Position Paper

Diagnosis of Periodontal Diseases*

This position paper on the diagnosis of periodontal diseases was prepared by the Research, Science and Therapy Committee of the American Academy of Periodontology. It is intended for the information of the dental profession and other interested parties. The purpose of the paper is to provide the reader with a general overview of the important issues related to the diagnosis of periodontal diseases. It is not intended as a comprehensive review of the subject. *J Periodontol 2003;74:1237-1247.*

Plaque-induced periodontal diseases are mixed infections associated with relatively specific groups of indigenous oral bacteria.[1-6] Susceptibility to these diseases is highly variable and depends on host responses to periodontal pathogens.[7-11] Although bacteria cause plaque-induced inflammatory periodontal diseases, progression and clinical characteristics of these diseases are influenced by both acquired and genetic factors that can modify susceptibility to infection.[12-15]

TRADITIONAL APPROACH TO DIAGNOSIS

Despite our increased understanding of the etiology and pathogenesis of periodontal infections, the diagnosis and classification of these diseases is still based almost entirely on traditional clinical assessments.[16,17] To arrive at a periodontal diagnosis, the dentist must rely upon such factors as: 1) presence or absence of clinical signs of inflammation (e.g., bleeding upon probing); 2) probing depths; 3) extent and pattern of loss of clinical attachment and bone; 4) patient's medical and dental histories; and 5) presence or absence of miscellaneous signs and symptoms, including pain, ulceration, and amount of observable plaque and calculus.[18-20]

Plaque-induced periodontal diseases have traditionally been divided into two general categories based on whether attachment loss has occurred: gingivitis and periodontitis. Gingivitis is the presence of gingival inflammation without loss of connective tissue attachment.[16] Periodontitis can be defined as the presence of gingival inflammation at sites where there has been a pathological detachment of collagen fibers from cementum and the junctional epithelium has migrated apically. In addition, inflammatory events associated with connective tissue attachment loss also lead to the resorption of coronal portions of tooth-supporting alveolar bone.[16]

This simple separation of plaque-induced periodontal diseases into two categories is not as clear-cut as it first appears. For example, if sites that have been successfully treated for periodontitis develop some gingival inflammation at a later date, do those sites have recurrent periodontitis or gingivitis superimposed on a reduced but stable periodontium? There are currently no data to definitively answer this question. However, since not all sites with gingivitis necessarily develop loss of attachment and bone,[17] it is reasonable to assume that gingivitis can occur on a reduced periodontium in which ongoing attachment loss is not occurring. A similar problem exists when the term "periodontitis" is assigned to sites with attachment loss and periodontal pockets in which ongoing periodontal destruction is not occurring.

Demonstration of the progression of periodontitis requires documentation of additional attachment loss occurring between at least two time points. Since this is not always possible, especially when a patient is examined for the first time, most clinicians assign the diagnosis of "periodontitis" to inflamed sites that also have loss of attachment and bone. This is a prudent practice since such sites may be either currently progressing or are at an increased risk for further periodontal destruction. Therefore, demonstration of progressive attachment loss is not generally considered to be a requirement for using "periodontitis" as a diagnostic label.

At the 1999 International Workshop for Classification of Periodontal Diseases and Conditions, a reclassification of the different forms of plaque-induced periodontal diseases was developed.[21] This revised classification includes seven general types of plaque-induced periodontal diseases: 1) gingivitis, 2) chronic

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periodontitis, 3) aggressive periodontitis, 4) periodontitis as a manifestation of systemic diseases, 5) necrotizing periodontal diseases, 6) abscesses of the periodontium, and 7) periodontitis associated with endodontic lesions.[21] The major departures from the previous classification system are: 1) the term "chronic periodontitis" has replaced "adult periodontitis" and 2) the term "aggressive periodontitis" has replaced "early-onset periodontitis." In the new classification system, depending on a variety of circumstances, all forms of periodontitis can progress rapidly or slowly and can be non-responsive to therapy. It was also acknowledged that gingivitis can develop on a reduced but stable periodontium.[21]

The above classification should not be confused with case types previously suggested by the American Academy of Periodontology for purposes of third-party insurance payments. The current case types for periodontal diseases include: gingivitis (Case Type I), mild periodontitis (Case Type II), moderate periodontitis (Case Type III), advanced periodontitis (Case Type IV), and refractory periodontitis (Case Type V).

DIAGNOSTIC INFORMATION

Periodontal diagnoses are determined by analyzing the information collected during a periodontal examination. A decision is then made regarding the disease category that is most closely associated with the patient's clinical status. The information routinely collected during a periodontal examination includes demographic data (e.g., age, gender, etc.), medical history, history of previous and current periodontal problems, periodontal probe measurements (i.e., probing depths, clinical attachment loss, etc.), radiographic findings, and miscellaneous clinical features or observations (e.g., gingival inflammation, plaque/calculus, mobility, occlusal problems). In some situations, supplemental qualitative or quantitative assessments of the gingival crevicular fluid (GCF) and subgingival microflora are performed. In addition, a genetic test for susceptibility to chronic periodontitis has become commercially available.[16]

It should be emphasized that, at the present time, supplemental information on GCF components, the subgingival microflora, and genetic susceptibility are not commonly used by practitioners in arriving at a diagnosis since the diagnostic utility of this information has not been validated. Indeed, genetic testing is primarily intended to assist in risk assessment and should not be considered a diagnostic test. In addition, testing for the presence of specific putative pathogens in the subgingival flora might be useful in identifying a microbial target of periodontal therapy, but it does not provide information that is used in determining a periodontal diagnosis.

SCIENTIFIC EVALUATION OF DIAGNOSTIC TESTS

Statistical validation of a potentially useful diagnostic test routinely involves use of a two-by-two decision matrix as shown in Figure 1. From such tables, the validity of a diagnostic or prognostic test can be estimated.[22] A diagnostic device or test is intended to detect the presence of a specified disease. Data collection to evaluate a diagnostic test frequently employs a cross-sectional sampling scheme, and the validity of the test can be estimated by calculating its sensitivity and specificity. These can only be determined in a cross-sectional study if the true disease status of the patient can be established from a single examination. This is the case for the presence or absence of periodontitis. The sensitivity of a diagnostic test refers to the probability of the test being positive when the disease is truly present. A perfect test would be able to detect the disease in all cases without registering a false negative. The sensitivity of such a perfect test would be 1.00. The specificity of a diagnostic test refers to the probability of the test being negative when the disease is not present. A perfect test would be able to correctly identify all instances in which the disease was absent without registering a false positive. The specificity of such a perfect test would be 1.00. However, in medicine and dentistry, perfect diagnostic tests do not exist. Therefore, a test's sensitivity and specificity will always be less than 1.00. It is reasonable to expect that a clinically useful diagnostic test for periodontal diseases should have high values for both sensitivity and specificity. There are, however, no preset upper and lower limits of sensitivity and specificity values that determine if a diagnostic test is clinically useful. Furthermore, since sensitivity and specificity values are calculated in diseased or healthy populations, respectively, these values may be higher than calculations performed in a mixed population. In contrast, predictive values are calculated in a mixed population of diseased and healthy patients.

The positive predictive value of a test refers to the probability that the disease is present when the test is positive. The negative predictive value refers to the probability that the disease is absent when the test is negative. However, predictive values are influenced by the prevalence of disease in a population. Thus, in a periodontal practice where there are many patients

	Disease Present	Disease Absent
Test Positive	A (true-positive)	C (false-positive)
Test Negative	B (false-negative)	D (true-negative)

$$\text{Sensitivity} = \frac{A}{A+B} \qquad \text{Specificity} = \frac{D}{C+D}$$

$$\text{Positive Predictive Value} = \frac{A}{A+C} \qquad \text{Negative Predictive Value} = \frac{D}{B+D}$$

Figure 1.
Decision matrix for diagnostic and prognostic tests.

	Disease Present	Disease Absent
Risk Factor Present	A	C
Risk Factor Absent	B	D

Absolute Risk
a) Risk Factor Present $= A/A + C$
b) Risk Factor Absent $= B/B + D$

$$\text{Relative Risk} = \frac{A/A+C}{B/B+D}$$

$$\text{Odds Ratio:} \quad \frac{A/B}{C/D} = \frac{AD}{BC}$$

Figure 2.
Contingency table for assessing risk.

with periodontal disease, a test may have a higher predictive value than the same test in a general practitioner's office where there is a lower prevalence of periodontitis.

In the current practice of periodontics, procedures performed during the course of a routine periodontal examination are usually sufficient to identify sites that have undergone pathologic changes associated with periodontitis. Such examinations can detect sites with features of periodontitis such as the presence of inflammation, periodontal pockets, local etiologic factors, and loss of clinical attachment and bone. However, current periodontal examination procedures performed at a single visit cannot determine whether sites are currently undergoing additional attachment loss.

A prognostic device or test is intended to assess the risk of developing the disease at some point in the future. Calculations can be made by using the two-by-two contingency table (Fig. 2) to determine absolute risk, relative risk and odds ratios that are measures of the increased risk of developing the disease. Absolute risk refers to the probability that an individual will develop an adverse outcome over a specified time and can be calculated in prospective studies. Relative risk is the ratio of disease in an exposed group to the risk of disease in an unexposed group. It indicates the strength of the assessed relationship. The odds ratio measures the odds of having the exposure (risk factor) if the disease is present, divided by the odds of having the exposure if the disease is absent. It is usually calculated in retrospective studies and also indicates the strength of the association. It is important to note that relative risk and odds ratios refer to the strength of a relationship and cannot be used to predict what will occur. For example, if a test that is designed to identify high-risk sites for developing additional bone loss has an odds ratio of 15, it means that sites with a positive test are at a 15-fold higher risk of developing additional bone loss within a specified time. For an in-depth analysis and discussion of the statistical evaluation and interpretation of the validity of diagnostic tests, readers are referred to an excellent review of the subject.[22]

SUPPLEMENTAL DIAGNOSTIC TESTS

Supplemental diagnostic tests can be used to perform two basic tasks. The first is screening, i.e., to separate diseased from non-diseased patients. The second is to detect sites or patients undergoing the progression of periodontitis. The second task is more demanding than the first. It is also of greater importance since the clinician can easily separate healthy from periodontitis patients based on customary clinical criteria. The clinical value of fully validated diagnostic tests is considerable in that the results of such tests are potentially useful in identifying the presence of therapeutic targets (i.e., putative pathogens), monitoring the response to therapy, identifying sites at high risk for progression, and assisting the clinician in determining a patient-specific recall interval for periodontal maintenance therapy. Several supplemental diagnostic tests are currently available and some are under develop-

ment. Most of them are designed to provide information presumably associated with progressing periodontal lesions.

Supplemental diagnostic tests fall into four general categories. They can be used to detect the presence of: 1) substances associated with putative pathogens; 2) host-derived enzymes; 3) tissue breakdown products; or 4) inflammatory mediators.

Several strategies have been developed to detect substances associated with putative periodontopathogens.[19] They include DNA analyses,[23-31] assessment of antigenic profiles,[32-41] and enzymatic activities of certain members of the subgingival flora.[42-52] The general aim of all of these approaches is to detect the presence of potentially pathogenic bacteria in subgingival plaque samples. They have the advantage of not requiring the collection and preservation of viable bacteria. Most of these tests can reliably identify sites that harbor certain putative pathogens and thereby provide information about potential therapeutic targets. For example, if recently treated sites continue to harbor high levels of pathogens, then it is reasonable to conclude that additional therapy may be required. In such instances, the tests could be used to monitor or assess the endpoint or effectiveness of therapy with the ideal result being a negative test for the putative pathogens. One drawback of existing microbiologic tests that do not culture the bacteria is that they are designed to detect only a limited number of pathogens. They cannot distinguish between virulent and avirulent clones of putative pathogens. Another drawback is their inability to provide any information about the antibiotic sensitivities of the infecting bacteria. The only known way to determine antibiotic susceptibilities of suspected pathogens is by cultural analysis and sensitivity testing of the subgingival flora.[53-56]

An array of enzymes, tissue breakdown products, and inflammatory mediators are released from host cells and tissues during the development and progression of periodontal infections. Some of these substances have been suggested as possible markers for the detection of progressing periodontal lesions. A number of studies have been conducted with the general goal of devising chairside assays for markers of disease progression in GCF.[19] Host-derived enzymes that have received the most attention in this regard are: aspartate aminotransferase,[57-63] alkaline phosphatase,[59,64-67] β-glucuronidase,[59,68-72] elastase,[59,73-83] cathepsins,[84-89] and dipeptidyl peptidase.[84-85,90] Inflammatory mediators in GCF that might be associated with advancing periodontal lesions include prostaglandin E_2[59,67,91-93] and several cytokines.[19,72,93-104] Tissue breakdown products in GCF that have been suggested as possible markers for progressing periodontal lesions include glycosaminoglycans[105-110] and several bone-associated proteins.[59,67,111-116]

Chairside tests for asparate aminotransferase (AST) and nonspecific neutral proteinases have been developed. Dead and dying host cells release AST. Results from several longitudinal studies of chronic periodontitis patients in which increased clinical attachment loss was used as the criterion for disease progression, suggest that the GCF content of AST might serve as a site-specific marker for ongoing periodontal destruction.[57-62] Since AST is elevated at sites with either gingivitis or nonprogressing periodontitis, it remains to be established if its levels in GCF can distinguish between sites that are breaking down and those that are not.[19]

The other GCF assay for host enzymes is a test for non-specific neutral proteinases. These lysosomal enzymes are primarily derived from neutrophils and have been shown to be elevated in GCF from sites with advanced periodontitis.[117-119] This enzyme-detection system has not been longitudinally tested to determine if it can reliably detect sites at an increased risk for progression. Neither the AST nor nonspecific proteinase assays were originally marketed under the claim that they could detect progressing sites. They were simply sold as enzyme assays. It was left up to the clinician to decide if the elevation of AST or neutral proteinases in GCF had any clinical relevance. Neither test is currently commercially available.

Further development and clinical testing of certain GCF-based diagnostic tests are warranted in order to identify markers that are useful in identifying sites that are undergoing loss of periodontal attachment. Such tests could be used to detect sites that require additional treatment prior to, or during, the maintenance phase of therapy. They also could be of value in establishing optimal recall intervals for previously treated patients. For example, patients with persistently positive tests may require more frequent recall visits. In addition, patients who are in the most urgent need of treatment might be more easily identified through the use of such tests.

In a research environment, neutrophil function assays and tests for cell-surface receptors can provide potentially useful diagnostic information. For example, neutrophils from some patients with localized aggressive periodontitis (LAgP) exhibit faulty chemotaxis and abnormal bactericidal activity.[9] Molecular markers of LAgP include an abnormally

low number of chemoattractant receptors and an abnormal amount of another cell-surface glycoprotein designated GP-110.[120,121] On the other hand, patients with generalized aggressive periodontitis have normal numbers of GP-110 receptors.[120,121] It is probable that tests of this type that are suitable for use in clinical situations will eventually be developed. However, at the present time, such tests are not available for widespread clinical application.

The only host-based test for susceptibility to periodontitis that is currently available to practitioners is a genetic test for polymorphisms in the interleukin-1 (IL-1) gene cluster.[15] The IL-1 gene cluster includes IL-1A, IL-1B, and IL-1RN genes that code for IL-1α, IL-1β, and the IL-1 receptor antagonist (IL-1ra) respectively. Approximately 30% of Caucasians are positive for a composite genotype of IL-1A and IL-1B polymorphisms consisting of allele 2 of both IL-1A + 4845 (or the concordant -889) and IL-1B + 3954.[15] People who carry this composite genotype may be at an increased risk of the following: bleeding upon probing,[122] severe chronic periodontitis,[15] tooth loss,[123] and reduced stability of gains of clinical attachment after guided tissue regeneration.[124] Presumably this is due to hypersecretion of IL-1β in response to inflammation-inducing stimuli.[125] In contrast, other studies have noted that the composite genotype cannot be used to identify patients that are predisposed to the following: tooth loss,[126] periodontitis,[127] attachment loss after therapy,[128] or increased secretion of IL-1β.[129] Since there is conflicting information in the literature, these concepts need further validation.

It should also be noted that the prevalence of the IL-1 composite genotype is very low in some populations. For example, in people of Chinese heritage only 2.3% are genotype-positive.[130] In addition, the IL-1 genotype associated with increased risk of severe chronic periodontitis does not appear to be a risk marker for aggressive forms of periodontitis.[131,132] Therefore, in certain populations, the test is of little or no value in establishing the risk for susceptibility to periodontitis. In conclusion, at present, how best to use this genetic test in clinical practice has not been established.

ADVANCES IN TRADITIONAL DIAGNOSTIC METHODS

In clinical practice, conventional periodontal probes are widely used to obtain two important measurements: probing depth (PD) and clinical attachment loss (CAL). PD is defined as the distance from the gingival margin to the base of the probeable crevice. CAL is the distance from the cementoenamel junction to the base of the probeable crevice. Probing depth measurements are clinically important since they provide a useful overall assessment of the depth of periodontal pockets which are the principal habitats of periodontal pathogens. In addition, PD measurements can be rapidly recorded and give a good assessment of the distribution of periodontal problems within a given patient. They are an essential component of a complete periodontal examination.

CAL assessments on the other hand are more difficult to accurately measure, but they give a better overall estimate of the amount of damage to the periodontium than do PD measurements. In prospective studies, CAL measurements are the most valid method of assessing treatment outcomes.[133] Multiple studies indicate that, in the hands of experienced practitioners, CAL measurements taken with conventional periodontal probes at different visits are repeatable to within ±1 mm more than 90% of the time.[19,133] Under clinical conditions, comparable repeatability values have been obtained with computer-linked, controlled-force electronic periodontal probes.[19,133] Electronic probes have the advantage of controlling insertion forces and automatically recording clinical information into a computer.[19,133,134] In addition to controlled insertion force, electronic probes have a better resolution than standard manual probes. This feature is important since it makes it theoretically feasible to detect smaller changes in clinical attachment levels than are possible with manual probes.[135] For example, in one study, untreated chronic periodontitis patients were examined over a 6-month period using a prototype of an automated probe which has an accuracy of 0.2 mm. It was found that if a threshold of 0.4 mm was used to indicate that a change in attachment level had occurred, the prevalence of sites that had progressed was 29% over the 6-month period. If a large threshold (i.e., 2.4 mm), comparable to that achievable with a manual probe was used, only 2% of the sites were determined to have experienced additional attachment loss.[136]

Manual (conventional) periodontal probes are highly satisfactory for the performance of routine periodontal examinations. Comparable results are obtained when either manual or electronic probes are used.[19] Some practitioners prefer electronic over conventional periodontal probes, especially because of the automatic data entry feature afforded by these devices. The main drawback of electronic probes is their tendency to underestimate PD and CAL measurements in untreated patients.[19] In such patients, the presence of subgingival calculus can interfere with probe inser-

tion. To minimize this problem, reproducibility of clinical measurements taken with controlled-force probes can be improved by using a "double-pass" method (i.e., measuring each site twice).[19,137,138] In treated patients, this reproducibility problem is not as great. Indeed, in treated patients, lower standard deviations of replicate single-pass clinical measurements have been obtained with controlled-force compared to conventional probes.[139,140]

In the past decade, many advances have been made in radiographic imaging methods for periodontal structures. Advanced direct digital (filmless) radiographic and computed tomographic techniques have been developed to the stage where they are already being used on a day-to-day basis by practitioners.[141] Intraoral radiographs, such as periapical films and vertical or horizontal bitewings, provide a considerable amount of information about the periodontium that cannot be obtained by any other non-invasive means. The information supplied by radiographs includes root length, root form, presence or absence of periapical lesions, root proximity, and estimates of remaining alveolar bone. Although valid periodontal diagnoses cannot be made from radiographs alone, they are an essential component of a complete periodontal examination.[19]

Conventionally read radiographs routinely underestimate the amount of bone loss.[19,142,143] In addition, sequentially taken radiographs, when examined by eye, are able to reveal changes in bone only after 30 to 50% of the bone mineral has been resorbed.[135,141,144] Subtraction radiography, on the other hand, allows detection of changes in bone density as low as 5%. Although subtraction radiography detects changes after they have occurred, it is possible with this technique to detect very small changes in alveolar bone that would go unnoticed with conventionally read films.[135,136,141,145,146]

Many of the logistical problems initially associated with subtraction radiography are being overcome. Software programs have been developed to correct for subtle differences in contrast, projection geometry, and other repeatability errors.[141] Standardization of film positioning and angulation can be achieved by using a cephalostat[147] or custom-made positioning devices.[148] Future development of subtraction radiography techniques promises to have a profound impact on the diagnosis of periodontal diseases. It is of interest that there is approximately an 80% concordance or agreement between probing and radiographic methods in identifying sites that have lost attachment.[73,149,150]

SUMMARY

At the present time, the diagnosis and classification of periodontal diseases are almost entirely based on traditional clinical assessments. Supplemental quantitative and qualitative assessments of the gingival crevicular fluid and subgingival microflora can potentially provide useful information about the patient's periodontal disease. In certain situations, these supplemental risk-assessment tests may be particularly valuable in establishing the endpoint of therapy prior to placing patients on a periodontal maintenance program. Although the clinical utility of none of these tests has been validated, their further development is warranted. A genetic test for susceptibility to periodontitis has become commercially available. How best to use this and future host-based tests in clinical practice remains to be determined. Probing depth and clinical attachment loss measurements obtained with periodontal probes are practical and valid methods for assessing periodontal status. Computer-linked, controlled-force electronic periodontal probes are commercially available and are currently in use by some practitioners. Many of the logistical problems associated with subtraction radiography are being overcome and this powerful diagnostic tool may soon come into widespread use. Future developments in this and other imaging techniques are likely to have a profound effect on our approach to the diagnosis of periodontal diseases.

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