Prognosis Versus Actual Outcome. II. The Effectiveness of Clinical Parameters in Developing an Accurate Prognosis

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THE ASSIGNMENT OF PROGNOSIS is one of the most important functions undertaken in clinical practice, yet there is little evidence to support the current decision-making process which is based on an outdated model of disease etiology and progression. This study evaluated 100 treated periodontal patients (2,484 teeth) under maintenance care for 5 years, with 38 of these patients followed for 8 years, to determine the relationship of assigned prognoses to the clinical criteria commonly used in the development of prognosis. The method of generalized estimating equations (GEE) for correlated data was utilized to determine the relationship of each clinical factor to the assignment of initial prognosis, improvement in prognosis at 5 years, and worsening in prognosis at 5 years. A multiple linear regression model was constructed for predicting initial prognosis based on initial clinical data. Increased probing depth, more severe furcation involvement, greater mobility, unsatisfactory crown-to-root ratio, malpositioned teeth, and teeth used as fixed abutments resulted in worse initial prognoses. The coefficients from this model were able to predict accurately the 5-year and 8-year prognoses 81% of the time. When teeth with "good" prognoses were excluded, the predictive accuracy dropped approximately 50%. Multiple logistic regression models indicated that improvement in prognoses and worsening in prognoses were both strongly associated with initial probing depth, initial furcation involvement, initial tooth malposition, and smoking when adjusted for initial prognosis. In addition, good hygiene was found to increase the probability of improvement in prognosis while initial mobility was found to decrease the likelihood of improvement in prognosis. Neither of these factors was found to be significant in worsening of prognosis. Smoking decreased the likelihood of improvement by 60% and doubled the likelihood of worsening in prognosis at 5 years. The results of this study indicate that some clinical factors used in the assignment of prognoses are clearly associated with changes in clinical condition over time. The data also demonstrated that the traditional approach for assigning prognoses is ineffective for teeth with an initial prognosis of less than good. Since most periodontally involved teeth are compromised, further work should include the development of a more effective method for assigning prognoses that is based on clear, objective clinical criteria. *J Periodontol 1996;67:658–665.*

Key Words: Tooth survival; decision making; periodontal diseases/diagnosis; prognosis; treatment outcome; tooth loss; risk factors; dental models.

Very few studies have evaluated the process for the assignment of an accurate prognosis. Recently, interest in the subject has increased, but close inspection of the literature reveals that researchers focus more on risk factors than on prognostic factors.[1-9] "Risk factors" are defined as those patient characteristics associated with the development of the disease in the first place; "prognostic factors" are defined as those characteristics that may predict the outcome once the disease is present but do not actually cause it.[10] Although some models will allow one to evaluate risk factors in an epidemiological sense, the real challenge lies in the development of a model that will predict outcome on an individual patient basis.[11]

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Table 1. Commonly Taught Clinical Factors Used in Assigning Prognosis

Individual Tooth Prognosis
Percentage of bone loss
Deepest probing depth (in mm)
Horizontal or vertical bone loss
Deepest furcation involvement: 0, 1, 2, 3
Mobility: 0, 1, 2, 3
Crown-to-root ratio: favorable or unfavorable
Root form: favorable or unfavorable
Caries or pulpal involvement: yes or no
Tooth malposition: yes or no
Fixed or removable abutment: yes or no
Overall Prognosis
Age
Significant medical history (smoker and/or diabetic): yes or no
Family history of periodontal disease (mother, father, sibling): yes or no and whom
Hygiene: good, fair, poor
Compliant: yes or no
Maintenance interval: 2 months; 2 months alternate; 3 months; 3 months alternate
Parafunctional habit with biteguard
Parafunctional habit without biteguard

Table 2. Definitions of Various Prognoses

- **Good Prognosis** (one or more of the following): Control of the etiologic factors and adequate periodontal support as measured clinically and radiographically to assure the tooth would be relatively easy to maintain by the patient and clinician assuming proper maintenance.
- **Fair Prognosis** (one or more of the following): Approximately 25% attachment loss as measured clinically and radiographically and/or Class I furcation involvement. The location and depth of the furcation would allow proper maintenance with good patient compliance.
- **Poor Prognosis** (one or more of the following): 50% attachment loss with Class II furcations. The location and depth of the furcations would allow proper maintenance, but with difficulty.
- **Questionable Prognosis** (one or more of the following): Greater than 50% attachment loss resulting in a poor crown-to-root ratio. Poor root form. Class II furcations not easily accessible to maintenance care or Class III furcations. 2+ mobility or greater. Significant root proximity.
- **Hopeless Prognosis:** Inadequate attachment to maintain the tooth. Extraction performed or suggested.

Even though the assignment of prognosis is one of the most important functions undertaken in clinical practice, no clear guidelines have yet been established. In fact, practitioners have handed down their particular approach for assigning prognosis from one generation to the next without investigating evidence to support the decision-making process. Most periodontal textbooks routinely include a chapter on prognosis which reflects the belief that the practitioner must consider many factors about the tooth, dentition, and individual (Table 1) to arrive at a prognosis, but how one arrives at that prognosis is not clear. The process is further confounded by therapists emphasizing factors based on their idiosyncratic judgment and past experience. As important as clinical intuition and judgment are, the evidence-based decision-making process has demonstrated that subjective variables may result in the clinician's overestimating the efficacy of a particular approach. The ability to assign a correct prognosis can be improved through the incorporation of unbiased quantitative data.[12,13]

The first paper in this series[14] evaluated 100 treated periodontal patients (2,484 teeth) under maintenance care for 5 to 8 years to determine the accuracy of assigned prognosis based on the commonly taught clinical criteria found in Table 1. The results indicated that the ultimate fate of teeth initially labeled as hopeless varied substantially and, even though the average prognosis of teeth studied at each interval remained relatively stable over time, individual prognosis categories and individual tooth prognoses changed frequently. Possible reasons for these shifts were discussed. In conclusion, it was found that projections utilizing the factors listed in Table 1 were ineffective in predicting outcomes other than good, and that prognoses tended to be more accurate for single rooted teeth than for multirooted teeth. These results were recently confirmed in a study reported by Ghiai and Bissada.[15]

The purpose of the present study is to further evaluate the data derived from the longitudinal investigation used in the previous article, to explore the relationship of each clinical factor in Table 1 to their prognosis assignment and, if possible, to determine which clinical parameters are the most important in developing an accurate prognosis.

MATERIALS AND METHODS

As reported earlier, 100 consecutive patients with at least 5 years of maintenance care were selected from one clinician's appointment book over a 2-month period.[14] All had been initially diagnosed as having chronic generalized moderate to severe adult periodontitis and were treated by the same clinician. Patients in the study were under maintenance regimens of 2- or 3-month intervals with the majority under a 3-month interval and reflected many of the characteristics observed in "well maintained" patients.[16] Additional information regarding the study population, therapy, and assignment of prognoses can be found in the initial report.[14] The prognostic criteria used in this series of studies are described in Table 2.

Determining the Actual Outcome

Teeth lost during the initial active phase of periodontal therapy were documented, along with the prognosis assigned each tooth following active therapy and prior to maintenance care. The same set of criteria were used for assigning prognoses at 5 and 8 years. Subsequent prognoses were determined by charted clinical data accumulated between initial and 5 years and 5 years and 8 years, rather than on information recorded only at the 5-year and 8-year examinations. A more accurate projection of prognosis was intended by this method. All assessments were

blind to previous assessments and conducted by the same examiner. The prognoses initially, at 5 years, and at 8 years were then compared.

Statistical Methods

Statistical analyses were conducted using SAS and S Plus statistical software packages. Prognosis was used to facilitate the exploration of which clinical factors impact a tooth in such a way as to change its prognosis over a period of time. Prognosis in this setting could be considered to be a measure of the tooth's overall clinical appearance at a particular point in time. To evaluate the relationship of each clinical factor (Table 1) to the assignment of prognosis, a series of simple linear regressions were performed using the method of generalized estimating equations (GEE) as outlined by Zeger and Liang.[17] This method was utilized since the data were correlated and ordinary least squares evaluations would be invalid. Prognoses were given numerical values from 1 to 5 for the initial prognoses and 1 to 6 for later prognoses with a score of 1 representing a good prognosis and a score of 6 representing a hopeless tooth that was extracted during the maintenance phase. The initial prognoses were regressed on each of the clinical factors individually. Clinical factors that were considered included age at the beginning of the study; history of smoking; history of diabetes; patient compliance; history of parafunctional habit; use of a biteguard; percent overall bone loss; deepest probing depth; type of bone loss (horizontal or vertical); degree of furcation involvement (0 for none up to 3 for the most involved); mobility (0 for no mobility up to 3 for the greatest mobility); crown-to-root ratio (satisfactory or unsatisfactory); root formation (satisfactory or unsatisfactory); endodontic involvement; presence of caries; root proximity (satisfactory or unsatisfactory); tooth malposition (satisfactory or unsatisfactory); fixed abutment; removable abutment; oral hygiene (good, fair, poor), and overall family history of periodontal disease (0 for no history, 1 for history in sibling, mother, or father). In all cases an exchangeable correlation structure was assumed.

To discover which clinical factors were related to improved prognosis (and by interference, improved condition), only teeth that had a prognosis of less than good were included. The response variable considered was a dichotomous variable that was assigned 1 if the tooth improved in prognosis and 0 otherwise. To evaluate what clinical factors were related to worse prognosis (and by inference, worse condition), only teeth that had a prognosis of better than questionable were fitted in the model. The response variable considered was a dichotomous variable that was assigned 1 if the tooth worsened in prognosis and 0 otherwise. The method of GEE was utilized to fit a series of simple logistic regressions to determine which clinical factors were significantly associated with improved prognoses and worsening prognoses. The clinical factors mentioned above were considered for analysis. Improvement in prognosis and worsening in prognosis were measured from initial to 5-year prognoses.

Multiple linear regression and logistic regression models were constructed including all clinical factors that were significantly correlated ($\alpha \leq 0.10$) with initial prognosis, improved prognosis at 5 years, and worsening prognosis at 5 years for the respective models. Insignificant variables were then dropped one at a time until all variables left in the model were significant at the 0.10 level of significance. The method of GEE was also used to fit the multiple regression models.

Multiple logistic regressions for improved prognosis and worsening prognosis incorporated initial prognoses. Indicator variables for the different levels of initial prognosis were used (poor, questionable, and hopeless for the improved prognosis model and fair and poor for the worsening prognosis model). A forward step-wise approach was utilized with indicator variables for the prognosis entered initially and variables added one at a time until a significance level of $\alpha \leq 0.10$ was achieved for every variable in the model.

To assess the validity of the multiple logistic regression models, specificity and sensitivity were calculated. Specificity is the proportion of teeth that did not improve that were correctly predicted not to improve by the model. Sensitivity is the proportion of teeth that improved that were correctly predicted to improve by the model. Specificity and sensitivity were calculated with different predicted probabilities used to categorize predicted improvement and predicted worsening in prognosis in order to jointly maximize sensitivity and specificity based on the data. Sensitivity and specificity were calculated for improvement and worsening at 5 years to obtain an upper estimate of the accuracy of the constructed models. To further test the validity of the models, parameter estimates obtained from the models for improved prognoses at 5 years and worsening prognoses at 5 years were then used to calculate sensitivity and specificity of improvement at 8 years and worsening at 8 years based on 5-year data.

RESULTS

The Relationship of Clinical Factors to Prognosis

Factors that were significantly correlated ($\alpha \leq 0.05$) with initial prognosis included history of periodontal disease in a sibling, history of parafunctional habit, percent overall bone loss, deepest probing depth, presence and severity of furcation involvement, tooth mobility, unfavorable crown-to-root ratio, unfavorable root formation, tooth malposition, and fixed prosthesis abutment. Unfavorable root proximity was also marginally significant (P value $= 0.054$). Those with a history of periodontal disease in a sibling had proportionally more teeth with worse prognoses when compared to those with no history of peri-

Table 3. Multiple Regression on Initial Prognosis

Parameter	Estimate	Standard Error	Robust z	*P* Value
Intercept	0.615	0.0531	11.57	<0.0001
Probing depth	0.143	0.0136	10.49	<0.0001
Furcation	0.192	0.0369	5.20	<0.0001
Crown/root ratio	0.108	0.0453	2.37	0.0178
Mobility	0.268	0.0788	3.40	0.0007
Malposed	0.332	0.1795	1.85	0.0643
Fixed abutment	0.125	0.0693	1.81	0.0703

odontal disease in a sibling. Those with parafunctional habits had teeth with worse prognoses than those without a parafunctional habit. As would be expected, teeth associated with greater overall bone loss had a worse prognosis. An increase in probing depths, furcation involvement, and mobility were all associated with a worse prognosis. Both unfavorable crown-to-root ratio, unfavorable root formation, and tooth malposition were associated with more unfavorable prognoses. Teeth used as abutments for fixed prostheses tended to have worse prognoses. Teeth with unfavorable root proximity also tended to have less favorable prognoses.

The final multiple linear regression model obtained for predicting initial prognosis is summarized in Table 3. The data in this table demonstrate that all variables in the model result in a worse prognosis. Increased probing depth, more severe furcation involvement, greater mobility, unsatisfactory crown-to-root ratio, malposed teeth, and teeth used as fixed abutments result in less favorable prognoses. To test the validity of this model, the coefficients from this model were used to predict 5-year and 8-year prognoses from the 5-year and 8-year data, respectively. These predicted values were then rounded to the nearest integer and compared to the actual prognosis recorded for that period. For the 5-year data, the regression model accurately predicted 81% (2,007 cases) of the actual prognoses; a worse prognosis in 116 (5%); and a better prognosis in 351 cases (14%). For the 8-year data, the regression model accurately predicted 81% (751 cases) of the observed prognoses, worse prognoses in 33 cases (4%); and more favorable prognoses in 140 cases (15%).

When evaluating the accuracy of this model according to tooth type, it was found that the model was most accurate for anterior teeth and least accurate for molars. At 5 years, the model accurately predicted 89% of anterior teeth while it accurately predicted only 65% of molars. Overall prediction of non-molars resulted in 87% accuracy at 5 years. Similarly, the model accurately predicted 92% of anteriors at 8 years, and only 65% of molars. Overall prediction of non-molars resulted in 87% accuracy at 8 years.

The first paper in this series[14] concluded that an accurate prognosis was more difficult to make for teeth with an initial prognosis of less than good. Since approximately 70% of the teeth being evaluated had an initial prognosis of good, it follows that the accuracy of the assignment process for individual tooth prognoses would be more sensitively tested by the evaluation of the study groups after the exclusion of all good prognoses. When teeth with "good" prognoses were excluded, the accuracy of prediction dropped considerably. The overall accuracy for teeth with less than "good" initial prognoses was 43% at 5 years and 35% at 8 years. Ironically, the model was most accurate for predicting less than "good" prognoses for molars with an accuracy of 59%. The accuracy for molars with less than "good" prognoses at 8 years was 47%. Accuracy of prediction of non-molars with fair or worse prognoses was much lower. Prognoses of anteriors with fair or worse prognoses were only 28% accurate at 5 years and 4% accurate at 8 years. The overall accuracy of non-molars with fair or worse prognoses was only 23% at 5 years and 21% at 8 years.

Table 4. Initial Clinical Factors Affecting Change in Prognosis at 5 Years

Clinical Factor	Improved (Odds Ratio)	Worse (Odds Ratio)
Father had periodontis	*1.716*	0.757
Smoking	**0.556**	**1.891**
Diabetes	0.723	*1.451*
Habit	0.901	*1.456*
No biteguard	0.847	**1.525**
50% bone loss	1.076	*1.594*
Probing depth (per mm)	**0.795**	**1.365**
Furcation	**0.715**	**1.710**
Mobility	**0.712**	1.219
Root formation	0.711	**1.835**
Caries	*5.596*	1.919
Endodontic	1.916	**4.349**
Malposed	*0.441*	**2.173**
Good hygiene	**3.274**	0.720
Fixed abutment	1.501	*1.446*

*Odds ratios significant at $\alpha = 0.05$ are shown in bold type. Factors significant at $\alpha = 0.10$ are shown in italics. Insignificant factors for both improved prognosis and worse prognosis at 5 years are not shown.

Clinical Factors Related to Improved Prognoses and Worsening Prognoses

A summary of odds ratios for improved prognosis and worsening prognosis at 5 years is given in Table 4. From these data, we see that smoking, initial probing depth, initial furcation involvement, initial mobility, and good oral hygiene were all significantly related to the probability that a tooth would improve at 5 years. We see that smoking, initial probing depth, initial furcation involvement, initial root form, initial endodontic involvement, malposition, and no biteguard in the presence of a parafunctional habit were all significantly ($\alpha \leq 0.05$) related to the probability that a tooth would worsen at 5 years. In addition, percent bone loss, parafunctional habit, and

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Table 5. Multiple Logistic Regression on Improved Prognosis at 5 Years Based on Initial Clinical Factors

Clinical Factor	Estimate	Standard Error	*P* Value	Odds Ratio
Intercept	2.565	0.3568	<0.0001	
Poor*	2.005	0.3386	<0.0001	7.426
Questionable*	2.459	0.5826	<0.0001	11.693
Hopeless*	0.944	0.6032	0.1164	2.570
Probing depth*	−0.312	0.0609	<0.0001	0.732
Furcation*	−0.401	0.1083	0.0002	0.670
Mobility*	−0.340	0.1496	0.0232	0.712
Smoking	−0.873	0.3314	0.0085	0.418
Good hygiene	0.918	0.3572	0.0102	2.504
Malposed*	−1.121	0.5598	0.0455	0.326

*Initial.

Table 6. Multiple Logistic Regression on Worse Prognosis at 5 Years Based on Initial Clinical Factors

Clinical Factor	Estimate	Standard Error	*P* Value	Odds Ratio
Intercept	−4.275	0.2953	<0.0001	
Fair*	−1.784	0.2872	<0.0001	0.168
Poor*	−3.767	0.4436	<0.0001	0.023
Probing depth*	0.465	0.0515	<0.0001	1.592
Furcation*	0.611	0.1113	<0.0001	1.842
Smoking	0.644	0.2468	0.0091	1.904
Malposed*	0.842	0.3988	0.0349	2.321
Diabetes (controlled)	0.736	0.1460	<0.0001	2.088
Root form*	0.475	0.3307	0.0394	1.608
Endodontic*	1.352	0.4449	0.0024	3.865

*Initial.

diabetes were all marginally associated to the probability that a tooth would worsen at five years.

The final regression model constructed for improved prognosis at 5 years is summarized in Table 5. From Table 5, it can be seen that increased initial probing depth, more severe initial furcation involvement, greater initial mobility, initial malposed teeth, and smoking were all associated with a decreased likelihood of improvement in prognosis. Good oral hygiene and prognosis of poor or worse were both associated with an increased probability of improvement in prognosis. In fact, teeth with poor prognoses initially had over 7 times as great a chance of improvement when compared to teeth with fair prognoses initially while teeth with questionable prognoses had nearly 12 times as great a chance of improvement at 5 years compared with those that had fair prognoses initially.

Sensitivity to improvement at 5 years based on initial data was 69%. The specificity of improvement at 5 years based on initial data was 69%. Based on 5-year clinical data, sensitivity and specificity for improvement in prognosis at 8 years were 65% and 63%, respectively.

The final regression model fitted for worsening in prognosis is summarized in Table 6. From Table 6, it can be seen that increased initial probing depth, more severe initial furcation involvement, initial endodontic involvement, smoking, diabetes, initial malposed teeth, and initial unsatisfactory root form were all associated with an increased probability of worsening in prognosis at 5 years.

Sensitivity to worsening at 5 years based on initial data was 67%. The specificity of worsening at 5 years based on initial data was 76%. Based on 5-year clinical data, sensitivity and specificity for worsening in prognosis at 8 years were 66% and 60%, respectively.

DISCUSSION

The traditional process for the assignment of prognosis is based on an outdated model of disease progression which assumes that all plaque is the same and everyone is equally susceptible. The influence of the host is largely ignored and environmental factors are believed to be very important in the initiation and progression of the disease. Under this paradigm, clinical factors (Table 1), primarily anatomical in nature, are used to develop a prognosis and eventual outcome dependent upon environmental factors that limit care. Today's paradigm, however, suggests that periodontal disease depends on the microbial insult, the body's reaction to the insult, and the control of the level of pathogens. The question we must answer is: does our traditional concept for the assignment of prognosis fit our new concept of periodontal diseases as site-specific infections that depend much more on pathogens, protective species, and host resistance than they do on the traditional list of factors used in prognosis determination? More research is needed to provide understanding about how different types of periodontal diseases affect the assignment of prognosis. Unfortunately, this work will be difficult because the newer concept of periodontal disease provides many more factors of uncertain influence that are difficult to measure or monitor.[11]

To assess the accuracy of assignment of prognosis, one generally has to rely on weaker study designs such as cohort studies or retrospective studies, such as the one reported in this paper. When evaluating the results of this study, one should consider a number of potential weaknesses, some of which were identified earlier.[14] For instance, the retrospective nature of data collection about prognostic factors often depends on the memory of patients and the accuracy of records, both of which can limit the strength of inference that can be drawn from these studies. Even though the examiner in this study had some knowledge about which prognostic factors the patient possessed, it is unlikely that this knowledge substantially biased the assessment since the examiner had no knowledge of which prognostic factors were important.[10] Finally, only limited inference can be drawn from this analysis since prognosis is not a true endpoint, but a predictor of the true endpoint - tooth loss. Future studies will include survival analysis based on tooth loss to determine the accuracy of predicting tooth survival. In addition, survival analysis of the various clinical factors studied here

should also be undertaken to better understand their relationships to tooth loss.

As previously reported, the study population had many of the characteristics of Hirschfeld and Wasserman's "well-maintained" group.[16] The only exception was that 40% of our group had parafunctional habits and of those, only 40% wore biteguards. The oral hygiene pattern for the group was rather typical for a periodontal maintenance patient, with the great majority of patients having fair oral hygiene (20% good, 66% fair, 14% poor). Almost one-half of the patients (47%) were on a 3-month alternating recall; one fourth (25%) were seen exclusively in the periodontist's office on a 3-month interval; the remaining patients were split between a 2-month recall exclusively in the periodontist's office (17%) and a 2-month alternating recall (10%). The study population was found to be very compliant, probably the result of the previously described selection process. In order to be included in the study, all patients had to be in maintenance for at least 5 years and, presumably, most of the non-compliant patients had dropped out by that time. Therefore, extrapolation of data from this study would be most valid when applied to other "well-maintained" periodontal maintenance patients.

The first paper in this series[14] concluded that an accurate prognosis was more difficult for clinicians to assign for teeth with an initial prognosis of less than good and suggested that most good prognoses tend to remain good. This current report not only reinforces the earlier conclusion, but also demonstrates that overall accuracy of the model at 5 years dropped by nearly 50% when teeth with "good" prognoses were excluded. At 8 years, the accuracy dropped even more when "good" prognoses were excluded, from 81% to 35%. Clearly, these data challenge the effectiveness of the traditional approach to the assignment of prognosis. A coin toss would be an easier and more accurate way for the clinician to assign a prognosis under traditional guidelines, if the initial prognosis is less than good. Surprisingly, the model was slightly more accurate for assigning prognosis to molars than for non-molars when teeth with "good" prognoses were excluded. This unexpected result perhaps can be explained by the proportionately greater number of anterior teeth excluded because of their good prognoses. In addition, more clinical factors such as "furcation involvement" apply to molars than anterior teeth when the traditional approach is used.

The previous analysis[14] revealed that prognoses often changed over time, and changed most frequently in teeth that had less than "good" prognoses initially. Statistical analysis revealed that several factors were significantly related, either positively or conversely, to the probability of improvement in prognoses at 5 years. In particular, increased probing depth initially, more severe furcation involvement initially, more mobility initially, and malposition of a tooth initially were all associated with a decreased probability of improvement. Initial hopeless prognoses did not significantly differ from initial fair prognoses in terms of the likelihood of improvement. Ironically, teeth with poor prognoses initially were almost seven and a half times as likely to improve when compared with teeth with fair prognoses initially, while teeth with questionable prognoses initially were nearly 12 times as likely to improve in prognoses when compared to teeth with fair prognoses initially. With the exception of teeth with hopeless prognoses, it appears that teeth with worse prognoses initially are more likely to improve. It was also shown that smoking decreased the likelihood of improvement by 60%. Good hygiene was found to increase the likelihood of improvement by about two and a half times that of teeth that had fair or poor hygiene (which did not differ significantly from each other in terms of improvement in prognoses).

Probability of worsening in prognoses was also evaluated using a multiple logistic regression model. Increased initial probing depth, more severe initial furcation involvement, malposition of a tooth initially, initial unsatisfactory root form, and initial endodontic involvement, history of smoking and diabetes were all associated with the probability that the prognosis of a tooth would worsen at 5 years. Fair prognoses initially and poor prognoses initially had a substantially lower probability of worsening in prognoses at 5 years when compared to teeth with good prognoses initially. Specifically, teeth with fair prognoses initially were only 17% as likely to worsen in prognosis compared with teeth with good prognoses initially, and teeth with poor prognoses initially were only 2% as likely to worsen in prognosis when compared to teeth with initial good prognoses. In other words, teeth that are already compromised tend not to get much worse under maintenance care. Smoking and diabetes both doubled the likelihood of worsening in prognosis at 5 years. Interestingly, hygiene level and mobility did not appear to significantly affect the probability of worsening in prognosis at 5 years, possibly because teeth with mobility and exposed to poor hygiene were initially assigned a worse prognosis. It is also possible that the professional maintenance that the patients received overcame any negative effects of poor personal oral hygiene.

Interesting observations can be made between the data reported in this communication and a paper recently published by Ghiai and Bissada.[15] Although their study population seems to closely parallel the one in this paper, comparisons should be viewed cautiously because of differences between the two studies in both the definition of prognoses and which clinical factors were evaluated. Taking that into account, they also found (when evaluating all teeth) that it was more difficult to accurately predict prognoses for posterior teeth than anterior teeth. When evaluating their success of assigning an accurate prog-

nosis to all teeth in their study over 5 to 13 years, they found that their model was 38% successful. (They did not evaluate the success of their model on teeth whose initial prognoses was less than good.) In their study, the only factors that showed statistical significance in their efforts to develop a predictive model were mobility, oral hygiene, and alveolar bone score. Mobility was the most important clinical parameter in predicting prognosis regardless of tooth type. Wheeler et al. also found that mobility was the most important clinical parameter when combined with other microbiologic and immunological risk factors for predicting alveolar bone loss in elderly populations.[18] Wang et al. reported in 1994 that teeth with furcation involvement and mobility had significantly more attachment loss during the maintenance period, which one might assume equates with a worsening prognosis.[19] With the exception of the probability of worsening in prognosis, our models also demonstrated the importance of mobility in the development of prognosis. Perhaps the reason mobility is such an important clinical parameter is that this one indicator provides a good overview of many other parameters such as the amount of attachment loss, the stability of the occlusion, and possibly the presence of parafunctional habits.

A number of recent studies[20–23] have implicated smoking as an important risk factor in periodontal disease. As mentioned earlier, our study indicated that smoking decreased the likelihood of improvement of prognoses by 60% and it doubled the likelihood of worsening in prognosis at 5 years.

The data from this study seem to indicate that the utilization of all of the factors listed in Table 1 to assign a prognosis may not be necessary. It appears that clinicians should weigh certain criteria (increased probing depth, more severe furcation involvement, greater mobility, unsatisfactory crown to root ratio, malposed teeth, smoking, and teeth used as fixed abutments) more heavily in the assignment of a prognosis when evaluating the population as a whole. The problem, however, with some of these significant clinical variables (increased probing depth, more severe furcation involvement, and greater mobility) is that they are a reflection of the progression of the disease process and not useful predictors for the assignment of prognosis because the variables themselves do not exist until the downward shift in prognosis occurs. On the other hand, the other four significant clinical factors (unsatisfactory crown-to-root ratio, malposed teeth, smoking, and teeth used as fixed abutments) are available when the assignment of prognosis occurs and the data would seem to indicate that more weight should be placed on their presence than the other commonly taught clinical parameters in Table 1.

Further work needs to be accomplished to validate the effectiveness of the predictive models outlined in this paper, especially as they relate to teeth whose initial prognoses is less than "good." In addition, studies need to be conducted to determine which, if any, microbial or immunological factors may also be important in the assignment of an accurate prognosis, especially in non-adult forms of the disease.

The goal of this paper was to evaluate the effectiveness of commonly taught clinical parameters in the development of an accurate prognosis. The summation of evidence from this study demonstrates that it is possible to predict prognoses using clinical parameters alone and, furthermore, that some clinical factors appear to be more important than others in the assignment of prognosis when the entire population is evaluated. The data indicate that a model which includes initial probing depth, furcation involvement, mobility, unsatisfactory crown-to-root ratio, malposed position of the tooth, and utilization of the tooth as a fixed abutment is surprisingly accurate in predicting actual prognoses at 5 (81%) and 8 years (81%). It appears, however, that this same approach for the assignment of prognosis is ineffective for teeth with an initial prognosis of less than "good." This is disappointing because the reality of clinical practice is that even after our best therapeutic efforts, many teeth that have suffered the ravages of periodontal disease cannot be brought back to a pristine condition and thus have less than a "good" prognosis. For these teeth, more effective methods for the assignment of prognoses are needed.

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