

Clinical Diagnosis of Dental Caries: A European Perspective

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Abstract: The aim of this paper is to provide a broad international perspective on aspects of the RTI/UNC systematic review, to introduce relevant literature not cited, and to make recommendations for clinical practice education and research suggested by the evidence. Clinical caries diagnosis represents the foundation on which the answers to most of the consensus questions will be based. This paper highlights needs for being clear about definitions and nomenclature; understanding the importance of the concepts underlying the D_1 and D_3 diagnostic thresholds used widely within the RTI/UNC Review; and appreciating that the diagnostic challenge now faced by clinicians is significant and is becoming more complex as the presentation and distribution of the disease changes over time and the range of preventive and operative treatment options expands. A series of recommendations informed by the evidence are made, including a rather contentious issue for many clinicians concerning the lack of evidence supporting the continued use of a sharp explorer as a diagnostic tool for primary caries diagnosis. This practice should be discontinued as it may cause some harm to the patient and yet fails to provide a significant balancing diagnostic benefit. Finally, it is suggested that dentistry should learn from the developing evidence base in medicine on how best to disseminate the findings of reviews and promote appropriate changes in clinical practice.

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Note: The Dental Health Services Research Unit is funded by the Chief Scientist Office of the Scottish Executive Health Department and is a member of the Medical Research Council's Health Services Research Collaboration (MRC HSRC). The views expressed in this paper are those of the author and not necessarily those of the Scottish Executive or the MRC HSRC.

Key words: dental caries diagnosis, evidence-based dentistry, treatment strategies, dental diagnostic systems

I applaud the organizers for setting out such an important and timely agenda for this conference which is, in a sense, overdue. I would also caution all participants as to the enormity of the task set out for us. Agreeing where the evidence leads us on the Diagnosis and Management of Dental Caries Throughout Life is a complex task, but one in which we should be able to make significant and valuable progress. The focus of the conference is rightly on clinical practice and using current knowledge to aid the provision of the best possible appropriate care for individual patients. It is important at the outset to realize that much of the research work in the field of caries diagnosis has been conducted and reported in three overlapping applications of the diagnostic process: clinical practice, clinical research, and clinical dental epidemiology. The differing objectives, environments, and priorities of research and work in these areas often confuse attempts to synthesize the relevant literature, particularly when comparing across countries and dental cultures.

As the aim of this conference is to develop scientifically based recommendations that can be applied by dentists and dental hygienists, it is important that the "everyday" fundamentals of clinical caries diagnosis are addressed clearly and objectively. Clinical caries diagnosis represents the foundation on which the answers to most of the consensus questions will be

based, either through providing information on caries detection (or acting as the benchmark from which other methods must be judged), being part of risk assessments, being used in the assessment of both primary and secondary preventive strategies, or playing a key role in informing clinical decision making. It is vital then that the objective findings of the RTI/UNC systematic review around which the conference is based, as well as those from a number of other reviews from a variety of countries, are carefully considered by the target group of end users—even if some of the findings seem to contradict the dental "facts of life" taught to many of us in an earlier era in different dental schools, and even if some of the more recent findings do not fit with the "classical" findings of research carried out some years ago. Different groups of clinicians in different countries will probably find different parts of the recommendations easy or difficult to comply with. We should learn from the work done in medicine that there is also a developing literature and evidence base on how to disseminate the findings of reviews effectively and, having achieved that, how any changes in clinical practice that might be indicated can best be brought about.¹ The potential for this conference to contribute to professional behavior change looks favorable, in that initiatives which are professionally led and are conducted to a high scientific standard with sys-

tematic and objective reviews of the international literature have been shown to work well, as long as they are then cascaded down to achieve true local ownership.¹

A key area, which will need to be addressed to build and achieve consensus, is clarity about the definitions and nomenclature used. Many apparently similar terms are used interchangeably in the literature, but are taken by different groups of researchers and clinicians to mean very different things. In the conference title (and hence the mission) there will have to be clarity with regard to defining the terms: *diagnosis* (not just detection); clinical *management* (encompassing preventive care of reversible lesions as well as surgical excision of tooth substance); what constitutes *dental caries* (the current research view, held for many years in Europe and now increasingly in the United States, is that caries is a continuum, rather than just the macroscopic cavitation, which merely represents the late stage of the disease process); *throughout life* (here we need to differentiate early childhood caries from lesions in children, adolescents, adults, and seniors, to plan minimally invasive care for the long-term benefit of the patient, and to appreciate the possibility of changes between risk groups over time).

The Parts of the RTI Systematic Review Relating to Clinical Caries Diagnosis

To make best use of the review, it is very important to understand the concepts of the D₁ and D₃ diagnostic thresholds used widely within the RTI/UNC review because this is an area that causes confusion to many. Figure 1a shows an updated version of the iceberg metaphor for conceptualizing dental caries and the impact that the changing diagnostic threshold has on what is considered by dentists and researchers to constitute sound and diseased tooth tissue.² The term “caries free” is frequently used when referring to data reported at the D₃ (caries into dentin only) diagnostic threshold. This term conveys the mistaken impression that no disease is present in an individual or population, even though large numbers of carious lesions have been recognized and scored by dentists and researchers as dental caries in the enamel.³ The diagnosis of so-called white spot and brown spot caries has been accepted for many years in Europe, so that monitoring the behavior of these lesions over time using clinical caries assessments is routine following the classic work of Backer-Dirks and others.⁴ It has been shown that the

progression of these enamel lesions with macroscopically intact surfaces is extremely slow and such lesions on free smooth surfaces do not always progress; they can stop—*lesion arrest*—or even reverse—*lesion regression*.^{5,6} Part of the confusion is that these enamel lesions are often referred to as D₁ lesions, as opposed to the D₁ diagnostic threshold that includes *both* D₁ and D₃ lesions (Figure 1). An example of the type of clinical visual diagnostic criteria used often in European studies, which can be reported at either or both the D₁ and D₃ diagnostic thresholds is the recently reported Dundee Selectable Threshold System, or DSTM.^{7,8} Note that traditional diagnostic aids (such as bitewing radiography and fiber-optic transillumination, FOTI) detect more lesions still. The newer and more sensitive research methods of caries diagnosis are now able to detect even more subclinical initial lesions, which are in a state of dynamic progression and regression at the early stage of the disease process, before they are discernible by conventional clinical methods. With this, lesions be detected and the impact of preventive care can be assessed to ensure that cavitation is avoided.

The same iceberg can be used to link the diagnostic divisions of the continuum of dental caries with the type of clinical caries management option that offers the patient the best long-term benefit (Figure 1b). This choice of the most appropriate care option involves balancing the risk of continuing tooth destruction if preventive care fails, against restorations placed and then replaced repeatedly over time with the imperfect restorative methods currently available. The approach used in Europe for some years is summarized by the acronyms **NCA** for **No (active) Care Advised** above normal prevention, **PCA** for **Preventive Care Advised** when stable and/or noncavitated lesions are diagnosed and **PCA + OCA** when both **Preventive and Operative Care are Advised** for progressive dentinal lesions and lesions with significant cavitation.^{9,10} There is a continuing debate in Europe as to exactly when restorative intervention is indicated, including a movement to recognize the need to tailor the decision to individual patients and their needs, wants, and circumstances, and with a focus on cavitation (surface discontinuity) rather than dentin involvement (lesion depth) per se. It should be noted that progressive dentinal hidden dentine lesions can sometimes be found in sites that are clinically sound and that these lesions are scheduled for operative care (Figure 1b). It also must be emphasized and re-emphasized that clinical caries diagnosed at the enamel lesion threshold with intact surfaces are *not* scheduled for restoration, but are typically managed preventively in Europe.

A number of technical aspects of the review are worthy of comment. First, the reviewers are to be con-

The “iceberg of dental caries” 2001—varying diagnostic thresholds & applications

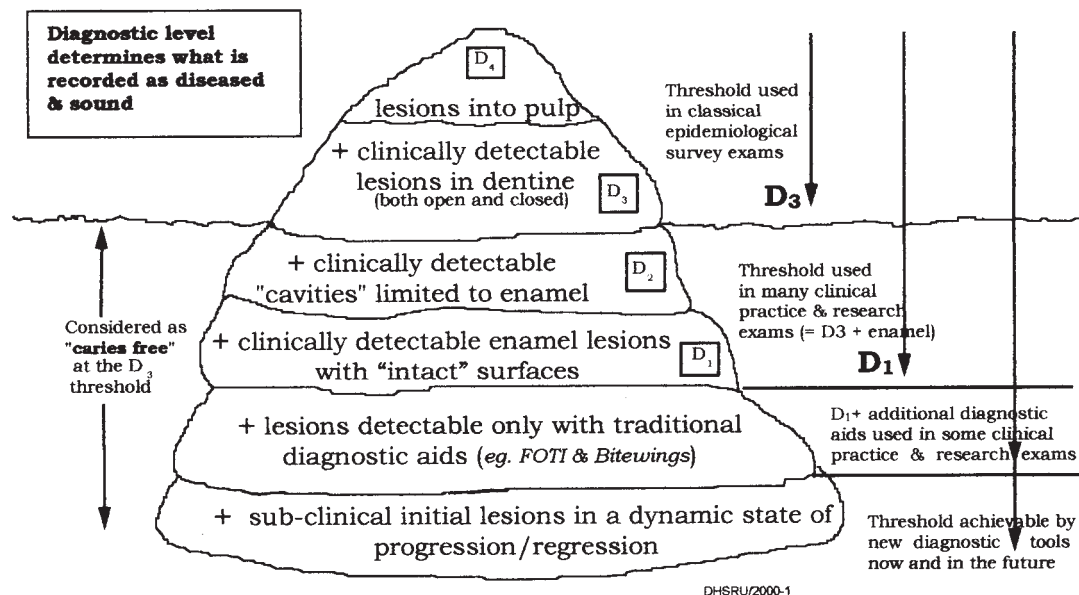


Figure 1a. Conceptualizing the caries process

gratulated for their diligence, endurance, and thoroughness in completing such a major task. The key finding that the quality of studies in the areas reviewed was often found to be poor may be seen as contentious by some in dentistry. It is frustrating that, when measured against contemporary methodological standards, there are so few useable studies. However, it is important for these findings to be judged in the context of similar reviews in many fields of medical care where similar findings are common. This represents a major challenge to the dental research community for the future.

Some areas of the review might have been improved if more time and resources were available. A key concern in this complex area of reviewing diagnostic literature in evidence-based healthcare is that the quality standards imposed on grading the papers included are pertinent to the objective(s) of the study. In this review, as data from some papers were employed for a number of different analyses, not always those intended by the authors of the primary research, it might be argued that some of the quality scores were therefore inappropriate for some evidence tables. The presentation of the data also was complex. Other areas for technical debate include the possible use of Receiver Operating Characteristic (ROC) analyses rather than relying solely on sensitivity and specificity. Some ar-

gue that this method captures more of the diagnostic information obtained, whilst others are less convinced.¹¹ Differences in the approach to histological validation employed represent a further challenge in this area. On the one hand in vitro studies are commended as they can provide a true gold standard; on the other hand, the differences between the diagnostic performance achieved in vitro and in vivo casts some doubt on the generalizability of the in vitro findings. Although very demanding in terms of logistics, the ideal study design would be to assess diagnosis in vivo first and then reassess the same surfaces in vitro following extraction of the tooth (for some ethically acceptable reason). A further difficulty occurs when the gold standard classically employed is potentially less sensitive than some of the methods being tested against it.

Additional Studies Not Included in the RTI/UNC Review

The papers cited in this section provide a European perspective on many of the challenges to clinical

NCA/PCA/OCA 2001—informing clinical decisions about prevention and operative care

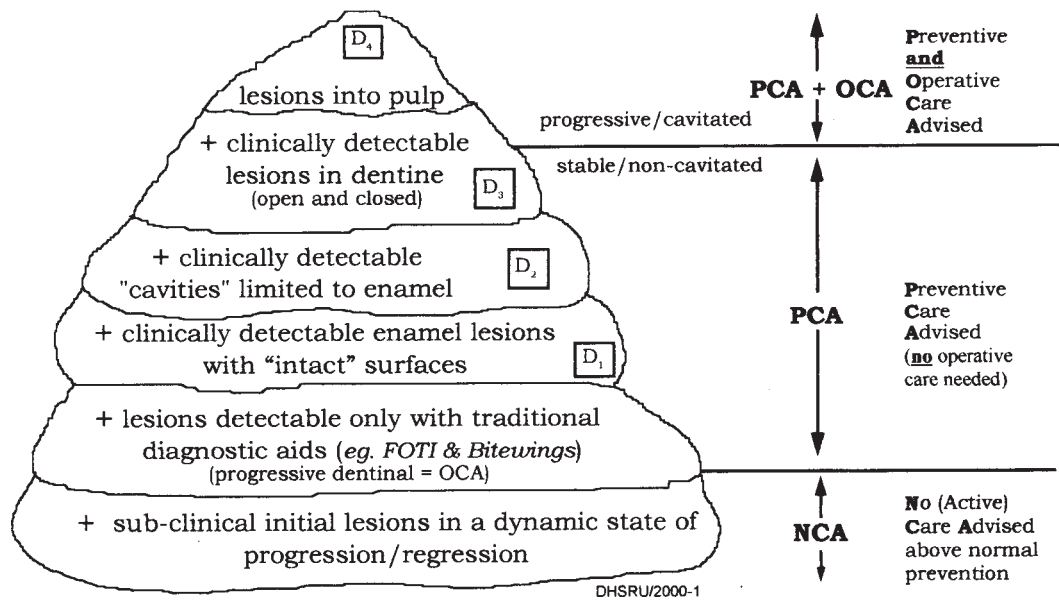


Figure 1b. Linking diagnosis to clinical management

caries diagnosis raised in the review. The diagnostic challenge now faced by clinicians should not be underestimated or regarded as a basic or undemanding skill. The presentation of the disease has changed at a time when the prevalence and incidence have slowed in some cases, but also when the disease has become more polarized between risk groups and the range of preventive and operative treatment options has expanded.^{12,13} Although the clinical examination is the bedrock of daily dental practice, it is clear from many studies that clinical examination used alone in vivo will miss many lesions until they become so advanced that preventive intervention to avoid cavitation is compromised. The occlusal surface presents particular difficulties as gross cavitation seems to occur less frequently and the limitations of the clinical visual method have led to a fear of underdetecting hidden (or occult) lesions involving dentin.¹²

A contentious issue for many clinicians concerns the lack of evidence supporting the continued use of a sharp explorer as a diagnostic tool. Although its use as part of a visuo-tactile clinical method is widespread and has been widely taught for many years in many countries, many European centers now teach that it is unethical to use an explorer in this way. This is because it has been shown many years ago in Sweden that iatro-

genic damage can readily be produced, particularly on initial caries within occlusal fissures, and this action will favor continued lesion development.¹⁴ Similar findings were shown by Ekstrand and colleagues nearly twenty years later¹⁵ when it was also shown experimentally that the effect of probing with an explorer had a deleterious effect in terms of subsequent enamel demineralization.¹⁶ Apart from any risk of conveying cariogenic organisms from one fissure system to another, it is argued that a practice likely to cause harm to the patient cannot be justified if it fails to provide a significant balancing benefit. In this case, work showing the absence of any diagnostic benefit from the visual + tactile method over the visual only method means that the use of the sharp explorer to sense "stickiness" in occlusal fissures for primary caries diagnosis should be discontinued. A further complication with interpreting this literature is the difficulty of comparing studies that include established, open cavities in the assessment of occlusal caries diagnosis, along with those confined to equivocal lesions.¹⁷

A significant extension of the well-used clinical visual method of caries diagnosis on accessible free smooth surfaces can be made by temporarily separating adjacent teeth with elastomeric tooth separators commonly used in orthodontic practice.^{18,19} This allows

Table 1. Recommendations in response to the relevant conference questions

Question 1. What are the best methods for detecting early-stage and late-stage dental caries?

1. Recognize that clinical caries diagnosis (with all its flaws) is the current foundation of lesion detection in clinical practice, clinical research, and clinical epidemiology. The literature evaluating the method is mixed between these three applications, and care is needed to separate out the objectives of use and the performance of the method in each field.
2. Clinical visual methods of caries diagnosis are universally employed, are rapid, economical, and acceptable for detecting early-stage disease (enamel lesions such as white and brown spot caries on accessible sites), noncavitated dentinal lesions, and late-stage cavitated caries. However, although the methods are inherently feasible, their inherent limitations must always be remembered.
3. Although clinical diagnostic methods are highly specific, the low sensitivity achieved, particularly for non-cavitated occlusal surfaces *in vivo*, means that the use of diagnostic aids with superior performance is indicated and that new methods for caries diagnosis are required.
4. Although the volume of high-quality evidence on new diagnostic methods is lower than desirable, the very limited high-quality evidence available to support traditional clinical diagnostic methods means that clinicians cannot be complacent about the status quo.
5. Given the potential for caries-inducing and caries-accelerating iatrogenic damage from the use of a sharp explorer in a visuo-tactile method, combined with the lack of any evidence of any additional diagnostic benefit, sharp explorers should no longer be used for the diagnosis of primary coronal caries in fissures.
6. Continuing, effective undergraduate, faculty, and postgraduate educational initiatives will be needed to share the evidence with teachers and clinicians in order to persuade those still using them to move away from sharp explorers.
7. The continuum of the caries process and the long-term benefits to the patient of preventive caries management should be more readily appreciated by practicing dentists and should thus be the subject of continuing, effective undergraduate, faculty, and postgraduate educational initiatives.
8. The state of scientific knowledge regarding caries diagnosis (and related preventive management) in all three fields has moved forward, ahead of many traditional professional, regulatory, and advisory frameworks, which should be objectively updated regularly.
9. The concepts of diagnostic thresholds should be more widely understood and the use of the ambiguous term “caries free” should be avoided.
10. It should be explicitly recognized that the current situation regarding the state of the art of caries diagnosis in clinical practice, clinical research and clinical dental epidemiology will need to alter with the continuing new developments in knowledge. Strategies for systematically sifting, grading, and promoting the adoption of worthwhile new caries diagnostic approaches should be put in place internationally.
11. Attempts should be made to harmonize epidemiological diagnostic methods in order to promote improved comparability and produce more reliable estimates of contemporary preventive care and restorative treatment needs.

Question 5. How should clinical decisions regarding prevention and/or treatment be affected by detection methods and risk assessment?

1. There is a need for more reliable diagnostic methods to provide unambiguous indications of the extent, surface status, and activity of lesions in order to plan appropriate care.
2. There is a need for diagnostic methods that can reliably assess sealed surfaces.
3. There is a need for better tools for the diagnosis and treatment planning of secondary caries, given the proportion of repeat dentistry currently carried out.
4. Before a decision to restore is made, clear evidence of significant cavitation or progressive dentinal involvement should be required.
5. Results of clinical diagnosis should be able to be fed into preventively-biased clinical decision frameworks compatible with a NCA, PCA, PCA + OCA style of classification in order to avoid the premature restoration of small noncavitated lesions.
6. There is a need for valid, reliable, automated clinical decision support systems

Question 6. What are the promising new research directions for the prevention, diagnosis and treatment of dental caries?

1. There is a need for more effective primary preventive products.
 2. There is a need for specific secondary preventive products that can deliver reliable lesion reversal *prior* to the cavitation stage ever being reached.
 3. There is an urgent need for more high-quality studies that are well conducted and well reported using an internationally agreed common minimum data set for reporting.
 4. There is a need for more studies evaluating the same lesions both *in vivo* and *in vitro*.
 5. There is a need for more studies evaluating caries diagnosis in primary teeth.
 6. There is a need for more studies evaluating diagnostic performance at the caries into enamel and dentin D₁ threshold.
 7. There is a need for more studies on combinations of diagnostic methods, with *adjunctive* and *supplemental* analyses.
 8. There is a need for more sensitive, specific, reliable, objective diagnostic methods to indicate sites vulnerable to lesion progression *prior* to too much damage being done, i.e., tools to specifically cater to early stage caries.
 9. There is a need for diagnostic tools to cater for lesions around the size/extent at which restorative intervention is indicated, in order to monitor the outcome of aggressive preventive care.
 10. There is a need for diagnostic tools tailored for rapid, reliable, and accurate use in epidemiological settings.
 11. There is a need for diagnostic tools to specifically detect hidden dentine caries.
 12. There is a need for better dental materials with physical properties that more closely match tooth tissue and the
 13. There is also a need to develop the evidence base on how to disseminate effectively the findings of systematic reviews in dentistry and, having achieved that, to establish how any changes in clinical practice that might be indicated can best be brought about.
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a direct assessment of the presence or absence of surface cavitation to be made without exposing the patient to ionizing radiation to obtain a bitewing radiograph which cannot give a definite indication of the integrity of the approximal surface. Although the technique does require some practice and, in some cases, a further visit, it has been shown to be feasible in a general practice setting.²⁰ The clinical visual elective temporary tooth separation method can also be used in diagnostic research where the lack of clinical cavitation in approximal sites with dentinal radiolucencies on bitewing radiographs has been striking.^{21,22} The probability of approximal cavitation has also been linked to caries activity.²³

Comparing of the relative merits of clinical visual and radiographic diagnoses represents an important area of changing practice as new evidence unfolds and evidence-based guidelines are produced to inform clinical decisions.^{24,25} There is perceived to be an urgent need, given the deficiencies of clinical and other traditional caries diagnostic methods, for new methods that avoid the use of ionizing radiation.²⁶ The comparative research of clinical and other diagnostic methods brings with it methodological difficulties in combining the data in the most effective and useable way. Longbottom advocated two different strategies for this, contrasting using *adjunctive* additional methods—when the additional method(s) are used/counted only in those cases where the clinical diagnosis is sound—with *supplemental* additional methods, when the highest-severest score from the clinical or additional method(s) are used/counted as the final diagnosis.²⁷ These approaches merit further consideration as new research unfolds. One neglected area of study is the diagnostic use of magnification in caries diagnosis.²⁸ (Further consideration of this topic can be found in the full version of this paper found at <http://www.nidcr.nih.gov>.)

Traditionally, it has been claimed that recording caries at the D_1 threshold is associated with very poor examiner reproducibility. However, there is a growing body of evidence to demonstrate that if the training employed and the criteria used are appropriate, it is possible to achieve adequate levels of reproducibility. Kappa values of 0.82 at the D_1 threshold as compared to 0.75 at the D_3 threshold have been reported by Deery who, in an earlier study, achieved a kappa value of 0.8 for the D_1 threshold examining Scottish adolescents.^{29,30} Similar values have been achieved by other examiners in vivo in adolescents³¹ and in examining four year olds; in vitro kappa values of around 0.7 have also been achieved.²⁸

Clinical diagnosis of dental caries plays a key part in clinical decision making and impacts on the provision of care that is appropriate in terms of both the evi-

dence base for effective care and the needs of an individual patient.³²⁻³⁴ More work is needed to understand better the interplay between the diagnostic and treatment decisions made by general dentists, particularly as they relate to more preventive modes of care, such as fissure sealants,³⁵ and how dentists value features of new technology in ways different from their patients.³⁶ This should lead to clearer evidence-based clinical guidelines for caries management³⁷ in different patient groups, including the socioeconomically deprived with most disease.³⁸ Taken together and building on a synthesis of the information taken from the reviews presented at the conference, this process should help clinicians to practice sound, effective, and up-to-date caries prevention and management based on more accurate and reliable caries diagnosis.

A Perspective on Recommendations for Clinical Practice, Education, and Research

Using the information presented in the RTI review, combined with the additional evidence cited in this contribution, a number of recommendations can be made to address the questions set out for the Consensus Development Conference. These are set out in Table 1.

Acknowledgments

The author would like to acknowledge the invaluable contributions made to the work outlined in this paper by very many colleagues and collaborators. Particular thanks are due to those contributing to the DHSRU Dental Service, Dental Caries, and Dental Practice Programmes, to our international collaborators, to all who assisted with the “Eurocaries” project, and to the members of the Guideline Development Groups of the Faculty of General Dental Practitioners and SIGN.

REFERENCES

(* denotes reference not in RTI/UNC review)

- 1.* Scottish Intercollegiate Guidelines Network. SIGN guidelines: a guideline developer's handbook SIGN publication no. 50. Edinburgh: SIGN, 2001.
- 2.* Pitts NB. Patient caries status in the context of practical, evidence-based management of the initial caries lesion. *J Dent Educ* 1997;61:861-5.
3. Pitts NB, Fyffe HE. The effect of varying diagnostic thresholds upon clinical caries data for a low prevalence group. *J Dent Res* 1988;67:592-6.
4. Backer-Dirks O, van Amerongen J, Winkler KC. A reproducible method for caries evaluation. *J Dent Res* 1951;30:346-59.
- 5.* Backer-Dirks O. Longitudinal dental caries study in children 9-15 years of age. *Arch Oral Biology* 1961;6:94-108.

6. Nielson A, Pitts NB. The clinical behaviour of free smooth surface carious lesions monitored over two years in a group of Scottish children. *Br Dent J* 1991;171:313-8.
- 7.* Fyffe HE, Deery CH, Nugent, ZJ, Nuttall NM, Pitts NB. Effect of diagnostic threshold on the validity and reliability of epidemiological caries diagnosis using the Dundee Selectable Threshold Method for caries diagnosis (DSTM). *Community Dent Oral Epidemiol* 2000;28:42-51.
- 8.* Fyffe HE, Deery CH, Nugent, ZJ, Nuttall NM, Pitts NB. In vitro validity of the Dundee Selectable Threshold Method for caries diagnosis (DSTM). *Community Dent Oral Epidemiol* 2000;28:52-8.
- 9.* Pitts NB, Longbottom C. Preventive Care Advised (PCA)/Operative Care Advised (OCA)—categorising caries by the management option. *Community Dent Oral Epidemiol* 1995;23:55-9.
- 10.* Lussi A, Megert B, Longbottom C, Reich E, Francescut P. Clinical performance of a laser fluorescence device for detection of occlusal caries lesions. *Euro J Oral Sci* 2001;109:1-6.
- 11.* ten Bosch JJ, Angmar Mansson B. Characterization and validation of diagnostic methods. In: Faller RV, ed. *Assessment of oral health, diagnostic techniques and validation criteria*, Basel, Switzerland: Karger, 2000:174-89.
- 12.* Kidd EAM, Ricketts DNJ, Pitts NB. Occlusal caries diagnosis: a changing challenge for clinicians and epidemiologists. *J Dent* 1993;21:323-31
- 13.* Paterson RC, Watts A, Saunders WP, Pitts NB. *Modern concepts in the diagnosis and treatment of fissure caries: a review of clinical techniques and materials for the busy practitioner*. London: Quintessence Publishing Co. Ltd., 1991.
- 14.* Bergman G, Linden L. The action of the explorer on incipient caries. *Svensk Tandlakare Tidskrift* 1969;62:629-34.
15. Ekstrand K, Qvist V, Thylstrup A. Light microscope study of the effect of probing on the occlusal surfaces. *Caries Res* 1987;21:368-74.
- 16.* Van Dorp CSE, Exterkate RAM, ten Cate JM. The effect of dental probing on subsequent enamel demineralization. *J Dent Child* 1988;55:343-7.
17. Lussi A. The impact of including or excluding cavitated lesions when evaluating methods for the diagnosis of occlusal caries. *Caries Res* 1996;30:389-93.
- 18.* Pitts NB, Longbottom C. Temporary tooth separation with special reference to the diagnosis and preventive management of equivocal approximal carious lesions. *Quintessence Int* 1987;18:563-73.
- 19.* Seddon RP. The detection of cavitation in carious approximal surfaces in vivo by tooth separation impression and scanning electron microscopy. *J Dent* 1989;17:117-20.
20. Rimmer PA, Pitts NB. Temporary elective tooth separation as a diagnostic aid in general dental practice. *Br Dent J* 1990;169:87-92.
21. Rimmer PA, Pitts NB. Effects of diagnostic threshold and overlapped approximal surfaces on reported caries status. *Community Dent Oral Epidemiol* 1991;19:205-21.
22. Pitts NB, Rimmer PA. An in vivo comparison of radiographic and directly assessed clinical caries status of posterior approximal surfaces in primary and permanent teeth. *Caries Res* 1992;26:146-52.
- 23.* Lunder N, von der Fehr FR. Approximal cavitation related to bitewing image and caries activity. *Caries Res* 1996;30:143-7.
- 24.* Pitts NB. The use of bitewing radiographs in the management of dental caries: scientific and practical considerations. *Dentomaxillofac Radiol* 1996;25(1):5-16.
- 25.* Pendlebury M, Pitts NB, eds. *Selection criteria in dental radiography*. London: Faculty of General Dental Practitioners (UK), 1998.
- 26.* Pitts NB. Need for early caries detection methods: a European perspective. In: Stookey G, ed. *Second international conference on detection of early caries*. Bloomington: Indiana University, forthcoming.
- 27.* Longbottom C. *The clinical diagnosis of dental caries—an initial examination of novel techniques*. Ph.D. Thesis, University of Dundee, Dundee, 1992.
- 28.* Forgie A. *Eyesight and magnification in dentistry*. Ph.D. Thesis, University of Dundee, Dundee, 1999.
- 29.* Deery CH, Care R, Chesters R, Huntington E, Stelmachonoka S, Gudkina Y. Prevalence of dental caries in Latvian 1- to 15-year-old children and the enhanced diagnostic yield of temporary tooth separation, FOTI and electronic caries measurement. *Caries Res* 2000;34:2-7.
- 30.* Deery CH. *An evaluation of the use of pit and fissure sealants in the General Dental Service in Scotland*. Ph.D. Thesis, University of Dundee, Dundee, 1997.
- 31.* Forgie AH, Paterson M, Pine CM, Pitts NB, Nugent ZJ. A randomised controlled trial of the caries preventive efficacy of a chlorhexidine containing varnish in high caries risk adolescents. *Caries Res* 2000;34:432-9.
- 32.* Pitts NB. Diagnostic tools and measurements—impact on appropriate care. *Community Dent Oral Epidemiol* 1997;25:24-35.
- 33.* Verdonschot EH, et al. Developments in caries diagnosis and their relationship to treatment decisions and the quality of care. *Caries Res* 1999;33:32-40.
- 34.* Axelsson P. Diagnosis and registration of carious lesions. In: *Diagnosis and risk prediction of dental caries*, Vol. 2. Chicago: Quintessence Publishing Company, Inc., 2000:208-47.
- 35.* Deery CH, Fyffe HE, Nugent, ZJ, Nuttall NM, Pitts NB. General dental practitioners' diagnostic and treatment decisions related to fissure sealed surfaces. *J Dent* 2000;28:307-12.
- 36.* Evans DJP, Matthews S, Pitts NB, Longbottom C, Nugent ZJ. A clinical evaluation of an Erbium:YAG laser for dental cavity preparation. *Br Dent J* 2000;188:677-9.
- 37.* SIGN guideline: targeted caries prevention in 6-16 year olds attending for dental care. Edinburgh: Scottish Inter-Collegiate Guideline Network, 2000.
- 38.* Sweeney PC, Nugent ZJ, Pitts NB. Deprivation and dental caries status of 5-year-old children in Scotland. *Community Dent Oral Epidemiol* 1999;27:152-9.