the incidence by RDFS. Again the studies of longer duration showed much lower annual incidence than did those of shorter duration.

Calculating a duration/sample-size weighted central estimate of the results of the four longest studies shows that about 8 percent (odds of 1:11) of subjects would be expected to acquire one or more new root
caries lesions in one year. Those four studies,\textsuperscript{21,23,24,25} plus the Birmingham (AL) study,\textsuperscript{26} show that dentate people would, on average, be expected to acquire about 0.19 new RDFS per year. Clarkson adds a cautionary note when she points out that the conventional incidence studies would not pick up restorations of secondary root caries leading to an understatement by as much as two-thirds of the actual incidence of the lesions.\textsuperscript{27}

**Diagnostic Systems**

Diagnosis of a root caries lesion is established by assessment using clinical descriptors. The descriptors vary and are subjective. They are based on color, texture, surface smoothness, depth of the lesion, and distinctiveness of the border, overlaid with whether the lesion is deemed to be active or inactive. Of the fifty-seven articles tagged with “diagnosis,” many had been so labeled in order to identify which diagnostic system was being used and others were nonsystematic reviews. Five articles\textsuperscript{16,28-31} were included in the evidence table for diagnosis.\textsuperscript{1} The accuracy of diagnostic tests is indicated by the sensitivity/specificity or the likelihood ratios of the test when compared to an independent gold standard. None of the five provides strong evidence. The accuracy of the sensitivity and specificity values for radiographs, calculated from two studies\textsuperscript{28,29} that provided sufficient (albeit somewhat inconsistent) data, are unlikely to apply in everyday practice since the radiographs were taken on single extracted teeth and the gold standard of hand examination was not 24 karat. The study on the modified explorer\textsuperscript{10} also used a weak gold standard. The two final studies did not provide sufficient data to calculate the sensitivities or specificities, but were included since they used microbiological profiles of the lesion (not the surface) to show that there is some validity to the texture classification system\textsuperscript{16} but little validity to color classification of lesions.\textsuperscript{31}

Reliability of few of the diagnostic systems has been reported. Rosen et al. have shown that three examiners achieved intra-examiner Kappa scores of 0.47 to 0.51 and inter-examiner Kappa scores ranging from 0.30 to 0.51 on their four category classification system.\textsuperscript{15} Banting,\textsuperscript{32} in a review paper, reported a previously unpublished study on the reliability of two examiners’ ratings of root surface decay from radiographs. The bitewing radiographs showed over 100 lesions, but the examiners agreed on only twenty-eight lesions, on 64 percent of all calls, for a Kappa of 0.58. Mojon et al.\textsuperscript{33} have reported that two examiners achieved at best fair (Kappa 0.36, 0.42) intra-examiner agreement, but somewhat better (Kappa = 0.61) inter-examiner agreement using the Hellyer et al.\textsuperscript{34} criteria for texture and the Fejerskov et al.\textsuperscript{35} criteria for activity.

The evidence demonstrates that practitioners are left with systems of diagnosing the disease for which the accuracy is unknown. While there is little to recom-

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**Figure 1. Prevalence of root caries**

![Prevalence of root caries](image-url)
mend one system over the other, color has been shown to have little validity. The texture (soft/hard) components of the Billings and the Hellyer systems have been shown to correspond to histopathology and penetration by micro-organisms. Three studies of reliability showed that the diagnostic systems had poor or fair to moderate reliability.

Remineralization

The database was searched for the occurrence of the word “treatment” in any field. The search identified sixty-nine articles, which were reviewed to determine if they met the criteria for inclusion in the evidence table. The inclusion criteria limited studies to primary studies of any kind, controlled/uncontrolled; valid diagnostic and outcome criteria, that is, diagnostic systems used by others or closely resembling others; duration of one year or more; and with no minimum number of subjects. Most of those eliminated were nonsystematic reviews, or they did not address treatment.

The evidence gleaned from the seven studies on remineralization is seen in Table 1. In four of the studies, the investigators randomly assigned the test and control interventions. However, each of these studies has characteristics that limit confidence in the findings. The study with the highest level of quality was conducted over four years in Birmingham, AL, and was limited only by the apparent lack of “blinding” of examiners and subjects. Even with that limitation, the recommendation is graded at the A level, indicating that this is strong evidence. The Boston and Portland study spanned only one year, and the Netherlands study ran one year with no blinding; both were therefore judged to provide fair evidence upon which to make a recommendation (B). The Texas study was limited by the few (six) subjects, imbalance in the random allocation, and lack of blinding. For one regimen (home use of fluoride gels) where there were no controls, by itself it was seen to provide insufficient evidence upon which to base a recommendation (C); for recontouring and smoothing lesions and home use of fluoride gels, the procedure rates a C or perhaps a very tentative B. The other three studies were conducted over one to four years, but lacked control groups of any kind, which must limit the confidence readers place in the findings.

The evidence supports remineralizing with fluorides including: daily fluoride rinses in a fluoridated community; and somewhat more tentatively, every three-month application of fluoride varnish; and very tentatively, recontouring followed by home fluoride gel. The evidence for fluoride in combinations is shown for: fluoride gels at home combined with professional applications every four months; (I, B); a mean of seven per year varnish applications plus twice daily lozenges or rinses (II-3, C); sixteen daily gels at home plus home rinsing; and fluoride dentifrice plus two, two-minute applications of sodium fluoride to lesions (II-3, C). While there is only one strong study that shows that lesions can be reversed with fluorides, the other studies with weaker design or shorter duration add consistent evidence to support the use of fluorides in the remineralization of root caries. The evidence for the efficacy of recontouring followed by treatment with sodium fluoride was demonstrated among only sixteen lesions in six people; hence, the C recommendation.

Every three-month application of chlorhexidine varnish was also shown to be efficacious in one arm of one study (I, B) where 15 percent of sixty-two lesions “hardened” (compared to 3 percent of controls).

Restoration

Evidence for the restoration of root caries was found in only four studies as shown in Table 2. The outcomes are intermediate; that is, they are measured on clinical retention and acceptability of the restoration as compared to a health related outcome such as longevity of the tooth or improvement in functional ability. The strongest study was conducted on fifty subjects with 104 lesions. While the allocation to treatment groups was random, the study ran for only twelve months, and there was a relatively large loss to follow-up. Thus the grade of the recommendation is set at (a weak) B or “fair evidence to support the recommendation.” Others might well argue for a lower grade of recommendation given the limitations to the study. The other studies lacked control groups, but with retention rates of 97 percent or higher would seem to demonstrate “dramatic results of uncontrolled experiments,” so they were classified as level II-3 evidence. However, each study ran for only two or three years and the long-term effects, especially potential harms, can not have been fully demonstrated. Thus, the recommendation for each is graded as C or “insufficient evidence to recommend for or against” the findings.

Evidence for restoration is tentative since the studies were of limited design and duration. The one study with random assignment to a comparison had a 31 percent loss to follow-up over the one year. No study examined amalgam, which is apparently still used. Thus, from the very limited data, dentists may restore root caries with: composite resins; composite resins with bonding agents; six daily lozenges or rinses; fluoride gels at home plus home rinsing; and fluoride dentifrice plus two, two-minute applications of sodium fluoride to lesions (II-3, C). Although conventional
Table 1. Evidence for remineralization of root caries

<table>
<thead>
<tr>
<th>Authors</th>
<th>Study setting</th>
<th>Interventions</th>
<th>Control</th>
<th>Test</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wallace, Bialek; Bradley (1993)</td>
<td>Birmingham, AL (fluoridated)</td>
<td>Placebo rinse, glass ionomer 38 (II-3, C)</td>
<td>1. 1% NaF gel + placebo rinse 2x yearly = placebo rinse 2x daily = placebo rinse daily</td>
<td>Random allocation to control and two test groups = placebo rinse daily</td>
<td>Mean number of reversions: 1.11 Control, 1.01 NaF gel, 1.53 NaF rinse</td>
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<tr>
<td></td>
<td>(603 subjects)</td>
<td></td>
<td></td>
<td></td>
<td>P &lt; 0.05</td>
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<tr>
<td>Capanno</td>
<td>Boston, MA, Portland, ME</td>
<td>Placebo gel at 4 mo intervals + daily brushing with fluoride dentifrice = extensive monitoring for compliance</td>
<td>12,000 ppm Fluoride gel at 4 mo intervals + 5000 ppm gel for daily home use + 2x daily brushing with fluoride dentifrice = extensive monitoring for compliance</td>
<td>Random allocation to control and test groups = placebo gel 10%</td>
<td>Percent of patients experiencing one or more lesions reduced: Fluoride gel 31%, Placebo gel 10%, Chi-square p&lt;0.025</td>
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<tr>
<td></td>
<td>(41 controls, 42 test subjects)</td>
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<tr>
<td>Scharenk, Katjesm, Van Der Hoven (1991)</td>
<td>Netherlands (?)</td>
<td>Professional tooth cleaning every 3 mo as part of standard maintenance program</td>
<td>1. Duraphat varnish at 3 mo intervals following professional tooth cleaning = placebo 2x weekly or daily</td>
<td>Random allocation = but control had fewer root caries lesions at baseline</td>
<td>Percent of (n) lesions hardening = 3% (29 control, 11% (49 Duraphat) 15% (62 Chlorhexidine) p&lt;0.05 McNeIm's Chi-square</td>
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<tr>
<td></td>
<td>1 yr</td>
<td>(40 periodontal surgery patients)</td>
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<tr>
<td>Witting, Brown, Naister (1995)</td>
<td>Houston, TX</td>
<td>For incident lesions: No control group</td>
<td>Gr I-Shallow lesions: Carefully excavated, surface recontoured, polished = home application of 1% NaF gel</td>
<td>For incident lesions: not stated</td>
<td>Not stated</td>
</tr>
<tr>
<td></td>
<td>2 yr</td>
<td>(6 patients at U of Texas with 54 active lesions)</td>
<td>Gr II-Shallow lesions: Carefully excavated, surface recontoured, polished = home application of 1% NaF gel</td>
<td>For shallow lesions: random allocation, but very unhealthy groups (originally 13 lesions in treatment group = 5 in the control)</td>
<td>Not stated</td>
</tr>
<tr>
<td></td>
<td></td>
<td>For shallow lesions: Home application of 1% NaF gel</td>
<td>Gr II-Shallow lesions: Carefully excavated, surface recontoured, polished = Home application of 1% NaF gel</td>
<td>For shallow lesions: random allocation, but very unhealthy groups (originally 13 lesions in treatment group = 5 in the control)</td>
<td>Not stated</td>
</tr>
<tr>
<td>Emsen, Rovak, Birkhed (1993)</td>
<td>Sweden</td>
<td>No control group</td>
<td>Intensive CHX: = polishing; = mean of 2 fluoride rinses (Duraphat) applications + 2x daily fluoride lozenges or rinses + fluoride toothpaste</td>
<td>Not stated</td>
<td>67 of 602 sound surfaces progressed; 15 of 69 active lesions progressed; of 89 active lesions 30 progressed and 37 became inactive</td>
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<tr>
<td></td>
<td>1 yr (periodontal patients and others referred for root caries - 15 people with 770 exposed roots)</td>
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<tr>
<td>Johansen, Pape, Olesen (1987)</td>
<td>Boston, MA, (fluoridated)</td>
<td>No control group</td>
<td>Projects 1 &amp; 2 daily oral hygiene; 15 days of NaF rinses in trays at home = 2 min home rinses, twice daily, over the study period = Non-sweet gum (ad lib)</td>
<td>Not stated</td>
<td>Percent of lesions remineralized = 53% (medical patients) 61% (healthy patients) 56% overall</td>
</tr>
<tr>
<td>For Project 1: Plackers, Olesen (1987)</td>
<td>Project 1: Patients attending private dental practice in New York State</td>
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<tr>
<td>For Project 2: Plackers, Olesen (1987)</td>
<td>Project 2: Patients aged = 45, referred to Tufts University, Boston, MA</td>
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<tr>
<td>For Project 2: Plackers, Olesen (1987)</td>
<td>Project 1: 4 yo</td>
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<tr>
<td>For Project 2: Plackers, Olesen (1987)</td>
<td>Project 2: 2 mo to 6 yr = 80% observed over 1-9 mo</td>
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<tr>
<td>For Project 2: Plackers, Olesen (1987)</td>
<td>Project 2: (30)</td>
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</tr>
<tr>
<td>Nyvad, Fejerskov (1996)</td>
<td>Denmark?</td>
<td>No control group</td>
<td>Oral hygiene instruction: twice daily brushing with fluoride dentifrice = eating lesion 2%, eight weeks apart, for 2 min with 2% NaF</td>
<td>Not stated</td>
<td>Typical lesion became hardened, dark (inactive?)</td>
</tr>
<tr>
<td></td>
<td>18 mo</td>
<td>(10)</td>
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</table>

Discussion

Estimates of disease prevalence and incidence are made with the same or similar relatively unreliable diagnostic methods. This limitation affects our ability to describe the prevalence, incidence, and natural history of the disease. Aside from the studies on incidence and prevalence, studies on the management of root caries do not offer strong evidence for the care of patients. They are few in number and compromised either in design or duration. The literature is so limited that the issues of which approach might be more appropriate in terms of patient preferences, costs, and efficiency can not be addressed. Clearly research is needed to: validate the accuracy of, or develop, valid, diagnostic methods; add to the evidence on the efficacy of therapeutic
Table 2. Evidence for restoration of root caries

<table>
<thead>
<tr>
<th>Authors</th>
<th>Study Setting Duration of study (# of subjects)</th>
<th>Interventions</th>
<th>Control</th>
<th>Test</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Levy, Jensen, Doering, Shefl (1988) RCT – I (B)</td>
<td>Iowa 1 yr (50 people needing 104 restorations)</td>
<td>Glass ionomer cement (GIC)</td>
<td>Composite resin</td>
<td>No blinding (29% Composite resin, 33% GIC, 31% combined)</td>
<td>Full retention: Composite 79% GIC 52% Clinically acceptable: Composite 86% GICs 70%</td>
</tr>
<tr>
<td>Duke, Robbins, Snyder (1991) Il-3 (C)</td>
<td>Patients attending university clinic in Texas? 3 yr (38 people needing treatment for ≥ 2 cervical lesions of which 32 were root caries)</td>
<td>No control group</td>
<td>Composite resin + dental adhesive</td>
<td>Not stated (8%)</td>
<td>Retention 97% Other quality criteria met 79% or higher</td>
</tr>
<tr>
<td>Sheth, Jensen, Wiefel, Levy (1988) Il-3 (C)</td>
<td>Iowa 1 yr (28 patients attending university clinic with 123 lesions)</td>
<td>No control group</td>
<td>Light activated composite resin + dentin bonding agent</td>
<td>Not stated (21%)</td>
<td>Retention rate = 99.9% of the 97 remaining lesions</td>
</tr>
<tr>
<td>Billings, Brown, Kaster (1985) Il-3 (C)</td>
<td>Houston, Texas 2 yr (6 patients at U of Texas with 54 active lesions, 10 of which were cavitated)</td>
<td>No control group</td>
<td>GIC restorations for Grade III (cavitated) lesions</td>
<td>Not stated (0%)</td>
<td>100% of 18 lesions intact</td>
</tr>
</tbody>
</table>

measures through more rigorous design extending over longer periods; and begin to address issues of patient-based measures of outcomes.

Acknowledgments
I would like to acknowledge and thank both Dr. P. A. Main and Dr. H. P. Lawrence who reviewed the original 807 references, assisted in the design of the decision making model referred to in the text, and reviewed and provided comments on the original paper.

REFERENCES