# Periodontitis Severity Plus Risk as a Tooth Loss Predictor

John A. Martin,*† Roy C. Page,‡ Elizabeth Krall Kaye,§ Mohamed T. Hamed,‖ and Carl F. Loeb†

**Background:** Tooth loss can be a consequence of the natural history of periodontitis. Stratification of periodontitis severity, risk, and tooth loss exists within the United States adult population, and tooth loss correlates to severity and risk. We evaluated the loss of teeth for a periodontitis-affected population categorized by the combination of severity and risk in which the subjects predominantly did not receive periodontal treatment.

**Methods:** The clinical records of 523 subjects enrolled in the Veterans Affairs Dental Longitudinal Study, covering a period of 15 years, were used. Disease severity, risk level, and the number of teeth lost for each subject were determined.

**Results:** A stepwise regression analysis showed that disease and risk scores predicted mean tooth loss rate. The *P* value for the disease score was <0.0005, and the *P* value for the risk score was 0.001. The ordinal logistic regression model showed that disease ($P = 0.002$) and risk scores ($P = 0.000$) were significantly associated with the probability of subjects losing a specific number of teeth.

**Conclusions:** Tooth loss is more precisely and accurately predicted by the combination of risk score and periodontal disease score than by either score alone. The combined scores may be a surrogate variable for periodontal status. Because the scores are derived from routine clinical measurements, they may be useful for population surveillance and dynamics, practice management, patient care decisions, practice-based research, and the determination of treatment effectiveness and the factors required for successful treatment, resulting in improved oral health and higher clinician productivity and income. *J Periodontol 2009;80:202-209.*

**KEY WORDS**

**Biologic markers; epidemiology; periodontal diseases; surrogate marker; tooth loss.**

* Private practice, State College, PA.
† PreViser, Mt. Vernon, WA.
‡ Department of Periodontics, School of Dentistry, University of Washington, Seattle, WA.
§ Veterans Affairs Dental Longitudinal Study, Veterans Affairs Boston Healthcare System, and Department of Health Policy and Health Services Research, Boston University Goldman School of Dental Medicine, Boston, MA.
‖ College of Dentistry, King Abdulaziz University, Jeddah, Saudi Arabia.

Tooth loss can be a consequence of the natural history of periodontitis.[1-3] More specifically, tooth loss parallels clinical attachment loss, which is a measure of disease severity.[4] Data from the Third National Health and Nutrition Examination Survey (NHANES III) show that the proportion of United States adults with periodontitis increases with age, tooth loss parallels age-based prevalence, and periodontitis severity varies widely.[1] The variation in tooth loss in a periodontitis-affected and untreated population is exemplified by the studies described in Table 1.[3-8] The mean tooth loss per subject ranged from 0.70 to 3.80, and the mean tooth loss rate (MTLR; number of teeth lost per subject per year) ranged from 0.14 to 0.38. The difference in rank order of mean tooth loss and the rate of tooth loss reflect the effect of the time period. In addition to severity and time, the risk for future periodontal deterioration is a factor of tooth loss by its effect on the rate of disease progression, which was reported to range from a mean of 0.10 to 0.26 mm loss of clinical attachment per person per year.[9] Page et al.[10,11] defined risk as the likelihood of disease progression, where risk does not specifically distinguish disease initiation from disease progression. The validity and accuracy of their five-level risk scores were established from clinical records covering a period of 15 years. The results of their study included the change in mean percentage of bone loss, and the mean annual rate of bone loss was in rank order with increasing risk

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**Table 1.**

## Tooth Loss for Subjects Without Periodontal Therapy

| Investigators | Length of Study (years) | Mean Tooth Loss | MTLR (teeth/subject/year) |
|---|---|---|---|
| Papapanou et al.[8] | 10 | 3.80 | 0.38 |
| Becker et al.[5] | 3.72* | 1.24 | 0.36 |
| Harris[7] | 2.1* | 0.70 | 0.33 |
| Gilbert et al.[4] | 4 | 1.12 | 0.28 |
| Buckley and Crowley[6] | 10 | 2.50 | 0.25 |
| Löe et al.[3] | 15 | 2.07 | 0.14 |

* Mean years.

level; the mean percentage of tooth loss increased in rank order with increasing risk level; the incidence rate of tooth loss seemed to be constant within each risk group; and the incidence rate of tooth loss increased in rank order with increasing risk level. Therefore, we hypothesized that tooth loss is unique for each combination of baseline periodontal severity and risk level for a given time period. Figure 1 is a simplified hypothetical example to illustrate the dynamics of tooth loss due to periodontitis: as time passes, there is an increase in clinical attachment loss, and the rate of loss is a function of risk. Modeling a population is complex because periodontitis severity and risk are stratified. This means that at baseline, subjects would be represented at numerous points on the vertical axis of Figure 1, and as time passes, each follows a trajectory with a slope that corresponds to their risk, resulting in a multitude of trajectories and a wide variation in tooth loss. We additionally hypothesized that the tooth loss experience for each group categorized by baseline disease severity and risk is unique. Accordingly, the purpose of this study was to determine whether tooth loss could be modeled using periodontitis severity and risk parameters. The categorization of subjects by periodontitis severity and risk is possible because the quantification of these entities by means of a disease score and risk score has been published.[11,12] The validity of the hypothesis may indicate that the combination of both scores could be a surrogate variable.[13] As a surrogate, and because the scores are objective, reproducible, and derived from routine clinical observations and measurements, they may be useful for population surveillance and dynamics, practice management, practice-based research, determining treatment effectiveness and the factors required for successful treatment, and the design of evidence-based dental insurance plans.

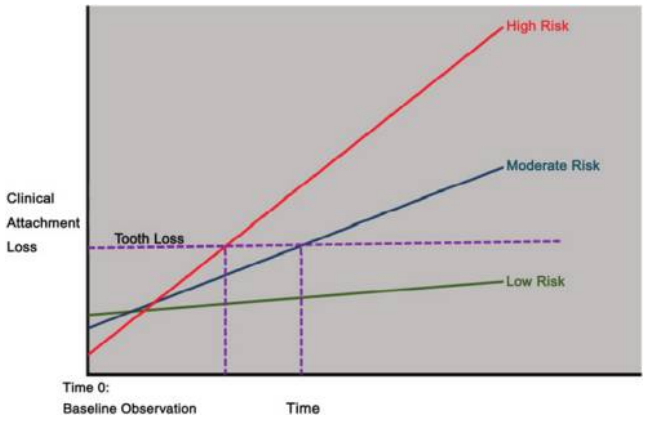


***Figure 1.***
*A simplified hypothetical example of three requisite factors for tooth loss: severity, risk, and time. The red, blue, and green lines represent three fictitious periodontitis subjects who differ by severity of clinical attachment loss at the initial examination (i.e., baseline observation). Clinical attachment loss, which is a measure of periodontitis severity, is displayed on the vertical axis. Time is displayed on the horizontal axis. Periodontal disease progresses over time; when a threshold of disease severity is reached and a tooth is lost, it is denoted by the purple horizontal line. Risk determines the speed of disease progression, which is depicted by the slope of the red, blue, and green lines. For subjects with an equivalent loss of clinical attachment, the time it takes to reach the critical level of clinical attachment loss for tooth loss is less for the subject with higher risk. The difference in time to experience tooth loss for two subjects with different risk levels and baseline severity is illustrated by the purple vertical lines. This conceptual model may appear to accurately represent reality for long time periods with few points of measurement, as reported in the studies of Table 1. However, this model would not be expected to be accurate for short time periods and many points of measurement.*

## MATERIALS AND METHODS

The study population consisted of men enrolled in the Veterans Affairs Dental Longitudinal Study (VA DLS), an ongoing closed-panel study of aging and oral health begun in 1968.[14] The VA DLS is a component of the VA Normative Aging Study, a closed-panel longitudinal study of aging and health in 2,280 men from the greater Boston metropolitan area. Of these men, there were 1,231 medically healthy male subjects who self-selected to enroll in VA DLS. For our analyses, we used data from 523 men who were dentate at baseline and who returned for each triannual examination through the 15-year follow-up. Although the majority of the participants are veterans, they are not patients of the VA health care system and receive their dental and medical care from private health care providers. Subjects return to the study site approximately every 3 years, at which time they receive comprehensive clinical dental and medical examinations; fill out questionnaires on smoking, alcohol, diet, and other lifestyle factors; and provide urine and blood samples for laboratory analyses. At each dental examination, assessments of oral hygiene (plaque and

**Table 2.**

## Disease Score Categories

| Severity | Disease Score* | Disease Score Category | Description† |
|---|---|---|---|
| Healthy or gingivitis | 1 to 3 | 1 | No sextant has periodontitis |
| Mild periodontitis | 4 to 7 | 2 | ≥1 sextant has mild periodontitis |
| | 8 to 10 | 3 | ≥40% of sextants have mild periodontitis |
| Moderate periodontitis | 11 to 26 | 4 | ≥1 sextant has moderate periodontitis |
| | 27 to 36 | 5 | ≥40% of sextants have moderate periodontitis |
| Severe periodontitis | 37 to 64 | 6 | 1 sextant has severe periodontitis |
| | 65 to 82 | 7 | ≥20% of sextants have severe periodontitis |
| | 83 to 92 | 8 | ≥40% of sextants have severe periodontitis |
| | 93 to 100 | 9 | >50% of sextants have severe periodontitis |

* The disease score is a quantification of the severity and extent of periodontal disease based on the number of sextants at each severity level, which is determined by probing depth (PD), alveolar bone loss, and bleeding on probing.[12]

† The severity of periodontitis for a sextant is determined by the deepest pocket, greatest bone loss, and bleeding on probing for the sextant. We defined mild periodontitis as PD <5 mm plus the radiographic distance from the bone crest to the cemento-enamel junction (RBH) as 2 to 4 mm or PD 5 to 7 mm plus RBH <2 mm. Moderate periodontitis was defined as the combination of PD <5 mm and RBH >4 mm, PD 5 to 7 mm and RBH 2 to 4 mm, or PD >7 mm and RBH <2 mm. Severe periodontitis was defined as PD 5 to 7 mm and RBH >4 mm or PD >7 mm and RBH ≥2 mm.[12]

calculus), clinical periodontal status (probing depth, bleeding on probing, and attachment loss), and caries/restorations are made on each tooth present. Dental radiographs are also taken for the measurement of alveolar bone loss. At each examination during the 15-year study, each subject was asked to respond "yes" or "no" to the question "Have you had any gum treatments or gum surgery since your last examination?" On the basis of the self-reports, 8% of the subjects had some form of periodontal treatment. Additional characteristics of the study population have been reported.[11,14]

Tooth loss for each subject was determined from the clinical records; the number of teeth lost by year 15 was used for our study. The risk level for each subject was determined from data at the VA DLS baseline visit using the method reported by Page et al.[11] and expressed as a risk score with a range of 1 to 5. Severity was determined for each subject from data at the VA DLS baseline visit using the method reported by Page and Martin,[12] which was expressed as a disease score with a range of 1 to 100. Study subjects were grouped into a two-factor matrix based on their risk score and disease score. Nine categories of disease scores, as shown in Table 2, were established to reduce the possible number of combinations of risk and disease scores from 500 to 45. The distribution of the subjects is shown in Table 3, a 45-cell matrix of risk and severity. The age range of the study subjects was 28 to 71 years. The mean age for the entire population was 47.3 ± 7.8 years and 46.6 ± 3.6 years for the matrix cells. The MTLR was calculated for each cell of the matrix, for each risk score, for each disease score category, and for the entire study population (Table 4). The proportion of subjects with a specific number of teeth lost was calculated for each combination of risk score and disease score category; the distribution is shown in Figure 2. Also shown in this figure is the proportion of subjects with a specific number of teeth lost for the entire study population.

The variable MTLR was analyzed using stepwise regression to assess the effect of the independent variables, risk score and disease score category, on the dependent variable, MTLR. An ordinal logistic regression model was fitted to five classes, which consisted of subjects categorized by the loss of no teeth, one to three teeth, four to six teeth, seven to nine teeth, and ≥10 teeth. The risk score was treated as a categorical factor, and the disease score was treated as continuous for both models. Analyses were performed using statistical programs.¶#

## RESULTS

Table 3 shows that a population can be categorized by risk level, disease severity, and the combination of both. Nearly every subject in our study population was categorized as having periodontitis, which included 20% with severe periodontitis, 56% with moderate periodontitis, and 24% with mild periodontitis. Disease score categories 3, 4, and 5 each had >100 subjects; collectively, they accounted for 75% of all subjects. Of the 104 subjects described as having severe periodontitis, 46 subjects (9% of all subjects) were in disease score category 6 (one of six sextants was severely diseased with the remaining five sextants less severely affected); 31 subjects (6% of all subjects)

¶ Minitab Statistical Software, Minitab, State College, PA.
# R statistical software, R Foundation for Statistical Computing, Vienna, Austria.

**Table 3.**

## Distribution of Subjects by Risk Score and Disease Score Category

| | | | Disease Score Category | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Healthy or Gingivitis | Periodontitis | | | | | | | | | |
| | | | | Mild | | Moderate | | Severe | | | | | |
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Total | % |
| Risk Score | Very low | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0.4 |
| | Low | 2 | 0 | 8 | 44 | 37 | 15 | 0 | 0 | 0 | 0 | 104 | 20 |
| | Moderate | 3 | 0 | 11 | 55 | 77 | 50 | 0 | 0 | 0 | 0 | 193 | 37 |
| | High | 4 | 0 | 0 | 7 | 69 | 44 | 0 | 0 | 0 | 0 | 120 | 23 |
| | Very high | 5 | 0 | 0 | 0 | 0 | 0 | 46 | 31 | 13 | 14 | 104 | 20 |
| | | Total | 2 | 19 | 106 | 183 | 109 | 46 | 31 | 13 | 14 | 523 | |
| | | % | 0.4 | 4 | 20 | 35 | 21 | 9 | 6 | 3 | 3 | | |

**Table 4.**

## MTLR

| | | | Disease Score Category | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Healthy or Gingivitis | Periodontitis | | | | | | | | |
| | | | | Mild | | Moderate | | Severe | | | | |
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Mean |
| Risk Score | Very low | 1 | 0.03 | | | | | | | | | 0.03 |
| | Low | 2 | | 0.04 | 0.04 | 0.03 | 0.05 | | | | | 0.04 |
| | Moderate | 3 | | 0.08 | 0.06 | 0.13 | 0.17 | | | | | 0.12 |
| | High | 4 | | | 0.13 | 0.16 | 0.18 | | | | | 0.17 |
| | Very high | 5 | | | | | | 0.25 | 0.32 | 0.51 | 0.61 | 0.35 |
| | | Mean | 0.03 | 0.06 | 0.06 | 0.12 | 0.16 | 0.25 | 0.32 | 0.51 | 0.61 | 0.16 |

were in disease score category 7 (20% to 39% of their dentate sextants were severely diseased [e.g., two of six sextants or one sextant of a dentition with three, four, or five dentate sextants] with the remaining dentate sextants less severely affected); and 27 subjects (6% of all subjects) were in disease score category 8 or 9 (≥40% of their dentate sextants were severely diseased with the remaining dentate sextants less severely affected). Only two subjects were assigned a risk score of 1; the remaining 521 subjects were fairly evenly distributed among risk scores 2 to 5. The study population of 523 subjects occupied only 16 of 45 possible combinations of risk and disease score categories.

A total of 1,251 teeth were lost during the 15 years of the study period, which was an average of 2.39 teeth per subject or 0.16 teeth per subject per year. Table 4 shows a wide variation in MTLR for risk score, disease score category, and the combination of risk and disease scores, which illustrates that categorization of subjects by risk and severity increases the specificity of this measurement compared to the population's MTLR. For example, the MTLR increased in rank order for the risk score and disease score categories. There was little difference in the tooth loss rate for risk score groups 1 and 2 (i.e., 0.03 and 0.04) or for disease score groups 2 and 3 (i.e., 0.06 and 0.06). However, the matrix cells showed that within each risk

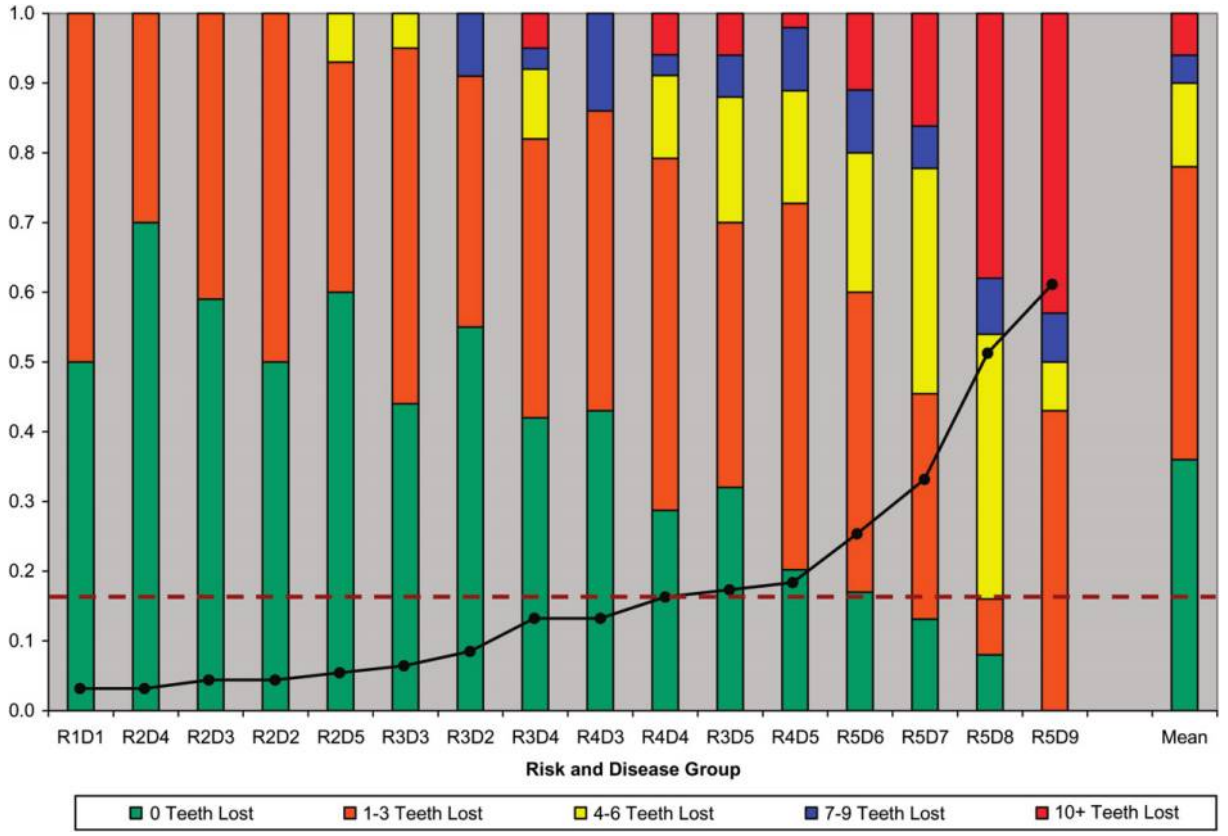


***Figure 2.***
*Tooth loss for the population that accounts for the 16 combinations of risk score and disease score categories. Each bar corresponds to the risk and disease group listed on the x axis; the number following "R" is the risk score, and the number following "D" is the disease score category. The bar labeled "Mean" represents the entire study population. Each bar consists of the percentage of subjects in the risk-disease group that lost a specific number of teeth. Each point on the solid black line is the MTLR for the respective risk-disease group. This value also appears in Table 4. The horizontal dashed red line is the MTLR for the entire study population. The y axis serves a dual purpose: the percentage of subjects in decimal fraction (e.g., 0.2 means 20%) for the bar length and the MTLR in standard decimal format for the dashed red line and each point on the solid black line.*

score group from 3 to 5, the tooth loss rate increased with increasing disease score group from 3 to 9; within each disease score group from 3 to 5, the tooth loss rate increased with increasing risk score group from 2 to 4. Figure 2 illustrates the variation in tooth loss using MTLR (black line) and the percentage of subjects who lost a specific number of teeth (bars) for risk and disease score categories. Furthermore, this figure shows the variation of combined risk and disease score categories from the population's mean.

Age could be expected to strongly influence tooth loss rates. However, the correlation between average age and all of the responses (e.g., MTLR, percentage of subjects who lost no teeth) resulted in only one correlation coefficient that was significant. Hence, age was not useful for this data set.

The regression analysis showed that disease and risk scores did a better job of predicting MTLR jointly, rather than individually. The *P* values for the disease and risk scores corresponding to the regression model that included both terms were <0.0005 and 0.001, respectively. This joint model outperformed the regression models with only disease score or risk score used as a predictor. The adjusted R-squared statistic for the joint model was larger (98.96% versus 84.02% with only the disease score and 75.4% for the model with only the risk score) than the corresponding statistic for the one-term models. We used the adjusted R-squared statistic to compare the goodness of fit for each model. This specific statistic is more valid for comparison of models with a different number of terms. Therefore, this analysis showed that the disease and risk scores can describe and predict MTLR when considered together, and the model itself outperformed other models that only had one of the scores as a sole predictor.

The ordinal logistic regression model showed that disease and risk scores were significantly associated with the probability of subjects losing a specific number of teeth. This model's *P* values for disease and risk scores were 0.020 and <0.0005, respectively. The measures of association indicated the relationship

between the observed responses and the predicted probabilities; 65.9% of the pairs were concordant, whereas 25.5% were discordant. Thus, there is a better chance for a pair to be concordant than discordant, indicating a good predictive ability of the model.

## DISCUSSION

The disease score was shown to accurately describe a patient's extent and severity of periodontal disease.[12] The risk score was shown to be a valid and accurate predictor of future periodontal status.[10,11] These two scores provided a way to categorize the subjects by disease severity, risk level, and the combination of severity and risk. Because the number of disease scores was 100, and the number of risk scores was five, the maximum number of combined levels of disease severity and risk was 500. Our analysis used nine categories of disease scores and five categories of risk scores, which reduced the number of combined categories from 500 to 45. Our observations and conclusions regarding tooth loss, which are based on 45 categories, cannot be extended to apply to the full spectrum of 500 combined scores.

Table 3 illustrates the variation in risk level and periodontal disease severity within our study population, which is consistent with previous reports.[1,10,11] Table 4 illustrates the variation in tooth loss within our study population, which is consistent with previous reports.[3-8] We compared our study population to the populations of seven studies of prevalence and tooth loss. These studies[1,3-8] used no more than five levels of severity, and risk was not used at all. Therefore, our method of combining severity with risk increased the categories for comparison nine-fold. The increased specificity that occurs with 45 combined severity and risk categories versus five severity categories is illustrated in Table 4. For example, the MTLR varied for seven disease score groups (3 to 9), which represented three levels of disease severity; the cells of the matrix revealed additional variation in the MTLR when the risk score was included.

By itself, the MTLR does not fully describe tooth loss for a population because it does not convey the distribution of patients who lost a specific number of teeth. Figure 2 illustrates this distribution for each combination of risk and severity in addition to the distribution for the entire study population. The bars of the graph show the added specificity of combining risk and severity, because the composition of each risk–severity combination is different from one another and the entire study population.

By itself, current periodontal disease severity cannot accurately predict future periodontal disease severity. This prediction is within the realm of risk. Risk affects the rate of disease progression.[10,11] Therefore, although disease severity is a determinant to predict tooth loss at a given moment,[4] current attachment level, risk level, and time are required to predict tooth loss in the future. Figure 1 provides a conceptual example of the relationship of these three factors, especially for studies like ours and those shown in Table 1, which measured tooth loss only at the end of the study period. Because the loss of attachment is not uniform, the lines depicting the progressive loss of attachment over time would not be straight for observations at frequent time periods. Furthermore, there is no absolute horizontal line that correlates tooth loss with a specific level of clinical attachment loss. Table 4 shows that the effect of two variable factors, severity and risk, in addition to a fixed time period, resulted in a variation in MTLR between combinations of severity and risk. Additional studies that measure tooth loss at frequent time periods during the progression of periodontal disease are suggested.

A clinical application can be explained using Figure 2. This figure shows that two subjects assigned a risk score of 5 and a disease score of category 8 could lose anywhere from 0 to 10+ teeth; each subject may lose a different number of teeth. Our data indicated that each of these subjects has an 8% probability of losing no teeth, an 8% probability of losing one to three teeth, a 38% probability of losing four to six teeth, an 8% probability of losing seven to nine teeth, and a 38% probability of losing 10+ teeth in 15 years without periodontal treatment. We caution the reader that the probabilities listed are based solely on this study and that valid and accurate probabilities require additional studies of much larger populations. With a sufficiently large study population, more accurate rates of tooth loss based on risk and disease severity combinations could be calculated; these data could be used to justify the cost of enhanced treatment or preventive activities for patients at higher risk levels but with the same severity level as patients at lower risk levels. Another application could be the comparison of actual to predicted tooth loss to determine the relative effectiveness of treatment between two or more treatment interventions.

The severity of periodontitis in our study population was higher than determined from NHANES III.[1] Although nearly 100% of our study population was categorized as having periodontitis, the prevalence from NHANES III was 34% (Table 3). More specifically, in our study population and NHANES III, respectively, severe periodontitis was assigned to 20% versus 3%, moderate periodontitis was assigned to 56% versus 10%, and mild periodontitis was assigned to 24% versus 22%. The variation in severity between our study population and NHANES III may be partially explained by the difference in definition and diagnostic method. The variation in estimates of periodontitis prevalence is acknowledged, and no consensus exists

on the true prevalence.[15] Because NHANES III did not categorize by periodontitis risk, it is not known how the two populations compare for this entity. Although the size of our study population was fairly large, it was much too small to fully populate all 45 cells of the matrix; hence, statistical analysis was restricted to 16 combinations of risk and disease severity. A much larger population would be needed for a statistical analysis of all 45 combinations of risk and disease severity.

The MTLR for our study was 0.16 (Table 4), which was substantially less than the mean of 0.29 for the six studies in Table 1. However, age is an important factor for disease severity and tooth loss. The Löe et al.[3] and Buckley and Crowley[6] study populations were much younger than those in the other four studies and in the current study. The ages of the subjects in the populations of Papapanou et al.,[8] Becker et al.,[5] Harris,[7] and Gilbert et al.[4] were similar to our population. The MTLR for these four populations was 0.34, but only the studies by Becker et al.[5] and Harris[7] described the study population as having severe periodontitis. The MTLRs of 0.36 reported by Becker et al.[5] and 0.33 reported by Harris[7] compare favorably to 0.35 for the subjects in our study population with a risk score of 5 and disease score groups 6 to 9. Furthermore, these three populations are consistent with the severity of disease in patients referred to a periodontist.[16]

The MTLRs for risk scores 1 and 2 and disease score categories 1 and 2 were similar and low (Table 4). We hypothesize that tooth loss due to caries is independent of tooth loss due to periodontitis, which would be expected to result in a similar MTLR for every combination of risk and disease. If proven to be true, this may mean that caries is a larger factor than periodontitis when risk and disease scores are low, and, hence, periodontal treatment would have a minimal effect on reducing tooth loss for patients with these low scores. However, periodontal treatment would be expected to have an increasingly profound effect with higher risk and disease scores. Because the data for our analysis did not include the baseline condition of teeth (e.g., caries and restorations) or the reason for extraction, this analysis did not differentiate tooth loss by cause. Future studies that include this information may result in different interpretations from those presented here. It would also be informative for future studies to analyze tooth loss when periodontal treatment is applied.

## CONCLUSIONS

This study showed that the combination of risk and disease scores more precisely and accurately predicted a patient's tooth loss than either category alone and suggested that the combined categorization is a surrogate variable of periodontal status.[13] Because the scores are objective, easily reproducible, and derived from routine clinical observations and measurements, they may be useful for population surveillance and dynamics, practice management, patient care decisions, practice-based research, determining treatment effectiveness and the factors required for successful treatment, and the design of evidence-based dental insurance policies. The net effect from these applications could be more accurate clinical decision making, reduction in the need for complex periodontal therapy, reduction in oral health care costs, improved oral health, and improved clinician productivity and income.[12,17,18]

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Correspondence: Dr. John A. Martin, 2521 Carnegie Dr., State College, PA 16803. Fax: 814/234-4997; e-mail: johnm@previser.com.

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