The Oral Health Information Suite (OHIS): Its Use in the Management of Periodontal Disease

Roy C. Page, D.D.S., Ph.D.; John A. Martin, D.D.S.; Carl F. Loeb, B.A.

Abstract: Health care costs continue to increase at a rapid rate. Dental costs alone have risen from $31.5 billion in 1990 to $70.3 billion in 2002, outpacing inflation by 160 percent. Payers for health care services have no means to evaluate the value of these large expenditures. Quantified information is not available regarding a patient's condition prior to and after treatment nor on the probability of future disease. The absence of this information prevents dentists from responding effectively to challenges by payers and patients, and specifically prevents dentists from effectively influencing the quality of periodontal care. We have developed a user-friendly Internet-based technology that quantifies risk for periodontitis and periodontal disease severity and extent and generates recommended treatments and interventions. A caries risk assessment tool has also been developed, and an oral cancer assessment tool is being developed. This technology, designated the Oral Health Information Suite (OHIS)™, provides quantitative information to the clinician and patient as an aid to diagnosis and to facilitate individual, needs-based treatment planning. OHIS enables successful application of the wellness model of oral health care, which may be expected to result in more uniform and accurate clinical decision making, improved oral health, reduction in the need for complex periodontal therapy, reduction in oral health care costs, and improved clinician productivity and income. It also will permit patients to become more involved in their oral health care, payers to quantify and predict their health care expenditures, dentists to experience an increase in trust and respect, and periodontists to be more properly consulted regarding periodontal care.

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The cost of health care including oral health care in the United States is increasing at an alarming rate. Managed care and other cost containment efforts have delivered as much savings as they are likely to be able to deliver. Health care expenditures were $1.6 trillion in 2002, growing by 123 percent since 1990 during a period when inflation rose by 36 percent. By 2013 this cost is projected to more than double to $3.4 trillion, yet again more than three times faster than the projected inflation rate.[1] Dental costs rose from $31.5 billion in 1990 to $70.3 billion in 2002, outpacing inflation by 160 percent.[2] About 75 percent of dental costs are directed to treating and managing caries and periodontal diseases.[3,4] According to the American Dental Association, expenditures for periodontal services in 1999 totaled $14.3 billion, with $9.8 billion expended on preventive procedures.[5] Payers for health care services have initiated methods to examine the value of these large expenditures,[6] but outcomes measurement remains elusive for oral health care.[7,8] Patients cannot evaluate the technical quality of care.[6] Clinicians cannot evaluate treatment effectiveness in the context of patient defined outcomes using true endpoints.[6-9] Numerous experts have explained how these deficiencies interfere with quality health care.[6,10-15] The Institute of Medicine defines health care quality as "the degree to which health services for individuals and populations increase the likelihood of desired health outcomes and are consistent with current professional knowledge."[16] Long-term studies by Axelsson et al.[17-21] indicate that oral health care quality can be improved with a net savings of at least 50 percent when treatment is targeted to the needs of each individual patient, based on their unique risk and disease profile. Axelsson's findings are consistent with projected savings in medicine due to improving quality.[11]

The purpose of this article is to present the case supporting transition from the repair to the wellness

model of oral health care and to describe the requirement for quantitative assessment and expression of disease risk and status for this transition to occur. We then describe an oral health information system, the Oral Health Information Suite (OHIS)™ that can provide the necessary information. The OHIS is comprised of related products for the major oral health conditions. The description of the clinical application of OHIS will center on transition to the wellness model in the management of periodontal disease. Use of the tool is expected to enable a value measurement for oral health care, determine treatment effectiveness, improve oral health, and stabilize or lower the cost of care while simultaneously increasing clinician productivity.

Rationale and Need for the OHIS

The Wellness Model of Dental Care

Dental caries and periodontal disease are the major causes of tooth loss.[22,23] Until roughly the 1970s, virtually all children and adults in the United States had dental caries, and almost all adults developed periodontal disease.[24,25] As shown in Figure 1, in the 1950s approximately 80 percent of children thirteen to fifteen years of age had gingivitis. Periodontitis was observed to begin in the late teenage years and to increase almost linearly until early middle age after which close to 100 percent of the adult population under sixty years was affected. Tooth loss began in the late teenage years and increased linearly through age sixty. Virtually all children and adults also manifested dental caries. Both diseases were ubiquitous throughout the dentulous population.

Traditionally, management of both diseases has been based on the repair model of care under which the clinician's goal was to diagnose the problems and resolve them via treatment. Treatments were empirical and basically the same for all patients. The concepts that host factors are important in the pathophysiology of periodontitis and that individuals may vary greatly in their level of risk had not been conceived until the 1970s. Preventive measures were largely ignored and later, when they were used, they were not applied uniformly throughout the population. It was in this environment that third party payer plans to finance dental care in the United States were

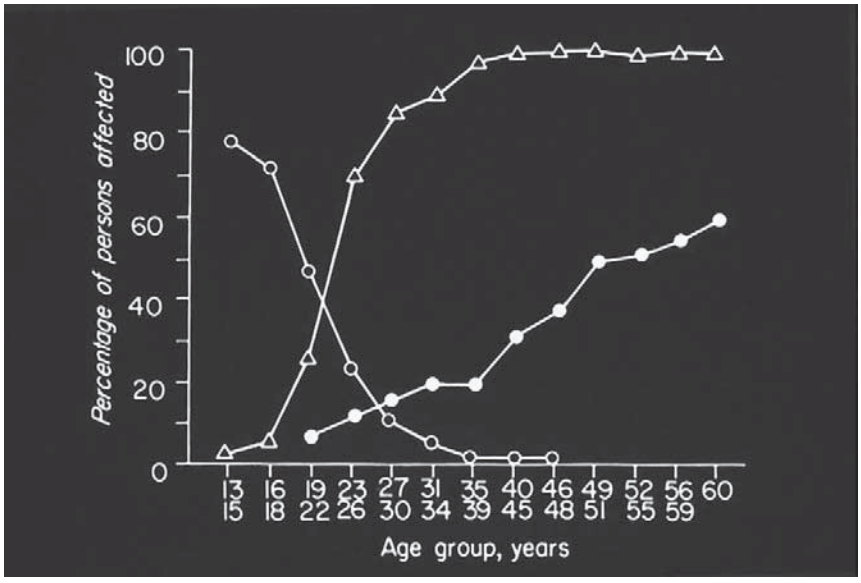

Figure 1. Prevalence of gingivitis and periodontitis in the 1950s

Gingivitis (open circle); Periodontitis (open triangle); Tooth Mortality (closed circle)

Source: Adapted from Marshall-Day CD, Stephens RG, Quigley LF Jr. Periodontal disease: prevalence and incidence. J Periodontol 1955;26:185-203.

developed. The first plan was developed and marketed by Washington Dental Service (WDS) in 1954 in the State of Washington; plans developed subsequently by other carriers were based on the WDS model. Under these plans, all covered individuals in a given plan paid the same premium, and all received the same level and intensity of care.

Knowledge about the nature of caries and periodontal disease has increased enormously since the 1970s, resulting in changing diagnostic and treatment paradigms. The evidence demonstrates that although periodontal disease and caries are infectious, bacteria alone are insufficient. A susceptible host is also essential for disease to occur. Susceptibility and risk for disease vary greatly from one individual to another, and major factors that place individuals at risk have been identified.[27]

Disease prevalence has changed markedly in recent decades. Caries and periodontal disease are no longer uniformly distributed in the population. While approximately 35 percent of Americans thirty to ninety years of age have periodontitis, the disease is moderate to severe in only about 13 percent.[28] Two surprising observations were made through the National Caries Prevention Program conducted from 1977 to 1982.[29] Examiners reported that 50 percent of children were caries free and that 60 percent of caries occurred in 20 percent of children. Recent information indicates that 85 percent of caries is found in about 15 percent of children in Washington State. Information derived from WDS claims reimbursement requests from providing dentists revealed that 65 percent of the total restorative costs were incurred by 23 percent of patients. Seventy percent of costs for patients aged five to nineteen were incurred by 12 percent of patients, and 60 percent of costs for patients aged thirty-five to sixty-four years were incurred by 11 percent of the patients. This and other evidence shows that about 10 percent of children and 10 percent of adults manifest high caries susceptibility.[17,18,28,29] Thus, both periodontitis and caries are now stratified in the population.

Approaches to prevention and treatment planning and the third party payment plans that reimburse for these interventions have not kept pace with the advances in knowledge and changes in disease distribution. Patients at high risk are not receiving the interventions they require to remain healthy; preventive measures continue to be applied uniformly to the entire population regardless of need; and treatments provided are not tailored to individual needs. A significant proportion of treatments and preventive measures now being provided appear to be either inappropriate or not needed.[30-32] These conditions fuel the escalating costs for oral health care.

Both dental caries and periodontitis are preventable diseases. Using the wellness or needs-based model of care and beginning in 1971-72, Axelsson et al. conducted studies on a test group of 375 patients and 180 controls enrolled into three age groups. For the first six years they provided intensive instruction and training in oral hygiene and frequent dental visits. Subsequently, risk was assessed based on patient response to the intensive and uniformly applied preventive interventions and provided individual, needs-based care based on that risk assessment. Focusing care based on disease severity and risk resulted in a 98 percent decrease in new caries lesions and periodontitis by greater than 95 percent. Reductions of this magnitude were maintained over the entire thirty-year period, and tooth loss averaged 0.6 teeth per patient over the thirty years.[17-19,21] These studies demonstrate clearly that both caries and periodontitis are preventable diseases. Identifying risk factors and undertaking measures that maximally reduce risk are the hallmarks of the wellness in contrast to the repair model of care. The wellness model of care guides the clinician and the patient toward a health care strategy based on risk reduction and disease prevention. The wellness approach results in improved oral health, reduction in the need for complex therapy, and a significant reduction in the cost of health care.

The Nature of Risk

In a given patient, most practitioners understandably but incorrectly equate risk for periodontitis with the extent and severity of periodontal disease, with patients having no disease assumed to be at low risk of disease. Risk for periodontitis and disease extent and severity are two entirely different entities. Risk predicts the disease state at some future point in time, or the rate at which a current disease state will likely progress. Severe disease logically implies high risk. However, an individual can, in fact, be at high risk for periodontal disease and have little clinical or radiographic evidence of disease. An example would be a twenty-five-year-old poorly controlled diabetic patient who is a heavy tobacco smoker and has one 5mm pocket that bleeds on probing and one defective restoration. Additionally, an individual can have periodontitis, especially

of mild or moderate severity, but be at low risk. An example would be a previously untreated sixty-one-year-old patient who formerly smoked heavily and has generalized 2mm crestal bone loss and 7mm pockets affecting all posterior teeth.

The proportion of the adult population at risk for periodontitis is considerably larger than the proportion that actually has the disease at any given point in time. As determined in the NHANES-III national study, approximately 35 percent of American adults between the ages of thirty and ninety years have periodontal disease.[28] Most of these, about 22 percent, have a mild stage of disease, while only about 13 percent have moderate to severe disease. When the same data set was examined by age cohort, a different picture emerged. The uppermost curve in Figure 2 shows the proportion of the population by age cohort who do not have periodontitis. At the youngest age cohort, 75-80 percent or more of the population do not have periodontal disease. This percentage decreases linearly with increasing age until at age eighty-five to ninety years when about 40 percent still do not have periodontal disease. Thus, 60 percent of the population is at risk of developing periodontitis. As shown by the middle and lowermost curves respectively by age eighty-five to ninety years, about 35 percent of the population has developed mild periodontitis, and 25 percent has developed moderate to advanced periodontitis for a total of 60 percent. This 25 percent differs from the 13 percent prevalence rate stated above because the 13 percent is the average prevalence for all age groups. Thus, about 40 percent of the population is at low risk, while about 35 percent are at moderate risk and 25 percent are at higher risk.

Figure 3 focuses on the portion of the population who are at risk for periodontitis. At age thirty to thirty-five years, a negligible percentage of persons have periodontitis, but about 60 percent of the population is at risk for the disease even though they may have no clinical or radiographic manifestations of periodontitis. With increasing cohort age, the percentage of the population having periodontitis increases, and the proportion who are at risk but do not have disease decreases. A significant current problem in dentistry is that we are unable to distinguish between those individuals who will develop periodontitis (or dental caries) and those who will not. Our goal has been to develop technology that permits identification of individuals at high risk to

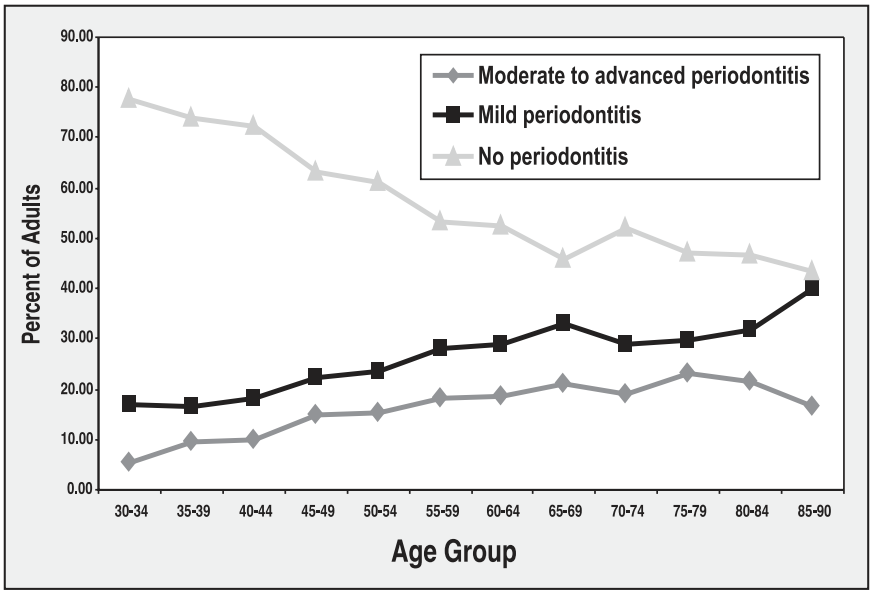

Figure 2. Proportions of the American population who do not develop periodontitis (triangles), who develop mild periodontitis (squares), and who develop moderate to advanced periodontitis (diamonds) by age cohort, based on the NHANES III data set

Source: Adapted from Albander JM, Brunelle JA, Kingman A. Destructive periodontal disease in adults 30 years of age and older in the United States 1988-1994. J Periodontol 1999;70:113-29.

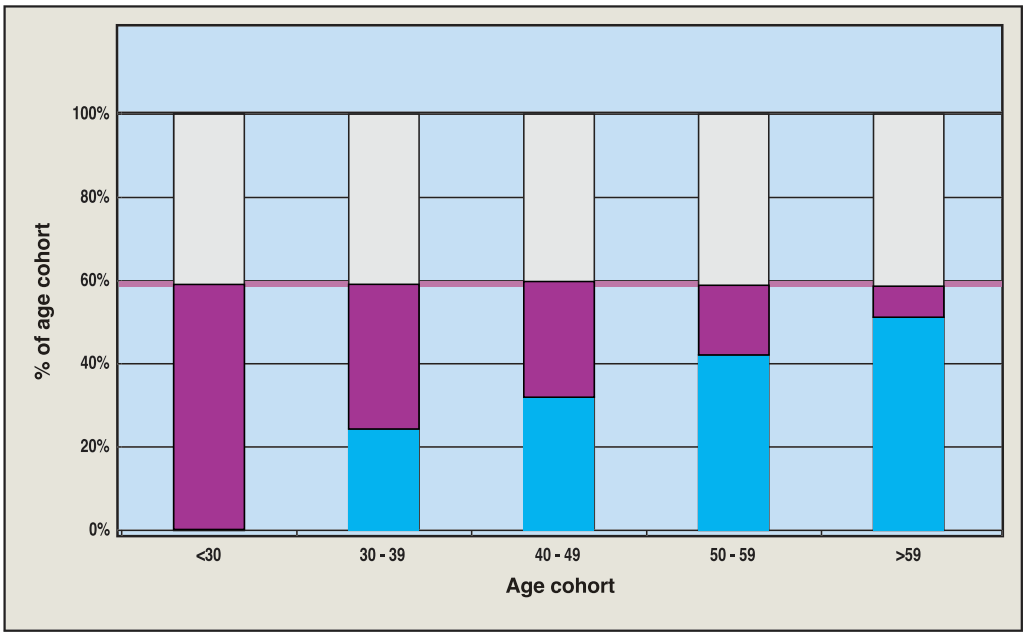

Figure 3. Changes in the proportion of individuals who were at risk for developing periodontitis but did not yet manifest disease (purple), those who were at risk and developed disease (blue), and those who were not at risk and did not develop disease (white) by age cohort. Based on the NHANES III data set.

Source: Adapted from Albander JM, Brunelle JA, Kingman A. Destructive periodontal disease in adults 30 years of age and older in the United States 1988-1994. J Periodontol 1999;70:113-29.

enable application of preventive interventions prior to the onset of disease.

Traditionally, diagnosis of periodontitis has been determined using two sources of data. These are clinical and radiographic conditions and patient history. As illustrated in Figure 4a, when levels of risk are not considered, three patients with the same clinical and radiographic conditions and comparable histories appear to have the same diagnosis, and all three would appear to require the same treatment plan. When the level of risk is considered in the diagnostic equation, as shown in Figure 4b, the same three pa-

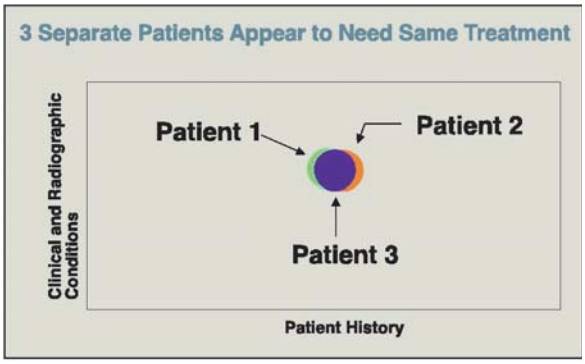

Figure 4a. Traditional diagnosis of periodontitis based on clinical and radiographic conditions and patient history without consideration of risk for three patients who all appear to have the same diagnosis and therefore will require the same treatment

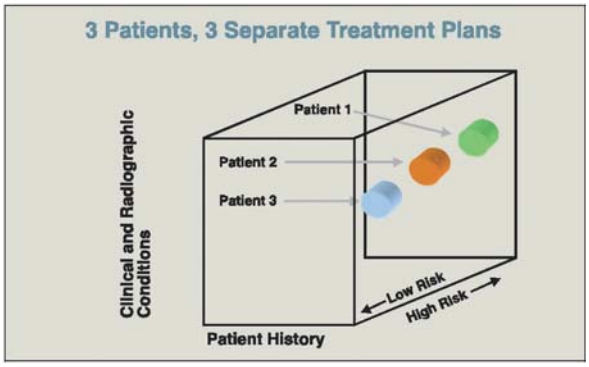

Figure 4b. Diagnosis when level of risk is included along with clinical and radiographic conditions and patient history for the same three patients seen in Figure 4a who now appear to require different treatments

tients are likely to require three different treatment plans. Even though each presents with the same clinical signs and symptoms, the patient with the lowest risk may require only scaling and root planing with recalls at six-month or longer intervals; the patient at moderate risk may require scaling and root planing with surgery in some areas followed by four-month recalls; and the high-risk patient may require referral to a periodontist, scaling and root planing, more aggressive and extensive surgery, and shorter recall intervals. It is clear that disease extent and severity are not the same as risk and that diagnosis and treatment planning in the absence of risk information may result in over- or undertreatment of a significant proportion of patients. As demonstrated in the Axelsson research, matching the intensity of intervention with the risk profile of the patient can significantly reduce disease incidence across the entire population.

The wellness model of care is relatively new to dentistry and to periodontics, and its application requires an accurate and valid assessment of risk. Factors that enhance risk for periodontitis have been identified, and some such as tobacco smoking have been investigated extensively.[27] However, most dentists and periodontists are not trained or experienced in risk assessment or in using interventions aimed at risk reduction in prevention and management of periodontal diseases. Practitioners are generally aware of factors such as tobacco smoking that enhance risk and the fact that their patients differ greatly in susceptibility for periodontitis. Furthermore, they generally collect the information required for risk assessment.[33] However, tools for quantification of risk previously have not been available. Consequently, as currently performed, risk assessment consists of identifying risk factors an individual patient may manifest during the examination and history taking process, and then making a subjective, qualitative judgment as to the magnitude and role these factors may be playing in the disease process. The evidence shows, however, that these subjective evaluations of risk, even when performed by expert clinicians, are of questionable value due in part to the complex effect of interactions among risk factors. Assessing risk is a complex task. Risk factors vary greatly in their relative importance, and the importance of a given factor may vary from one patient to another because risk factors are interactive and synergistic, not additive. Consequently, it should come as no surprise that qualitative assessment of risk by subjective expert judgment may yield less than ideal results.

A study was designed and conducted by Persson et al.[34] to evaluate the validity of qualitative risk assessment performed by expert clinicians. A study group of 107 patients was assembled to have the broadest possible range of risk for periodontitis, and a periodontal examination was performed on each. The examination data were entered into a periodontal risk calculator (described in the next section), and a risk score on a scale of 1 (lowest risk) to 5 calculated for each subject. The records of these patients were then evaluated by two expert groups of periodontists (N=15) and one expert group of general dentists (N=36) who assigned a risk score to each patient using the scale of 1 to 5. The scores assigned by the expert evaluator groups were compared with one another and with calculated risk scores, and inter-evaluator and inter-group variation was determined.[34]

A very large inter-evaluator variation was observed in all three expert evaluator groups, and the greatest was for the general dentists (Figure 5). For both groups of periodontal experts, the percentage of patients placed in risk groups three and four clustered around the scores assigned by the risk calculator. The same was true of risk group one although the range was somewhat greater. Fourteen of fifteen periodontists placed fewer patients in risk group five than the periodontal risk assessment tool, and all fifteen placed more patients in risk group two than the risk assessment tool. These data suggest that both periodontist groups significantly underestimated risk, especially for high-risk patients. Percentages of subjects assigned to each of the risk groups by general dentists were spread over the entire scale. Risk assessment by expert clinician opinion appears to be too variable to be clinically useful in diagnosis and treatment planning for periodontitis. These observations clearly demonstrate the need for more objective quantitative ways to assess risk for periodontitis. The periodontal assessment component of the OHIS appears to satisfy that need.

The Oral Health Information Suite (OHIS)™

OHIS™ (PreViser, Inc., Mount Vernon, WA; www.previser.com) is an information system protected under U.S. Patent #6,484,144. The system is comprised of a suite of related tools for the major oral health conditions including caries, periodontal

disease, and oral cancer. The periodontal and caries tools are developed and available for use, and the oral cancer tool is in development. OHIS is unique for clinical dentistry by virtue of quantifying the risk for future disease in addition to quantifying the current periodontal disease state. These features provide the means to measure oral health care and determine its value. This aspect alone can facilitate cost reduction and quality improvement. Objective measurement of outcomes is a mandatory first step in an effort to improve any aspect of a system of health care. The wellness model, by its focus on preventing disease, is enabled by our assessment of risk and disease status and generation of needs-based treatment plans. Use of the tool can reduce oral health care costs and improve the quality of care. The design principles that guided development of the OHIS have been reported.[35]

OHIS is shown diagrammatically in Figure 6. Thorough clinical and radiographic examinations are conducted including medical and dental histories with specific questions concerning risk factors for oral disease. As indicated by the uppermost arrow, diagnostic and demographic data and the patient and provider objectives are entered into the assessment tool appropriate for the disease state under consideration (periodontal disease, dental caries, or oral cancer). Using periodontal disease to illustrate, a diagnosis is made (as described below), and a risk score and a disease score are calculated. Based on these scores and the published literature, needs-based treatments for the particular patient's set of conditions are selected from the library of all possible treatments. Treatments and interventions are ranked and color-coded as those most likely to be successful, those less likely, and those unlikely to be successful. The recommended treatment plan is evaluated and modified by the dentist and patient to their satisfaction, and the treatments and interventions are performed. On re-examination following treatment, post-treatment risk and disease assessments are performed. Changes in risk and disease state are automatically analyzed by the system and are used to update the risk and disease scores as well as to refine and improve, over time, the selection of the most appropriate treatments for any given set of conditions. The system allows a broad view of the patient's oral health, creates a range of appropriate treatment options that address the full view of the patient, and self-corrects treatment recommendations as actual health outcomes are compared to predicted outcomes. This information is intended to aid the clinician in making diagnoses and formulating treatment plans. It is not a substitute for the clinician's experience and clinical judgment.

The Periodontal Assessment Tool

The Periodontal Assessment Tool (PAT) is an integral part of the OHIS. The development and validation of the PAT and the information required for its use have been reported.[36-38] Following the input of only twenty-three items taken from a routine periodontal examination, the system generates linguistic and numeric periodontal diagnoses and a risk score for future disease, and prepares a report in two versions—one for the dentist's clinical documentation and another for the patient. The traditional documentation of six pocket depth measurements per tooth has been reduced to the deepest pocket for each sextant. Our method further simplifies clinical documentation and improves reproducibility by using categories of <5 mm, 5-7 mm, and >7 mm for pocket depth measurements. PAT also requires the greatest distance of the bone crest to the cemento-enamel junction determined from radiographs, again using one measurement for each sextant and three categories: <2 mm, 2-4 mm, and >4 mm. Detailed information on use of the tool is included with the software in the user's guide and has been published.[35,38]

Figure 7 shows the section of the clinical report that lists the risk and disease state scores along with their change over time, providing an easily understood means to assess care. The risk score ranges from 1 (lowest risk) to 5 (highest risk) based on the patient's unique set of risk factors and patient history.[36-38] The disease state score is reported using a range of 1 (health) to 100 (most severe periodontitis) based on the distribution of sextants with a specific diagnosis of health, gingivitis, and beginning, moderate, and severe periodontitis. Our method quantitatively differentiates between levels of disease within standard nomenclature and provides a uniform system to compare patients regardless of the number of teeth present. A traditional text-linguistic diagnosis is included with the numeric score. Language limits the description of periodontal disease to seventeen types of severity and extent, whereas the numeric score increases the range nearly sixfold.[38] The direc-

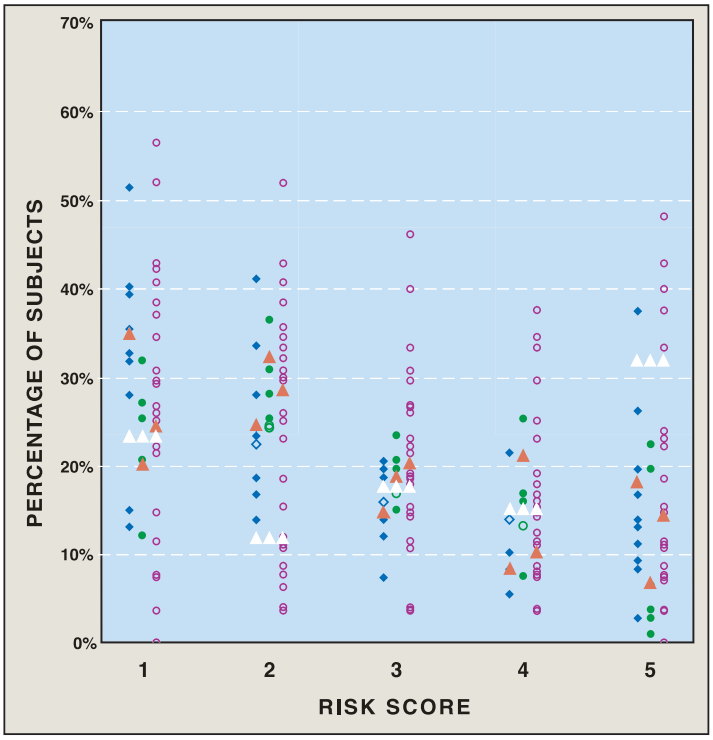

Figure 5. Percentages of subjects assigned to risk score groups 1 (low risk) through 5 (high risk) by the Periodontal Assessment Tool (white triangle) and percentages of total subjects assigned by each expert evaluator in Group A (10 periodontists) (blue diamond), Group B (5 periodontists) (green closed circle), and Group C (36 general dentists) (purple open circle) and the evaluator group consensus (average) scores (red triangle)

Source: Adapted from Persson GR, Mancl LA, Martin JA, Page RC. Assessing periodontal disease risk. J Am Dent Assoc 2003;134:575-82. Reproduced with permission.

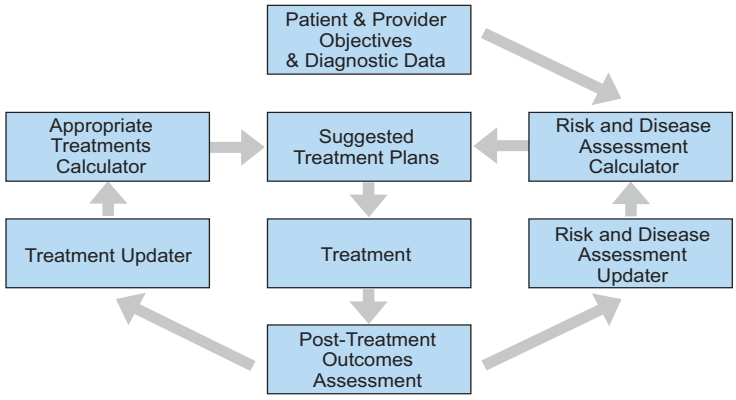

Figure 6. Diagram of the components and their relationships of the Oral Health Information Suite (OHIS)

tion and magnitude of change in the disease and risk scores over time are especially meaningful and valuable to the clinician and the patient.

Figure 7 also shows the section of the report that lists interventions that may be needed; these are grouped by clinical condition. These interventions are stack ranked and color coded as those interventions that, based on current standards of care, are deemed to be generally most effective, those that may be effective and those less likely to be effective. These treatment options can be printed or omitted from the patient report if desired. Included in the report but not shown is a recommendation on the number of visits per year needed to maintain health, comments on oral hygiene, tobacco smoking and diabetes mellitus, and access to free online tutorials that are available for additional patient education about their conditions and treatment.

Changes in the risk and disease scores over time reveal effectiveness of treatment and provide a powerful method to continually and dynamically select the best treatment. The report affords the patient a means to understand the effects of their treatment choices and thereby facilitates informed consent and improved compliance. The risk score or its change and disease score or its change can be of considerable value to the general dentist and patient in determining whether and when to seek care from the periodontist.

Validity and accuracy of risk scores calculated using the tool were determined from the clinical records and radiographs of 523 subjects enrolled in the VA Dental Longitudinal Study of Oral Health and Disease covering a period of fifteen years.[36,37] Data from the

baseline examinations were entered into the Periodontal Assessment Tool, and a risk score for periodontal deterioration was calculated for each subject. Actual periodontal status in terms of alveolar bone loss determined using digitized radiographs, and tooth loss determined from the clinical records, were assessed at years three, nine, and fifteen. The strength of the association between the risk prediction and actual outcome was determined statistically.

The calculated risk scores were strong predictors of future periodontal status measured as worsening severity and extent of alveolar bone loss and

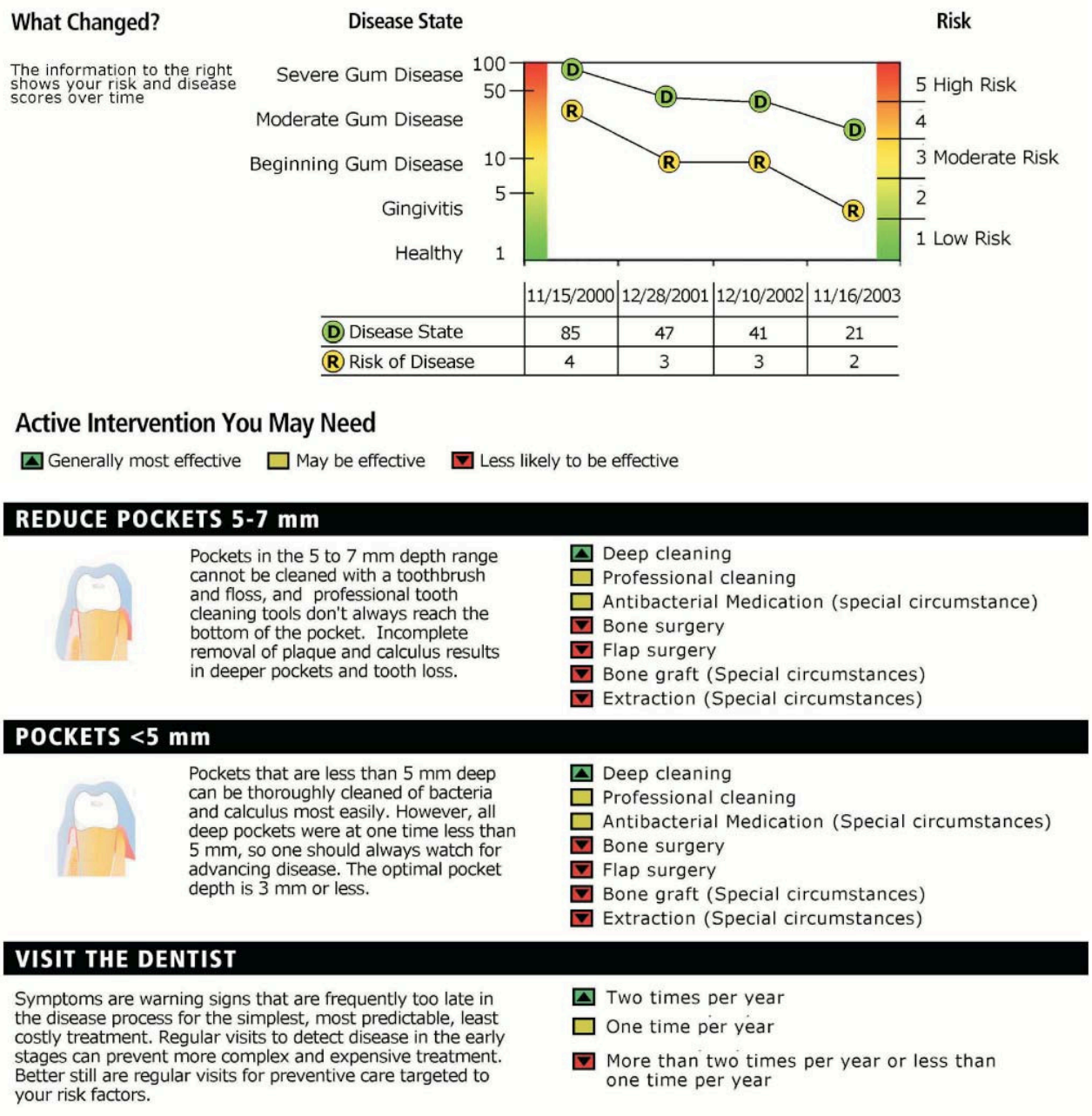

Figure 7. Section of the clinical report showing risk and disease scores and their change over time, along with treatment recommendations

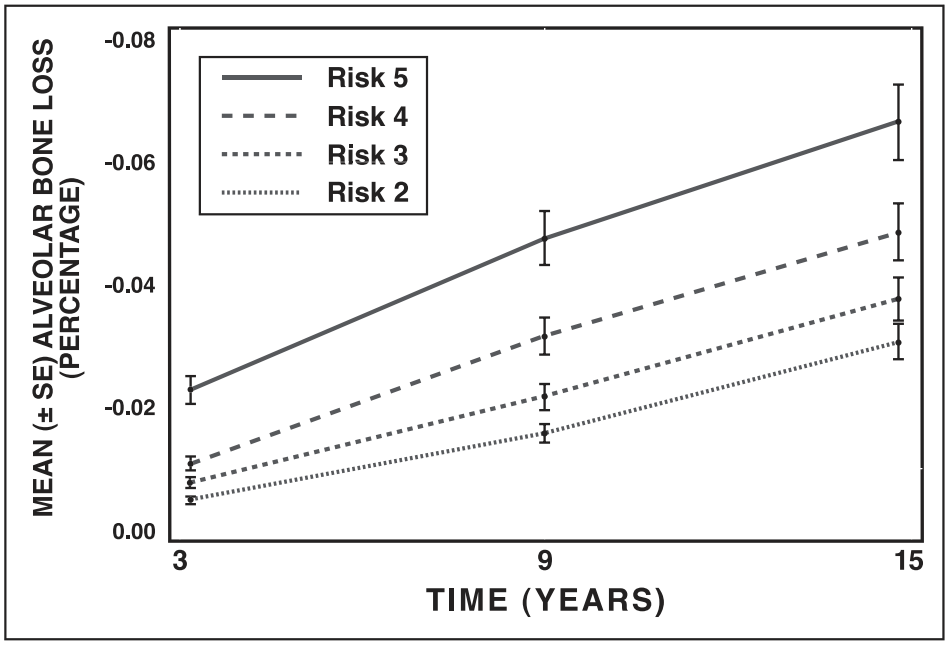

Figure 8. Mean (+- standard error) alveolar bone loss from baseline for risk groups 2 through 5, at sites exceeding the threshold of 2 percent loss of alveolar bone height for all sites that could be compared

Source: Page RC, Krall EA, Martin JA, Mancl LA, Garcia RI. Validity and accuracy of a risk calculator in predicting periodontal disease. J Am Dent Assoc 2002;133:569-76. Reproduced with permission.

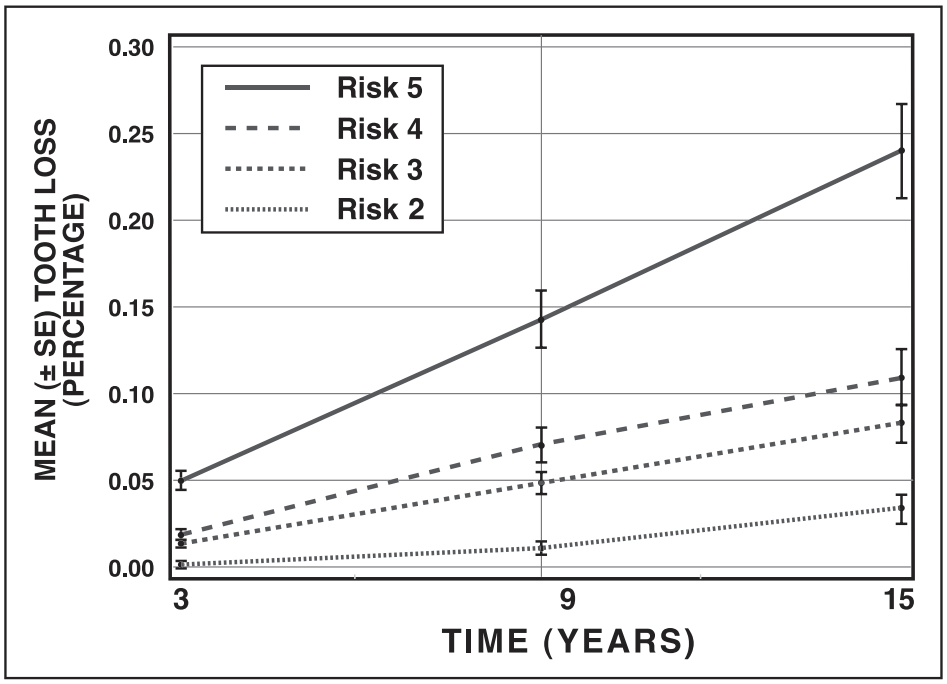

Figure 9. Mean (+-standard error) tooth loss from baseline for risk groups 2 through 5, defined as the percentage of teeth present at baseline that were subsequently extracted

Source: Page RC, Krall EA, Martin JA, Mancl LA, Garcia RI. Validity and accuracy of a risk calculator in predicting periodontal disease. J Am Dent Assoc 2002;133:569-76. Reproduced with permission.

tooth loss, especially loss of periodontally affected teeth. Over the entire fifteen-year period risk scores consistently ranked patient groups from least to most alveolar bone loss (Figure 8) and tooth loss (Figure 9). Risk groups differed greatly from one another. By year 3, the incidence rate of bone loss of risk group 5 was 3.7-fold greater than for risk group 2; and by year 15, loss of periodontally affected teeth was 22.7-fold greater than for risk group 2 ($p<0.001$). As compared to a risk score of 2, the relative risk (RR) for any tooth loss was RR=3.2 for risk score of 3, RR=4.5 for risk score of 4, and RR=10.6 for risk score of 5. Risk scores calculated by the periodontal assessment tool using information gathered during a standard periodontal examination predicted future periodontal status with a high level of accuracy and validity.

Summary

The OHIS is an information system that compiles, analyzes, and quantifies clinical information about current oral health status, interventions needed, and treatment outcomes, be they beneficial or detrimental, that are attributable to treatment and behavioral decisions. The OHIS satisfies the need for a quantitative way to assess risk for periodontitis as well as providing, for the first time, quantification of periodontal status and changes in status over time. This is very powerful information for all stakeholders. It provides patients with a superior understanding of their oral health condition and the interventions recommended. The patient and clinician benefit from the objective measures of the outcomes and effectiveness of the interventions chosen. It permits payers of health care services to determine the value of health improvements achieved relative to the funds expended. Use of the OHIS enables a transition from the repair to the wellness model of dental care. The wellness model guides the clinician and patient toward a health care strategy based on risk reduction and disease prevention. Use of the wellness model over time may be expected to result in improved oral health, reduction in the need for complex therapy, and stabilization or reduction in oral health care costs.

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