

A Closer Look at Diagnosis in Clinical Dental Practice: Part 6. Emerging Technologies for Detection and Diagnosis of Noncaries Dental Problems

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A b s t r a c t

The final article of this series examines some recent innovations in diagnostic procedures for noncaries dental problems and assesses the potential for new endodontic and periodontal methods to become everyday tools of the dental clinician.

MeSH Key Words: *decision support techniques; periodontal diseases/diagnosis; predictive value of tests; risk assessment methods*

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In this series¹⁻⁵ we have introduced a variety of statistical and epidemiologic methods for assessing diagnostic tools and have demonstrated how these methods can be applied to established and novel diagnostic technologies. In the penultimate article⁵ we considered novel methods for detecting and diagnosing demineralized dental tissues. Although caries are still the primary focus of attention for most general dentists, chronic periodontal diseases run a close second. Tooth loss is less common now than in previous decades,⁶ but many patients still lose permanent teeth due to periodontal conditions,⁷ treatment based on perceived socioeconomic conditions (i.e., dentists are more likely to suggest extractions to individuals in lower socioeconomic groups than those in higher groups),⁸ and root decay.⁹ In the current paper we examine novel diagnostic technologies for periodontal disease and other important diagnostic dilemmas encountered by dentists.

A glossary, with concise definitions of terms, is available for the entire series (see Appendix 1, Glossary of epidemiology terms, at <http://www.cda-adc.ca/jcda/vol-70/issue-4/251.html>).

Periodontal Diseases

Periodontal diseases are usually subdivided into 2 main categories: gingivitis and periodontitis. Gingivitis is the presence of gingival inflammation with no loss of connective tissue, whereas periodontitis is inflammation of the periodontal tissues at a site where tissue loss has taken place. Such tissue loss occurs where the collagen fibres separate from the cementum, and the junction epithelium migrates apically, with or without commensurable loss of tooth-supporting alveolar bone. This situation illuminates a diagnostic obstacle — Should a site with attachment loss and periodontal pocketing, but without active inflammation, be considered as representing periodontitis? If the clinician takes the stance that the disease must be active to be diagnosed as periodontitis, such a diagnosis could be made only after documentation of additional attachment loss occurring between 2 time points.¹⁰ For a new patient with periodontal problems, this type of longitudinal diagnosis would be impossible, yet the clinician would not want to delay intervention until a second visit could be scheduled. It is therefore prudent to diagnose as periodontitis any periodontally involved sites exhibiting signs of inflammation.¹⁰



Figure 1: A conventional probe is used to determine the depth of a periodontal pocket. How accurate are these probes and does their limited resolution reduce their diagnostic value?

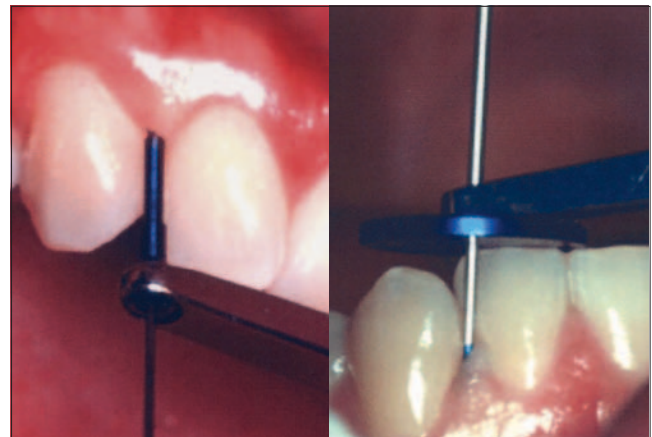


Figure 2: The Florida Probe. This electronic force-controlled probe has a 100-times higher resolution than a conventional probe. Does this increase translate into a useful diagnostic gain or does it simply provide too much information?

Table 1 Repeatability of conventional and force-controlled periodontal probes^a

Reference	Repeatability (measured as SD [mm] of mean difference between duplicate measurements)		
	Conventional	Florida, single pass	Florida, double pass
Osborn and others ¹⁴	0.81	1.15	0.44
Osborn and others ¹⁵	0.62	0.82	0.63
Rams and Slots ¹⁶	0.39	0.59	0.62

^aAdapted from Jeffcoat and Reddy¹³
SD = standard deviation.

The data usually collected during a routine clinical examination include demographic, medical and social details; dental history; periodontal probe measurements; radiographic findings; and miscellaneous observations, such as spontaneous gingival bleeding, plaque volume and bleeding on probing.¹¹

Enhancement of a Traditional Method — Reliability of Probing

Periodontal probing, a commonly used technique, provides the clinician with measurements of 2 important variables: probing depth and loss of clinical attachment. Probing depth is the distance from (usually) the gingival margin to the base of the probeable crevice.¹⁰ Loss of clinical attachment is measured from the cemento-enamel junction to the base of the pocket. Relative attachment loss (RAL) is measured from another fixed point such as a stent and is not necessarily related to root length. RAL is, in general, used to determine disease progression over a period of time or within clinical trials comparing different interventions. For a fuller discussion of the methods currently used to objectively quantify the progression of attachment loss in periodontal disease, and for guidance in choosing

specific analytic frameworks, the reader is referred to the excellent review by Beck and Elter.¹²

In addition to improvements in the analytic and methodological aspects of measuring periodontal disease, the use of electronic force-controlled probes is becoming increasingly popular. Do such devices offer any diagnostic improvement over conventional systems, such as the Michigan O probe (Fig. 1)? A number of studies¹³ have examined the repeatability, indicated by standard deviation, of one of the most popular force-controlled systems, the Florida probe (Florida Probe Corporation, Gainesville, Fla.) (Fig. 2), relative to that of conventional systems (Table 1). It is important to mention that the Florida probe takes measurements from the occlusal or incisal surfaces, and the data generated therefore incorporate tooth height.

The studies have shown that for single site measurements, the force-controlled probe offered no improvement in accuracy over the conventional probe; however, when each site was examined twice and a mean value determined, error was significantly less with the Florida probe. With all types of probes, an increase in pocket depth leads to an increase in standard deviation. The Florida probe, however, had greater resolution, with precision of 0.1 mm (the traditional probe allows resolution of only 1.0 mm). This greater resolution also explains some of the reduction in repeatability — higher resolution usually leads to greater opportunities for disagreement. The automated system used by the force-controlled probes reduces, or eliminates, errors in data entry. It is worthwhile to keep in mind that the 1996 World Workshop in Periodontics developed a consensus paper stating that automated recording and presentation of data by force-controlled probes offered no diagnostic advantage over conventional probes.¹⁷ It should also be noted that force-controlled probes are considerably more expensive than conventional probes.



Figure 3a: Standard radiograph.

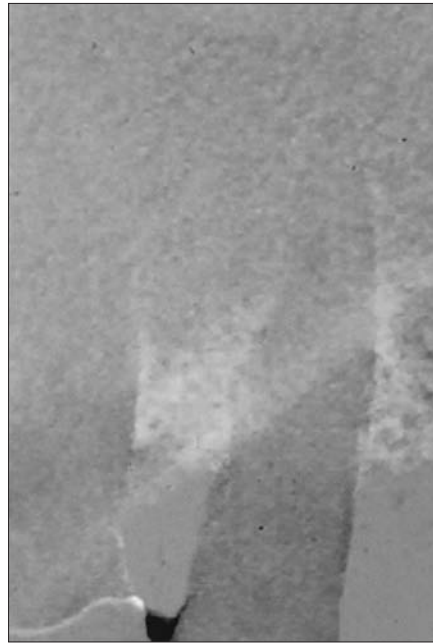


Figure 3b: Subtraction radiography showing bone loss (white areas) that has occurred since the last radiographic examination (Fig. 3a).

Radiographic Developments

Digital radiography, discussed previously in this series,³ has been applied to periodontal diagnosis with great success. Currently available technologies can discriminate changes in bone mass of as little as 1 mg in the imaged area.¹³ Whether or not such changes hold substantial clinical relevance should not detract from the obvious advantages that this technology affords. The ability to accurately measure the effects of therapies in a chronic condition such as periodontal disease is of great interest to those developing new treatments, as it permits a reduction in the number of subjects, as well as time, required for clinical trials.

Many different methods of radiographic diagnosis exist, each with its own resolution, reliability and accuracy.¹³ Radiographs are most commonly assessed by visual interpretation, usually via transillumination. Studies suggest that such interpretive radiology detects changes in bone only after 30% to 60% of the mineral has been lost, because of basic limitations in the technology, compounded by factors such as the clinician's experience, the method of processing the film and image geometry.¹³

Digital subtraction radiography (DSR) can overcome many of these potential limitations. The principle of DSR is a comparison of 2 images by software that automatically "subtracts" or deletes areas that are the same, leaving only areas of discrepancy (e.g., alveolar bone height). The software can apply quantitative measures and may even be able to correct for skew and magnification (although such systems usually require that the 2 images be identical in size and orientation).¹³ These corrections constitute what is

known as image registration. Failure to obtain correct registration will confound the data, and the resulting comparative image will exhibit areas of difference that are due to distortion rather than disease progression or regression (Figs. 3a and 3b). DSR¹³ can detect change of as little as 1% to 5%,¹⁸ and bone change of 1 mg can be identified with 87.8% sensitivity and 100% specificity.¹⁹ The correlation between measured and actual mass was more than 94%,¹⁹ which suggests that identification of changes in density allow for close correlation between measured and actual mass.²⁰

It is likely that as digital radiography becomes more common in dental practice, DSR will become a useful tool for periodontal specialists and anyone who works with

populations in which the disease is highly prevalent. Software that enables simple registration and colour-coded analysis of the images, for example showing bone loss in one colour and bone gain in another, should make the system an effective way to motivate and educate patients.

Other Methods

In addition to enhancements to these 2 traditional methods (probing and radiography), a number of additional diagnostic aids have recently become available, including analysis of gingival crevicular fluid, DNA tests of antigenic profiles, chairside tests for aspartate aminotransferase (which is released from dead and dying host cells) and neutrophil function assays. Although many of these methods may eventually reach general practice, DSR will remain the predominant technology in the detection, diagnosis and longitudinal monitoring of periodontal disease. This technology may in fact become widespread in the near future, such that many practitioners will require only simple software updates to enable them to conduct such analyses.

Other Advances in Nonperiodontal Diagnostic Science

Dentists observe and treat a wide range of diseases, abnormalities, pathoses and effects of trauma, and the range of diagnostic approaches and devices that could be used in management of these conditions continues to grow. Each field of dentistry has a variety of techniques to assist practitioners in detecting and diagnosing conditions of interest. Many of these technologies are well established



Figure 4a: The Periotest device.



Figure 4b: The Periotest device is used to determine the stability of the implants by measuring their dampening characteristics. Research has shown that the device is of great value in detecting failed or failing osseointegration.

and have been available to practitioners for quite some time (e.g., staining with toluidine blue), whereas others are not expected to be widely used until sometime in the distant future (e.g., computed tomography for apical lesions). The following is a brief review of some of the areas in which diagnostic science is advancing.

Endodontic Therapies

Like periodontal researchers, endodontists are interested in using DSR for a variety of tasks, including evaluation of periapical healing after endodontic therapy²¹ and detection of apical root resorption.²² In the assessment of root resorption, DSR analysis had a significantly better receiver operating characteristic value (ROC value of 1.00, or perfect) than traditional radiography value (which had an ROC of 0.64). Resorption as low as 0.5 mm could be detected.²² Recent research examining the detection of apical lesions by DSR found significant improvements in sensitivity over traditional transilluminated views. The mean sensitivity and specificity of the DSR system for detecting bone lesions of all sizes were 87.9% and 85.2%, respectively. The corresponding results for conventional radiographic images were 47.5% and 97.4%.²³

The use of apex locators within endodontic practice is now so ubiquitous that it cannot be considered an emerging technology, but researchers are still investigating ways to improve accuracy, especially under moist conditions. Initial *in vitro* research suggested that the resolution of apex locators would be ± 0.5 mm of the apex. However, the results of contemporary *in vivo* trials are conflicting.²⁴ There appears to be little difference between the radiographically measured and electronically determined apical position, and the use of such devices cannot guarantee precise determination of the apical constriction.²⁵ It seems that apex locators should be selected with care. In a recent comparison of 2 common brands of apex locators (both frequency-

based), the mean distance from the apex was 0.19 mm for one and 1.03 mm for the other.²⁶ This study, which employed teeth that were planned for extraction, had an *in vivo* component and an *in vitro* histological assessment. A systematic evaluation of the diagnostic performance of some of the tools described in the present series¹⁻⁵ would be useful to aid clinical practitioners in their purchasing decisions.

Advances in Implant Diagnostic Science

Dental implants are rapidly becoming an important treatment option for partially and completely edentulous patients. One diagnostic dilemma within implant dentistry is the assessment of osseointegration and the determination of the presence or absence of peri-implant bone defects. Implant dentistry has used some tests that cannot on their own be considered novel, yet their application in this field is relatively new. The Periotest device (Medizintechnik Gulden, Bensheim, Germany), originally designed to provide a qualitative value for tooth mobility, is now being used to assess osseointegration and the presence of pathological bone loss on implant review (Figs. 4a and 4b).

Teerlinck and others²⁷ have shown that the Periotest device yields extremely reproducible (and hence reliable) results for measurement of implant osseointegration, with 95% of measurements falling within a range of 1 unit on the Periotest scale. They discovered that the degree of bone apposition was closely related to the Periotest value (PTV). In a 1997 study²⁸ reporting Periotest data for a total of 1,182 Brånemark implants observed over an 8-year period, the PTV provided an accurate measurement of initial success, healing times and progress. The study also determined that a PTV of 9 or above indicated failure. This threshold value has enabled earlier detection of failure, often before the placement of expensive prostheses. Despite these very encouraging results, others have reported that the

striking height and angle of the Periotest device can affect the data obtained²⁹ and have suggested that caution is required in the interpretation of the PTV.

The vast majority of Periotest research, however, endorses the use of this device for detection of nonradiographically visible failure or for monitoring of bone remodelling. The device is currently available commercially and, given the desire to reduce the number of radiographs obtained after implant placement, may be of interest to those involved in the surgical and prosthodontic aspects of implant work.

Conclusions

This article is not intended to provide an exhaustive list of dental diagnostic innovations; for example, it has not covered the important area of diagnosis in oral medicine, where the development of new systems for the detection of premalignant lesions is a topic worthy of consideration. Rather, we have presented an overview of some areas in which diagnostic science is developing in dentistry today.

Through this series we have sought to empower the reader by providing the basic tools to assess the value of diagnostic tests, and we hope that these tools will lead to changes in practice habits, by allowing clinicians to determine whether a certain test, such as a bitewing radiograph, will really provide the information that he or she needs. They may also assist clinicians who are considering the purchase of a new diagnostic device. By accessing some of the many online bibliographic databases, such as PubMed, prospective purchasers can avail themselves of the applicable research and, with an understanding of the attributes of a diagnostic test as described in the present series of articles, determine if the proposed tool will address the diagnostic dilemma. In the years to come, we can look forward to tests that can help us to identify active occlusal caries, measures that will provide accurate quantitative information on tooth wear and erosion, and perhaps endodontic tools that will provide accurate, tridimensional working lengths.

Diagnosis is an essential part of what we, as clinicians, do every day. By better understanding the principles behind diagnostic science we can make *informed* diagnostic and treatment decisions and thus better serve our profession and our patients. ♦

Acknowledgements: Permission to reproduce Figures 3a and 3b kindly granted by the British Institute of Radiology. From Shi XQ, Eklund I, Tronje G, Welander U, Stamakatis HC, Engstrom PE and other. Comparison of observer reliability in assessing alveolar bone changes from color-coded with subtraction radiographs. *Dentomaxillofac Radiol* 1999; 28(1):31–6.



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References

1. Pretty IA, Maupomé G. A closer look at diagnosis in clinical dental practice: Part 1. Reliability, validity, specificity and sensitivity of diagnostic procedures. *J Can Dent Assoc* 2004; 70(4):251–5.
2. Pretty IA, Maupomé G. A closer look at diagnosis in clinical dental practice: Part 2. Using predictive values and receiver operating characteristics in assessing diagnostic accuracy. *J Can Dent Assoc* 2004; 70(5):313–6.
3. Pretty IA, Maupomé G. A closer look at diagnosis in clinical dental practice: Part 3. Effectiveness of radiographic diagnostic procedures. *J Can Dent Assoc* 2004; 70(6):388–94.
4. Maupomé G, Pretty IA. A closer look at diagnosis in clinical dental practice: Part 4. Effectiveness of nonradiographic diagnostic procedures and devices in dental practice. *J Can Dent Assoc* 2004; 70(6):470–4.
5. Maupomé G, Pretty IA. A closer look at diagnosis in clinical dental practice: Part 5. Emerging technologies for caries detection and diagnosis. *J Can Dent Assoc* 2004; 70(8):540. Available from: URL: <http://www.cda-adc.ca/jcda/vol-70/issue-8/540.html>
6. Centres for Disease Control and Prevention. Public health and aging: retention of natural teeth among older adults — United States, 2002. *Morb Mortal Wkly Rep* 2003; 52(50):1226–9.
7. Haddad I, Haddadin K, Jebrin S, Ma'ani M, Yassin O. Reasons for extraction of permanent teeth in Jordan. *Int Dent J* 1999; 49(6):343–6.
8. Gilbert GH, Duncan RP, Shelton BJ. Social determinants of tooth loss. *Health Serv Res* 2003; 38(6 Pt 2):1843–62.
9. Fure S. Ten-year incidence of tooth loss and dental caries in elderly Swedish individuals. *Caries Res* 2003; 37(6):462–9.
10. Armitage GC. Research, Science and Therapy Committee of the American Academy of Periodontology. Diagnosis of periodontal diseases. *J Periodontol* 2003; 74(8):1237–47.
11. Armitage GC. Clinical evaluation of periodontal diseases. *Periodontol* 2000, 1995; 7:39–53.
12. Beck JD, Elter JR. Analysis strategies for longitudinal attachment loss data. *Community Dent Oral Epidemiol* 2000; 28(1):1–9.
13. Jeffcoat MK, Reddy MS. Advances in measurements of periodontal bone and attachment loss. *Monogr Oral Sci* 2000; 17:56–72.
14. Osborn J, Stoltenberg J, Huso B, Aeppli D, Pihlstrom B. Comparison of measurement variability using a standard and constant force periodontal probe. *J Periodontol* 1990; 61(8):497–503.
15. Osborn JB, Stoltenberg JL, Huso BA, Aeppli DM, Pihlstrom BL. Comparison of measurement variability in subjects with moderate periodontitis using a conventional and constant force periodontal probe. *J Periodontol* 1992; 63(4):283–9.
16. Rams TE, Slots J. Comparison of two pressure-sensitive periodontal probes and a manual periodontal probe in shallow and deep pockets. *Int J Periodontics Restorative Dent* 1993; 13(6):520–9.
17. Armitage GC. Periodontal diseases: diagnosis. *Ann Periodontol* 1996; 1(1):37–215.

18. Ortman LF, Dunford R, McHenry K, Hausmann E. Subtraction radiography and computer assisted densitometric analyses of standardized radiographs. A comparison study with 125I absorptiometry. *J Periodontol Res* 1985; 20(6):644-51.
19. Jeffcoat MK, Reddy MS, Magnusson I, Johnson B, Meredith MP, Cavanaugh PF, Jr., and other. Efficacy of quantitative digital subtraction radiography using radiographs exposed in a multicenter trial. *J Periodontol Res* 1996; 31(3):157-60.
20. Reddy MS, Weatherford TW 3rd, Smith CA, West BD, Jeffcoat MK, Jacks TM. Alendronate treatment of naturally-occurring periodontitis in beagle dogs. *J Periodontol* 1995; 66(3):211-7.
21. Yoshioka T, Kobayashi C, Suda H, Sasaki T. An observation of the healing process of periapical lesions by digital subtraction radiography. *J Endod* 2002; 28(8):589-91.
22. Heo MS, Lee SS, Lee KH, Choi HM, Choi SC, Park TW. Quantitative analysis of apical root resorption by means of digital subtraction radiography. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2001; 91(3):369-73.
23. Dove SB, McDavid WD, Hamilton KE. Analysis of sensitivity and specificity of a new digital subtraction system: an in vitro study. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2000; 89(6):771-6.
24. Tinaz AC, Maden M, Aydin C, Turkoz E. The accuracy of three different electronic root canal measuring devices: an in vitro evaluation. *J Oral Sci* 2002; 44(2):91-5.
25. Hoer D, Attin T. The accuracy of electronic working length determination. *Int Endod J* 2004; 37(2):125-31.
26. Welk AR, Baumgartner JC, Marshall JG. An in vivo comparison of two frequency-based electronic apex locators. *J Endod* 2003; 29(8):497-500.
27. Teerlinck J, Quirynen M, Darius P, van Steenberghe D. Periotest: an objective clinical diagnosis of bone apposition toward implants. *Int J Oral Maxillofac Implants* 1991; 6(1):55-61.
28. Aparicio C. The use of the Periotest value as the initial success criteria of an implant: 8-year report. *Int J Periodontics Restorative Dent* 1997; 17(2):150-61.
29. Meredith N, Friberg B, Sennerby L, Aparicio C. Relationship between contact time measurements and PTV values when using the Periotest to measure implant stability. *Int J Prosthodont* 1998; 11(3):269-75.