Assessing periodontal disease risk
A comparison of clinicians' assessment versus a computerized tool

G. RUTGER PERSSON, D.D.S., Ph.D.; LLOYD A. MANCL, Ph.D.; JOHN MARTIN, D.D.S.; ROY C. PAGE, D.D.S., Ph.D.

In the last several decades, periodontal diseases have been researched intensively, and our knowledge base and understanding have grown greatly. Studies have demonstrated that while bacteria are an essential cause of peridontitis, bacteria alone are insufficient; a susceptible host also is essential. Susceptibility and its quantitative measure, risk, vary greatly from one person to another.[1-9] Several determinants of risk and susceptibility have been identified.[10-14] Heredity alone appears to account for roughly 50 percent of the risk of developing periodontitis.[15] Poor oral hygiene, tobacco smoking and certain systemic diseases and conditions, especially diabetes mellitus, are some of the most significant risk factors.[11] These and other factors directly enhance or decrease a person's risk of experiencing periodontal deterioration.

Assessment and use of risk level in prevention and management of periodontitis is complex and difficult. Individual risk factors differ greatly in their importance in enhancing disease susceptibility, and multiple risks appear to be synergistic rather than additive.[8] Very little is known about relative weighting of individual factors or interactions among factors that may affect weighting when more than one

The risk scores generated for individual patients by subjective expert clinician opinion are highly variable and could result in the misapplication of treatment for some patients.

A B S T R A C T

Background. The authors conducted a study to compare risk scores assigned by subjective expert clinician opinion with quantitative scores generated for the same subjects using the Periodontal Risk Calculator, or PRC.

Methods. The authors assembled a group of 107 subjects and performed standard periodontal examinations. The authors entered the resulting information into the PRC and calculated risk scores for two and four years, assuming no treatment would be performed. Using the same subject records, three groups of expert clinicians assigned risk scores for years 2 and 4. The authors analyzed the data to reveal the extent of interevaluator variation and the level of agreement between expert clinician scores and PRC scores.

Results. The extent of variation among scores assigned by individual expert clinicians was greater than the authors had expected. Expert clinicians consistently assigned more subjects to PRC risk group 2 and fewer to risk group 5 than did the PRC. The authors observed very high heterogeneity in the risk scores expert clinicians assigned to patients in each of the PRC-assigned groups. Thus, expert clinicians varied greatly in evaluating risk and, relative to the PRC, they appeared to underestimate periodontitis risk, especially for high-risk patients.

Conclusions and Practice Implications. The authors' observations suggest that use of risk scores generated for individual patients by subjective expert clinician opinion about risk in periodontal clinical decision making could result in the misapplication of treatment for some patients and support the use of an objective tool such as the PRC. Use of the PRC over time may be expected to result in more uniform and accurate periodontal clinical decision making, improved oral health, reduction in the need for complex therapy and reduction in health care costs.

factor is involved. Consequently, risk assessment and application of risk evaluation to the management of periodontitis remain in their infancy. Risk assessment for periodontitis remains subjective, empirical and variable from one clinician to another and from one patient to another. Development of methods for objective, accurate quantification of risk and susceptibility and application of the results would greatly facilitate patient care.

We have developed a computer-based tool for assessing a patient's risk of experiencing periodontal disease and for predicting disease onset and progression. The tool, called the Periodontal Risk Calculator, or PRC (Dental Medicine International, Philadelphia), is based on mathematically derived algorithms that assign relative weights to the various known risks that enhance a person's susceptibility to periodontitis. It is user-friendly and requires only information that is gathered during routine dental or periodontal examinations. Risk scores determined using the PRC are accurate and valid predictors of future periodontal deterioration, as measured by actual alveolar bone loss and tooth loss over a period of 15 years.[16]

The purpose of the study reported here was twofold:
- to determine the extent of individual variation in risk scores assigned to study subjects by expert clinicians;
- to explore the relationship between risk scores assigned subjectively by expert clinicians and those calculated by the PRC.

Compared with general dentists, periodontists have more training and experience in managing periodontal diseases. We therefore tested the hypothesis that the variation among individual periodontists in assessing levels of risk would be relatively small and the agreement with the PRC-calculated risk scores would be strong, while among general dentists the variation would be greater and agreement with the PRC scores would be weaker. We performed and recorded the findings of oral examinations for a group of 107 subjects with a wide range of risk levels. On the basis of this information, we calculated a risk score for each subject using the PRC. Using the same records, two groups of periodontists and one group of general dentists assigned risk scores for each subject. We determined the extent of interevaluator and intergroup variation and agreement, as well as the extent of agreement between risk scores assigned by the groups of expert clinicians and scores calculated by the PRC.

METHODS

Subject population. Our recruitment goal was to assemble a study population of approximately 100 subjects who represented a wide range of risk of experiencing periodontal deterioration. We designed the recruitment so that the final study population would have specific proportions of subjects who
- either had a healthy periodontium or had early, moderate or severe periodontitis;
- were smokers or nonsmokers;
- had diabetes;
- were racial minorities;
- were premenopausal or postmenopausal women;
- had had previous periodontal therapy.

Our other inclusion/exclusion criteria were that subjects must be 21 years or age or older; could not have had active periodontal or orthodontic therapy within the previous six months but could have had periodontal maintenance; could practice any type of daily oral hygiene, including use of antimicrobial oral rinses; must give informed consent; and must be willing and able to come to the Regional Clinical Dental Research Center at the University of Washington School of Dentistry in Seattle for one screening visit and one two-hour examination.

We obtained potential subjects through advertisements in local newspapers and on radio stations. We interviewed respondents by phone; we appointed those who appeared to qualify and performed screening examinations on them. We enrolled subjects who were qualified and gave informed consent and performed full examinations on them.

Periodontal examination and generation of risk scores. We took full-mouth periapical radiographs with bitewings for each enrolled subject. We evaluated the films for hopeless teeth, periapical and carious lesions, extent of alveolar bone loss, vertical bone lesions, root calculus, and retained and fractured roots. One dental hygienist examiner performed full-mouth charting, including missing and carious teeth, gross occlusal abnormalities, gingival recession greater than 2 millimeters, probing pocket depth and clinical attachment level at six positions around each tooth, tooth mobility (recorded on a scale of 0-3 to indicate normal, slight, moderate

and severe mobility), presence of any oral mucosal lesions and bleeding on probing. We recorded medical and dental histories, including any medications being taken and any systemic diseases and conditions. Clinical photographs (35-mm color slides) were taken with the teeth occluded from the facial anterior, left and right posterior and, using mirrors, lingual and palatal aspects. We arranged the record components in a standardized order in chart folders and checked them for completeness. All records were coded, and all other identifying information was removed. The information required by the PRC for calculation of risk scores has been reported previously.[16] Using the PRC and information from the records, we calculated risk scores for each subject for years 2 and 4 from the baseline examination, assuming that no treatment would be performed. We expressed the level of risk on a scale of 1 through 5, with 5 representing the highest level of risk.

Expert periodontists and general dentists. We assembled three groups of expert evaluators. Group A consisted of 10 periodontists, all of whom we assumed had a greater than average interest in and knowledge of periodontal risk assessment because of their participation in the development of the PRC. (R.C.P. and J.M. were among these periodontists.) Group B consisted of two internationally recognized full-time periodontal practitioners, both of whom were past presidents of the American Academy of Periodontology, two academic periodontists who were in part-time practice, one full-time periodontist practitioner from the U.S. military and one Swedish full-time periodontist who also is a recognized expert and author of numerous publications on risk assessment. Group C consisted of 36 general dentists, all of whom were in full-time practice and who were judged to be periodontally aware based on their records of referring patients for specialty periodontal care.

We randomly assembled subject records in batches of 26 to 28, 21 to 22 and five to six for groups A, B and C, respectively. We instructed the evaluators to assess subjects based on their risk of developing periodontal disease for those who did not have it, and the risk of experiencing future progression of periodontal diseases for those who already had it. We asked each evaluator to study the records and assign risk scores for two and four years, assuming no treatment was performed. We provided an overall descrip-

tion of the study design, but we gave no information or instructions to the evaluators other than that they were to evaluate the subject records provided and assign risk scores. There was no limit on the length of time expended by each evaluator on the evaluation. Evaluators could not discuss their evaluations and scoring with anyone, nor were they permitted to ask questions of the investigators or others associated with the study.

Each periodontist in both groups evaluated the records for all 107 study subjects. Each general dentist evaluated the records of 16 to 30 subjects (median = 27 subjects), and seven to 10 general dentists evaluated each subject (median = nine dentists). The evaluators recorded scores on the coded forms provided and transmitted them to the principal investigator, who entered the results into secure computer files and checked them for accuracy.

Data processing and statistical analysis. We computed risk score frequencies for each evaluator and for the PRC. Within each evaluator group, we used the median risk score for each subject to define consensus or average risk scores, which we rounded to the nearest integer. We used the intraclass correlation coefficient to assess interevaluator reliability separately for the two periodontist groups and the dentist group based on a two-way analysis of variance model with random effects for evaluator and subject.[17] We used a weighted κ statistic to quantify the agreement between the PRC and the consensus risk scores for each evaluator group. We used Cicchetti-Allison weights when ratings with the same score were given a weight of 1 and decreasing weight was given as the difference between ratings increased. Ratings that differed by 4 received a weight of 0.[18] We also used the weighted κ statistic to assess the agreement of each evaluator with the group consensus and PRC risk scores, and the Spearman rank correlation coefficient to describe the association between the group consensus and PRC risk scores.

RESULTS

All 107 subjects who enrolled in the study completed it. The group was 44 percent male, had a mean age of 49.6 (± standard deviation of 2.6) years and had an average of 26.2 teeth. Twenty-three of 35 postmenopausal female subjects were taking hormonal replacement or alendronate therapy. About 75 percent of the subjects had
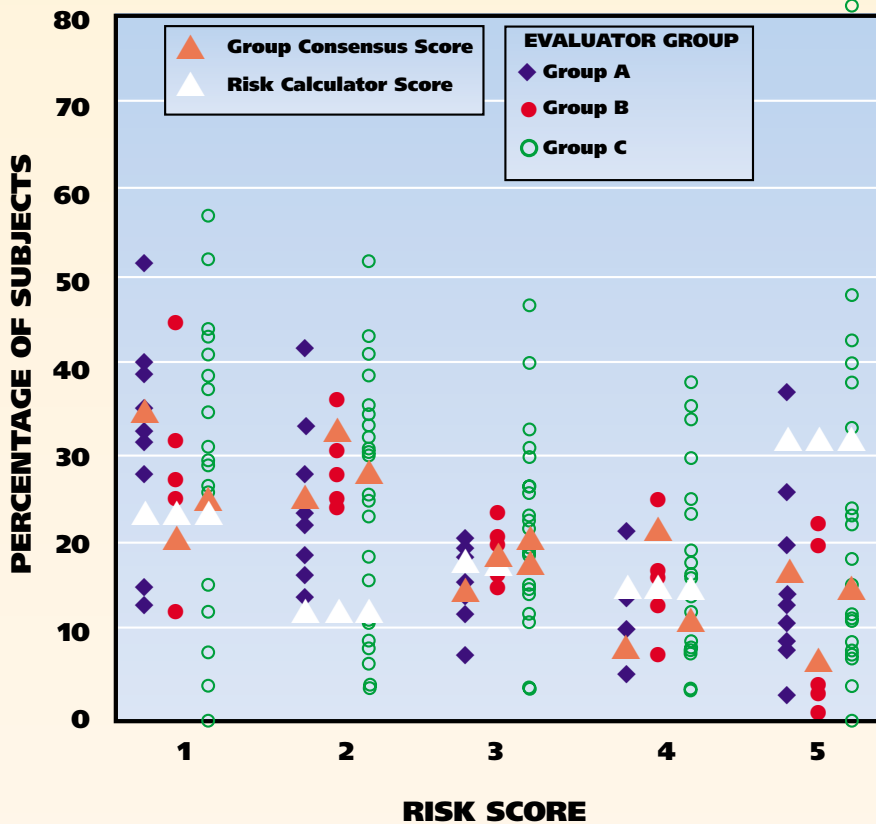
Figure 1. Percentages of subjects assigned to risk score groups 1 (low risk of periodontal disease) through 5 (high risk of periodontal disease) in year 2 by the Periodontal Risk Calculator (Dental Medicine International, Philadelphia) and the percentages of total subjects assigned by each expert evaluator in Group A (10 periodontists), Group B (six periodontists) and Group C (36 general dentists) and the evaluator group consensus scores (average scores).

early-to-severe periodontitis, and 6 percent reported having had some form of periodontal therapy. Fifty-two percent were current or former smokers, and 45 percent reported some level of alcohol consumption. Ten percent reported having a history of diabetes, and 17 percent reported having a history of heart disease. Based on the PRC-calculated risk scores for year 2 (Figure 1), the subject population was well-distributed among the five risk groups, although possibly weighted somewhat toward the higher risk scores.

The percentages of subjects assigned by the PRC to the risk groups for year 2 were 23 percent, 12 percent, 18 percent, 15 percent and 32 percent, for groups 1 through 5, respectively (Figure 1). Consensus or average scores were very similar for all three evaluator groups. Consensus scores for evaluator groups clustered around the PRC scores for risk groups 3 and 4 and to a lesser extent for

group 1, but they were all much higher for PRC group 2 and much lower for PRC group 5. A similar pattern of distribution was seen for year 4 (data not shown). Weighted κ values for agreement of consensus scores for the three evaluator groups among the groups and with the PRC scores are shown in the table. The consensus scores for years 2 and 4 exhibited good but not excellent agreement among the evaluator groups (0.59-0.70), but only fair agreement with the PRC (0.44-0.49). The consensus scores for agreement between group A and B periodontists and the general dentists in Group C for years 2 and 4 were similar, but the range for general dentists was greater than for periodontists. The Spearman rank correlation coefficients indicated a somewhat stronger relationship than the κ statistic. Rank correlation for individual evaluators with their group consensus scores ranged from 0.76 to 0.88 for years 2 and 4; rank correlation for group consensus scores and PRC scores ranged from 0.72 to 0.78 for year 2 and 0.61 to 0.75 for year 4.

The intraclass correlation coefficient, or ICC, provides a measure of interevaluator reliability for each evaluator group. The group A periodontist evaluators had the highest level of agreement (ICC of 0.67-0.70), followed by group B periodontists (ICC of 0.63-0.66); the general dentist evaluators in Group C had the lowest level of agreement (ICC of 0.53-0.55). The fraction of the variance due to systematic differences among evaluators for both periodontist groups was less than 0.07, compared with 0.20 for the general dentists. Interevaluator variability also was reflected in the range of weighted κ values for individual evaluators (Table).

There was substantial variation among individual evaluators with their group consensus

scores and with the PRC scores, with the range being greatest for general dentists (Figure 1). Twelve of the 16 periodontist evaluators placed more subjects in risk group 1, and all 16 placed more subjects in risk group 2 than the PRC. In marked contrast, 15 of the 16 periodontists placed fewer subjects in group 5 than the PRC. We observed a very similar pattern of distribution of subjects for year 4, in that all periodontists except one assigned fewer subjects to group 5 and more to group l than the PRC (data not shown). The Swedish periodontist did not differ significantly from his American counterparts. Thus, relative to the PRC, the periodontists' consensus and individual scores appear on average to underestimate risk, especially for high-risk subjects.

The distribution of individual evaluator scores shown in Figure 1 and the ICC and weighted κ scores demonstrated substantial interevaluator variation between expert evaluator- and PRC-assigned scores, but they do not reveal other differences between the PRC and expert clinicians in assigning risk scores. Figure 2 displays the extent of heterogeneity of subjects in the five PRC risk groups based on the consensus risk scores assigned by the three groups of expert clinicians. Clearly, the PRC groups are highly heterogeneous. While more than one-half of subjects in PRC group 1 have an expert evaluator consensus score of 1, others have scores of 2, 3 and 4. Conversely, subjects with consensus scores of 1 also are found in risk groups 2, 3 and 4. Only

a minority of subjects in PRC group 5 has an expert consensus score of 5, while the majority have consensus scores of 2, 3 and 4. Risk groups 2, 3 and 4 also are highly heterogeneous.

DISCUSSION

The PRC is a computer-based tool designed to determine and quantify risk for periodontal deterioration. The risk scores determined using the PRC have been shown to predict periodontal deterioration with high accuracy and validity ($P < .0001$) when measured as radiographic alveolar bone loss and tooth loss over a period of 15

TABLE

WEIGHTED κ VALUES AND 95 PERCENT CONFIDENCE INTERVALS FOR AGREEMENT BETWEEN THE PERIODONTAL RISK CALCULATOR* AND EXPERT EVALUATOR GROUPS.

EVALUATOR GROUP AND MEASUREMENT PERIOD	SUMMARY STATISTICS	WEIGHTED κ VALUES (95 PERCENT CONFIDENCE INTERVALS)		
		Periodontal Risk Calculator	Group A Periodontists	Group B Periodontists
Group A: Periodontists (10)				
Year 2	Consensus	0.49 (0.39 to 0.59)		
	Median	0.43		
	Range	0.32-0.64		
Year 4	Consensus	0.44 (0.34 to 0.54)		
	Median	0.40		
	Range	0.28-0.55		
Group B: Periodontists (6)				
Year 2	Consensus	0.48 (0.39 to 0.57)	0.66 (0.59 to 0.74)	
	Median	0.43	0.56	
	Range	0.22-0.53	0.38-0.70	
Year 4	Consensus	0.49 (0.39 to 0.59)	0.70 (0.62 to 0.78)	
	Median	0.40	0.59	
	Range	0.26-0.51	0.43-0.76	
Group C: General Dentists (36)				
Year 2	Consensus	0.47 (0.36 to 0.57)	0.67 (0.57 to 0.76)	0.68 (0.60 to 0.76)
	Median	0.41	0.50	0.51
	Range	0.19-0.60	0.13-0.75	0.24-0.73
Year 4	Consensus	0.45 (0.33 to 0.56)	0.59 (0.48 to 0.69)	0.63 (0.53 to 0.73)
	Median	0.47	0.55	0.58
	Range	0.21-0.75	0.06-0.75	0.38-0.76

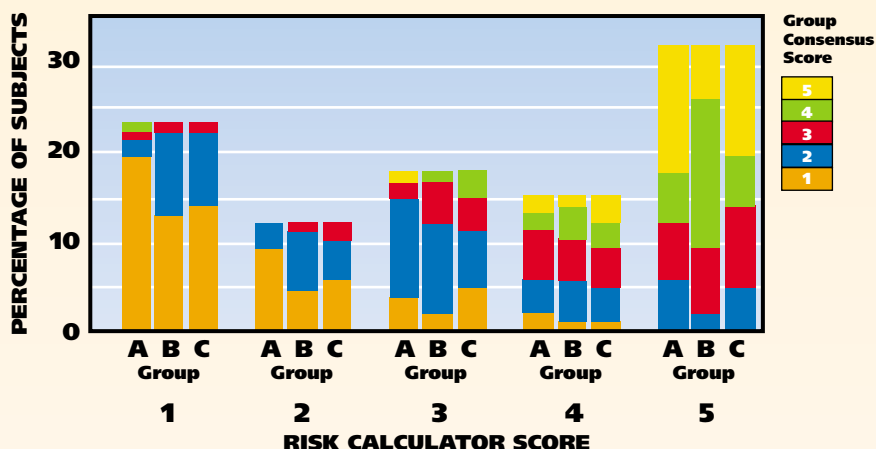* The Periodontal Risk Calculator was developed by Dental Medicine International, Philadelphia.

Figure 2. Composition of Periodontal Risk Calculator-, or PRC, assigned risk groups 1 through 5 based on consensus scores assigned by each of the expert evaluator groups. Bars labeled A, B and C designate each expert evaluator group. Total bar height is the percentage of the total subject population assigned to that risk group by the PRC. Colors within each bar show the proportion of the total subject population with each score based on the consensus risk scores assigned by that evaluator group. PRC was developed by Dental Medicine International, Philadelphia.

years.[16] The purpose of our study was twofold:
■ to determine the extent of interevaluator and intergroup variation in risk scores assigned to study subjects by groups of expert clinicians;
■ to explore the relationship between risk scores assigned by expert clinicians based on subjective judgments and those calculated using the PRC.

To this end, we assembled a group of 107 study subjects, selected to manifest a broad range of risk, and performed standard dental examinations, periodontal examinations or both, including preparation of periapical radiographs and clinical photographs. We entered the resulting information into the PRC and obtained a risk score for each subject for years 2 and 4 hence. The sample size was sufficient to achieve the aims of the study as indicated by the relatively narrow confidence intervals for the weighted κ values (Table). With the given sample size, we were able to estimate within ± 0.1 with 95 percent confidence the reliability between the PRC and each evaluator group, as measured by the weighted κ statistic. The distribution of scores for the 107 study subjects among PRC groups 1 through 5 demonstrated that the study subjects manifested a wide range of risk of experiencing periodontitis.

The expert clinician evaluators were a very diverse group. Group A consisted of 10 practicing periodontists whom, we reasoned, would have greater-than-average knowledge about assessment of risk of periodontitis because of their par-

ticipation in the development of the PRC. Group B included experts from the practice community, academic periodontic departments and the U.S. military who were expected to have no special knowledge of risk assessment, and one Swedish periodontist who is a recognized expert. Group C consisted of 36 periodontally aware general dentists in full-time general practice whom, we reasoned, would have less knowledge about periodontal risk assessment than the periodontists, but would have more knowledge than the average general practitioner.

We tested the hypothesis that group A periodontists and the Swedish periodontist would have the highest level of agreement with their group consensus and with the PRC-assigned scores, followed by group B periodontists, and that the general dentists in group C would have a lower level of agreement with their group consensus and with the scores assigned by the PRC. We then performed statistical analyses to test the extent of intra- and interevaluator group variation, as well as the extent of agreement with group consensus scores and with the risk scores assigned by the PRC. We determined the heterogeneity of each of the five PRC groups on the basis of the expert clinician evaluators' scores.

The weighted κ statistic is an index commonly used for measuring agreement with ordinal data. κ statistics have a range from –1 to 1, where 1 indicates perfect agreement and less than 0 indicates agreement less than expected by chance. In general, a weighted κ value greater than 0.75 indicates excellent agreement beyond chance, 0.40 to 0.75 indicates fair to good agreement and less than 0.40 indicates poor agreement. We used the weighted κ statistic to evaluate the extent of variation among evaluators and the extent of agreement of evaluators with their group consensus and agreement between risk scores calculated by the PRC and those assigned by expert evaluators. On the basis of the κ statistic, we found that the two groups of periodontists and

general dentists did not differ in their risk assessments, although the range was greater for general dentists. Agreement between expert evaluator scores and PRC scores was only fair (0.44-0.49), mostly because a substantial proportion of subjects received a lower score according to the expert clinician group consensus than by the PRC.

The ICC is an appropriate statistical approach to evaluate differences between individual groups of periodontist and general dentist evaluators. The ICC apportions the variance as that due to variation among subjects and that due to variation among evaluators. The ICC has a range of 0 to 1, in which 1 indicates that all of the variation observed is due to variation among subjects. A value of greater than 0.75 among subjects indicates excellent reliability in the sense that relative to the variation between subjects, the variation due to differences between evaluators or other sources is small. For periodontists, the proportion of variation assigned to subjects was high (0.63-0.70) and that assigned to evaluators was low (about 0.07); periodontist groups A and B were very similar to each other. Among general dentists, the proportion of variation assigned to subjects was lower (0.53-0.55) and that assigned to evaluators was almost threefold higher (0.20). Whereas there was no indication of large systematic differences among the evaluators in either of the periodontist groups (including the Swedish periodontist), a systematic difference among general dentists was apparent.

The Spearman rank correlation is a measure of the trend for changes in one variable to be reflected by changes in the other variable. The rank correlation between group A and group B periodontist scores was high for both years 2 and 4, and the scores for general dentists were only slightly lower. The rank correlations for the three groups of evaluators with the PRC scores were considerably lower. Thus, the rank correlations indicate a higher level of evaluator association between clinician evaluators and the PRC than suggested by the κ statistic and ICC. This relationship most likely is owed to the better agreement among evaluators in the ordering of the risk scores than in the actual assignment of numerical scores.

The extent of variation in scores assigned to subjects for years 2 and 4 by the two periodontist groups was large, but it was even larger for the general dentist group. Nevertheless, the con-

sensus scores for the three groups of evaluators, which are independent of the range of variation of individual scores, clustered near one another for each of the five risk groups and near the PRC values for groups 3 and 4 and to a lesser extent for group 1, but not for groups 2 and 5. Relative to the PRC calculations, expert clinician opinion assigned a larger proportion of the subject population to PRC risk groups l and 2 and a much smaller proportion to group 5. These observations are notable. When looked at overall, if the PRC-calculated risk scores are correct as suggested by a previous study,[16] not only is there an unexpectedly large variation among dentists and periodontists in assessment of risk for a given case, but also dentists and periodontists generally appear to underestimate risk. Many people in lower risk groups actually may belong in risk group 5, and many of the excessive numbers of subjects in groups 1 and 2 may belong in higher risk groups.

When the data are examined in greater detail, an additional feature is apparent. If expert evaluator consensus and PRC risk scores were in complete agreement, the group of bars for each of the five risk groups in Figure 2 would have a uniform color; clearly, that is not the case. The extent of deviation from uniform colors and the distribution of colors among the bar groups are an expression of heterogeneity or lack of agreement. The composition of the PRC risk groups is highly heterogeneous. For example, subjects with expert evaluator consensus scores of 2 or 3 are distributed throughout PRC risk groups 1 through 5, and only a minority of subjects in PRC risk group 5 actually have an evaluator consensus score of 5; the majority has risk scores of 2, 3 and 4. Subjects with a score of 1 based on expert opinion are distributed through PRC groups 1 through 4 and those with scores 2 and 3 are found in all five PRC groups. This pattern of heterogeneity is apparent for all three expert evaluator groups. For a given subject and a given expert, the probability of congruence of the expert opinion and PRC score is relatively small.

CONCLUSION

Our data demonstrate that interevaluator variation among expert clinicians in assessing subjects' risk of experiencing periodontal disease under the conditions of this study was unexpectedly large. The level of agreement of individual expert clinician scores with their group consensus was high, and the consensus scores for the three evaluator

Dr. Persson is a professor of periodontics and the associate director, Regional Clinical Dental Research Center, School of Dentistry, University of Washington, Seattle.

Dr. Mancl is a research associate professor, Department of Dental Public Health Sciences, School of Dentistry, University of Washington, Seattle.

Dr. Martin is in private practice in State College, Pa.

Dr. Page is a professor, Department of Periodontics; the director, Regional Clinical Dental Research Center; and a professor, School of Dentistry, University of Washington, 1959 N.E. Pacific, Box 357480, Room B-530 Health Sciences, Seattle, Wash. 98195, e-mail "roypage@u.washington.edu". Address reprint requests to Dr. Page.

groups were very similar. Agreement of the consensus scores with the PRC-assigned scores, however, was only fair. The lack of better agreement was due, in part, to the underestimation of risk by the expert clinicians relative to the PRC as reflected by their assignment of fewer subjects to PRC risk group 5 and more to risk groups 1 and 2.

In general, on the basis of expert clinician consensus scores, we found that more than one-half of the subjects in PRC risk groups were dispersed throughout groups other than that assigned by the PRC. Dispersion would have been even greater had individual rather than group consensus scores been used. If the PRC risk scores are correct as indicated by a previous study,[16] both dentists and periodontists appear to underestimate the risk of developing periodontitis. These observations suggest that risk scores generated for individual patients by subjective expert clinician opinion are highly variable and, when used in periodontal clinical decision making, could result in the misapplication of treatment for some patients. Use of a risk assessment tool over time may be expected to result in more uniform and accurate periodontal clinical decision making, improved oral health, reduction in the need for complex therapy and reduction in health care costs.[19] ■

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