The Potential Prognostic Value of Some Periodontal Factors for Tooth Loss: A Retrospective Multilevel Analysis on Periodontal Patients Treated and Maintained Over 10 Years


**Background:** The great challenge in clinical periodontology is assigning a prognosis to a periodontally affected patient. Many different factors can affect the long-term maintenance of periodontally compromised teeth. The main questions usually considered by the periodontist are: 1) Will a tooth lose more bone in the future? 2) Will the tooth itself be lost in the future? The purpose of this retrospective study was to evaluate the value of some clinical, genetic, and radiographic variables in predicting tooth loss in periodontal patients (aged 40 to 60 years) treated and maintained for 10 years.

**Methods:** Sixty consecutive non-smoking patients (aged 46.77 ± 4.96 years) with moderate to severe chronic periodontitis (CP) were treated with scaling and root planing (SRP). Some patients also underwent additional surgical treatments. All patients were maintained in the same private practice for 10 years. The frequency of recall appointments was 3.4 ± 1.0 months. At baseline (T₀) and 10 years later (T₂) the following clinical variables were evaluated: the number of teeth, probing depths (PD), tooth mobility (TM), and presence of prosthetic restorations (PR). In addition, radiographic measurements were taken of the mesial and distal distances from the cemento-enamel junction (CEJ) to the bottom of the defect (BD), to the bone crest (BC), and to the root apex (RA). At T₀, a genetic test to determine the IL-1 genotype and genetic susceptibility for severe periodontal disease was performed for all 60 patients, and they were classified as IL-1 genotype positive (G+) or negative (G–) according to the test results. Tooth loss was used as the outcome variable. Different predictor variables were then tested using a two-level statistical model (patient and tooth levels). At the patient level, these were: age, gender, mean bone loss (mean CEJ-BD)ₚ, the interleukin-1 (IL-1) genotype, the interaction between mean bone loss, and IL-1 genotype (mean CEJ-BDₚ × IL-1 genotype). At the tooth level, the variables were: TMₜ, prosthetic restorations (PR)ₜ, molar teeth (MT)ₜ, and residual supporting bone (BD-RA)ₜ.

**Results:** Among the considered predictor variables, the following were significantly associated with the outcome variable: 1) MTₚ (P < 0.0001); 2) BC-BDₚ (P = 0.0377); and 3) BD-RAₚ (P < 0.0001). MTₚ were found to be more prone to loss and the amount of BD-RAₚ prognostic for tooth loss: the lower the residual amount of supporting bone, the higher the probability of tooth loss. Conversely, the BC-BDₚ was associated with a reduced probability of future tooth loss: the greater the infrabony component, the lower the probability of tooth loss. None of the other considered predictors proved predictive for tooth loss.

**Conclusions:** Within the scope of this study, many traditional prognostic factors were ineffective in predicting future tooth loss and, therefore, were of no prognostic value. Conversely, a few specific factors at the tooth level emerged as viable prognostic factors. The use of these factors may be of great value to practitioners as predictors of tooth loss when assigning a prognosis. J Periodontol 2006;77:2084-2089.

**KEY WORDS**
Genotype; interleukin-1; periodontal disease; prognosis; tooth loss.

One of the main goals of periodontal treatment is to obtain a complete healing of diseased sites to foster the long-term maintenance of the patient’s teeth.

Practitioners often deal with hard tissue loss that makes the diseased tooth uncertain regarding the long-term outcome of the treatment. Multiple treatment planning (i.e., periodontal-prosthetic) must take into consideration the reliability of a tooth for prosthetic...
rehabilitation, and the frequent concern is whether a tooth should be treated or extracted.

These considerations create the need for a prognosis in terms of the likelihood of future progress of the disease and of tooth loss. This is particularly important in cases in which the practitioner will need precise, objective information to develop a more reliable long-term prognosis for the tooth.

A previous article reported that some factors commonly used by practitioners in assigning prognoses actually proved ineffective. These factors are based only on personal periodontal training, judgment, and past experiences.

An article by McGuire and Nunn pointed out that some clinical variables (i.e., initial probing depth [PD], initial furcation involvement, and smoking habits), strongly associated with assigning a “good to poor prognosis” to a tooth, were ineffective in assigning a prognosis of “less than good.”

Some articles highlighted the association between interleukin-1 (IL-1) genotype positivity and more severe periodontal disease, reinforcing the theory that genetics alone, and/or in combination with other risk factors, may be of high prognostic value.

In 1992, Albendar and Goldstein suggested using a multilevel statistical model to assess the reliability of certain variables. Due to its statistical validity and efficiency, that model offers several advantages with respect to unilevel methods.

Using a three-level statistical model in a previously published study on the same sample of patients, some possible prognostic factors on bone loss were evidenced. The results showed that interactions between initial mean bone level and positive IL-1 genotype, tooth mobility (TM), initial bone level at a site, the infrabony component of a defect, and initial PD at a site were indeed predictive for future bone-level variations.

Taking into consideration this background, the aim of the present study is to evaluate whether clinical, genetic, and radiographic variables are of prognostic value in predicting tooth loss in patients treated and maintained over 10 years using a two-level statistical model (patient and tooth levels).

**MATERIALS AND METHODS**

Patients from previous studies were included in this study population that consisted of 60 subjects consecutively selected in a private periodontal practice between 1999 and 2000 during routine periodontal maintenance visits. All patients signed an informed consent to participate in the study. Patients enrolled in this study had to satisfy the following criteria: 1) moderate to severe chronic periodontitis (CP) prior to treatment with the presence of ≥15 teeth, excluding third molars; 2) previous periodontal treatment; 3) 40 to 60 years old at the beginning of therapy; 4) non-smokers for ≥5 years prior to treatment and throughout the subsequent years of maintenance; 5) a negative medical history (diabetes and cardiovascular systemic diseases); 6) and compliance with maintenance for ≥10 years.

The patient group comprised 29 males (48%) and 31 females (52%), of white heritage from middle-income levels and a mean age of 46.77 ± 4.96 years (range, 40 to 58 years) at the beginning of the treatment. All subjects were treated and maintained for 10 years (12.7 ± 2.2 years) between 1980 and 1999. The study was conducted in accordance with the Helsinki Declaration of 1975.

**Treatment**

Each patient was treated by a single practitioner, with ≥10 years of experience in a private practice limited to periodontology.

At baseline (T₀), all subjects underwent clinical and radiographic evaluations and were thoroughly instructed in proper oral hygiene methods (modified Bass technique and interproximal cleaning procedures). All subjects were treated with full-mouth scaling and root planing, under local anesthesia, in four appointments. The patients were clinically reevaluated 5 to 7 weeks after the initial treatment (T₁).

On the basis of the practitioners’ clinical judgment regarding the nature of the periodontal defect, some subjects were subsequently treated surgically with a modified Widman flap or resective surgery. Moreover, during the maintenance phase, if bleeding on probing was evident at a recall appointment, subgingival instrumentation was performed, under local anesthesia, at those specific sites. If bleeding on probing was still present at the following recall visit or if x-ray or probing revealed a negative change, surgery was performed.

All patients participated in a stringent maintenance program. At each recall appointment (3.4 ± 1.0 months), they received a full-mouth professional prophylaxis and localized subgingival instrumentation as needed. Oral hygiene procedures and patient compliance were reinforced at each visit.

After a minimum maintenance period of 10 years (T₂), patients were clinically and radiographically reevaluated. During this maintenance period, any tooth extractions or additional prosthetic, endodontic, or restorative treatments were performed by other dentists but in consultation with the study operator (periodontist).

**Clinical Evaluation**

At T₀ and T₂, the same study operator performed the clinical examination evaluating the following parameters: the number of teeth, PD measurements in millimeters at six points for each tooth, TM (0, 1, 2, or 3 degree), and presence of prosthetic restorations.
(PR). No third molars were included in this study. In addition, at the T2 appointment, the IL-1 genotype test was evaluated for all 60 patients. On the basis of the test results, the patients were then classified as IL-1 genotype positive (G+) or negative (G–).

**Radiographic Evaluation**

The measurement technique for determining bone levels, also described in a previous study, was obtained as follows: x-rays were obtained with a film holder and the long-cone technique. The films were placed on a diaphanoscope without any magnification, and a millimeter rule was used directly on the films to obtain the linear measurements (to the closest millimeter). Radiographic measurements were taken from standardized reference points and from the referring axis on the tooth. Two operators evaluated all radiographic measurements.\(^7\)

The following measurements were taken by projecting these referral points on the main axis and measuring the following distances: 1) distance from cemento-enamel junction (CEJ) to the root apex (RA) (CEJ-RA); 2) distance from CEJ to the deepest point of the bone defect (BD) (CEJ-BD); and 3) distance from CEJ to the most coronal point of the bone crest (BC) (CEJ-BC). These distances were obtained both on the mesial and the distal aspect of each measured tooth.

The BD-RA distance (residual supporting bone) was calculated as the difference between CEJ-RA – CEJ-BD, and the BC-BD distance (infrabony component of the defect) was calculated as the difference between CEJ-BD – CEJ-BC. The distance CEJ-BD indicates a horizontal bone defect in case of absence of the infrabony component of the defect. If the reference points were not detectable on the x-ray film, due to the overlapping of images or points out of film view, the respective measurements at the missing point were excluded. When the CEJ point was not detectable because of a restoration (filling or prosthetic crown), the margin of that restoration was used as the reference point.

**Statistical Analysis**

The reliability of the radiographic measurements as performed by the two examiners, already described in a previous article,\(^7\) was assessed by a preliminary intra- and interexaminer reliability study by evaluating the same measurement of the same x-ray at two different times. Intraclass correlation coefficients (R), considering raters fixed, were determined for 1) the reproducibility of measurements taken by each observer and 2) the measurements taken by one observer versus the other. The measurements evaluated were CEJ-RA mesial and distal, CEJ-BD mesial and distal, and CEJ-BC mesial and distal. Approximately 50 random sites were analyzed for each variable.

A two-level statistical model was applied;\(^\dagger\) the patient and the tooth level were analyzed. The restricted generalized least squares (RIGLS) algorithm and the second-order penalized quasilikelihood (PQL) were used to calculate estimates.\(^9\)

A total of 1,495 teeth of the 1,566 teeth present at baseline were considered in the multilevel analysis. Seventy-one teeth on which it was impossible to measure CEJ-RA (mesial and distal) and CEJ-BD (mesial and distal) were excluded from the statistical analysis. Of the 71 excluded teeth, seven had been lost during the maintenance phase. Tooth loss was used as the outcome variable.

**Model**

\[
\text{Logit } \pi_{ij} = \beta_0 + \beta_1 \text{age}_{ij} + \beta_2 \text{gender}_{ij} + \beta_3 \text{PR}_{ij} + \beta_4 \text{MT}_{ij} + \beta_5 \text{IL-1 test} + \\
\beta_6 \text{MT}_{ij} + \beta_7 \text{PD}_{ij} + \beta_8 \text{CEJ-RA}_{ij} + \beta_9 \text{CEJ-BC}_{ij} + \beta_{10} \text{CEJ-BD}_{ij} + \beta_{11} \\
\text{BD-RA}_{ij} + \beta_{12} \text{BC-BD}_{ij} + \beta_{13} \text{PD}_{ij}
\]

The applied model was used to evaluate the variables associated with each level.

At the patient level, the following predictor variables were considered: 1) age; 2) gender; 3) mean bone loss (mean CEJ-BD)\(^\ast\); 4) IL-1 genotype (IL-1 test); and 5) interaction between mean bone loss and IL-1 genotype (mean CEJ-BD \(\times\) IL-1 test).

At the tooth level, the following variables were included: 1) TM\(^\ast\) (yes or no); 2) presence of PR\(^\ast\) (yes or no); 3) presence of molar teeth at baseline (MT\(^\ast\)) (yes or no); 4) the infrabony component of the defect at baseline (BC-BD\(^\ast\)); 5) the bone level of a site at baseline (CEJ-BD\(^\ast\)); 6) residual supporting bone of a site at baseline (BD-RA\(^\ast\)); and 7) probing depth at baseline (PD\(^\ast\)). The mean values per tooth were calculated for PD. Binomial explanatory variables were considered with 0-1 codices (0 = absent; 1 = present).

The mean value between mesial and distal measurements was used for BC-BD\(^\ast\), CEJ-BD\(^\ast\), and BD-RA\(^\ast\).

The variable mean CEJ-BD\(^\ast\) is defined as the mean value of CEJ-BD\(^\ast\) over all sites included at the patient level.

**RESULTS**

The reliability of radiographic measurements on the mesial CEJ-RA, distal CEJ-RA, mesial CEJ-BD, distal CEJ-BD, mesial CEJ-BC, and distal CEJ-BC variables showed no significant interexaminer reliability.

\(^\dagger\) PST, Interleukin Genetics, Waltham, MA.
\(^\S\) Rinn XCP, Rinn, Elgin, IL.
\(^\parallel\) MLwiN software, version 1.00, Multilevel Models Project, Institute of Education, London, U.K.
difference ($\alpha = 0.05$) with $R > 0.85$. A descriptive statistical analysis of the whole sample has been presented in a previous article.\(^1\)

The 1,495 considered teeth (Table 1) consisted of 386 molars and 1,109 non-molar teeth. A total of 753 teeth were mobile (1, 2, or 3 mobility degrees),\(^8\) whereas 742 were non-mobile (0 degree). The mean values in millimeters of the main bone level measurements taken into consideration in the multilevel analysis were as follows: CEJ-RA\(_{T0}\) = 15.83 ± 2.34; CEJ-BD\(_{T0}\) = 4.19 ± 1.94; BC-BD\(_{T0}\) = 1.14 ± 1.37; and BD-RA\(_{T0}\) = 11.65 ± 2.80. The mean PD\(_{T0}\) was 4.38 ± 1.24. Prosthetic restorations were present on 111 teeth. Fifty-two teeth (3.3%) of 1,566 were lost due to periodontitis between $T_0$ and $T_2$.

**Multilevel Model (Table 2)**
Among the variables at the patient level, none of the considered predictors were associated with tooth loss. At the tooth level, $MT_{T0}$ ($P < 0.0001$) were found to be more prone to loss.

The BC-BD\(_{T0}\) ($P = 0.0377$) was associated with tooth loss: the greater the BC-BD, the lower the probability of losing the corresponding tooth.

The BD-RA\(_{T0}\) ($P < 0.0001$) was associated with tooth loss: the lower the amount of residual supporting bone, the greater the probability of losing the tooth. $TM_{T0}$, $PR_{T0}$, $PD_{T0}$, and the CEJ-BD\(_{T0}\) were not found to be predictive for tooth loss.

**DISCUSSION**
In recent years, a great deal of attention has been focused on the identification of clinical factors capable of predicting the future course of a periodontally compromised tooth.

In a previous article, McGuire and Nunn\(^3\) noted that some commonly used clinical variables such as initial PD, initial furcation involvement, initial tooth malpositioning, and smoking habits are ineffective in assigning a prognosis of “less than good.”

A previous article focused on some factors (e.g., PD and amount of bone loss) capable of predicting bone-level variations using a three-level statistical analysis.\(^1\) The authors found that some variables (PD, TM, and amount of bone loss) were predictive for bone-level variation. On the other hand, some clinical (age, gender, molars, and presence of prosthetic restoration) and radiographic variables (amount of residual bone) did not prove predictive in terms of future bone loss.

The aim of the present article was to test whether the same variables used in the previous study would be predictive for tooth loss in the same population using a two-level statistical model (patient and tooth).\(^1\)

In this sample, 52 (3.3%) teeth of 1,566 teeth present at baseline were lost to periodontitis between $T_0$ and $T_2$.

**Table 1.**
Mean Values at $T_0$ of the Whole Sample After Teeth Exclusion

<table>
<thead>
<tr>
<th>Category</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient population</td>
<td>60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Molar teeth</td>
<td>386</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-molar teeth</td>
<td>1,109</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mobile teeth</td>
<td>753</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-mobile teeth</td>
<td>742</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Restored teeth*</td>
<td>111</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-restored teeth</td>
<td>1,384</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEJ-RA (mm)</td>
<td>15.83</td>
<td>2.34</td>
<td></td>
</tr>
<tr>
<td>CEJ-BD (mm)</td>
<td>4.19</td>
<td>1.94</td>
<td></td>
</tr>
<tr>
<td>BC-BD (mm)</td>
<td>1.14</td>
<td>1.37</td>
<td></td>
</tr>
<tr>
<td>BD-RA (mm)</td>
<td>11.65</td>
<td>2.80</td>
<td></td>
</tr>
<tr>
<td>PD (mm)</td>
<td>4.38</td>
<td>1.24</td>
<td></td>
</tr>
</tbody>
</table>

* Single crown and bridges.

**Table 2.**
Tooth Loss Related to Potential Explanatory Variables (parameter estimates from a two-level variance analysis)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Estimate</th>
<th>SE</th>
<th>P Value (Z statistic)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>0.544</td>
<td>3.328</td>
<td>0.8701</td>
</tr>
<tr>
<td>Patient level</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>-0.007</td>
<td>0.049</td>
<td>0.8864</td>
</tr>
<tr>
<td>Gender</td>
<td>0.971</td>
<td>0.514</td>
<td>0.0589</td>
</tr>
<tr>
<td>Mean CEJ-BD(_{T0})</td>
<td>0.260</td>
<td>0.324</td>
<td>0.4223</td>
</tr>
<tr>
<td>IL-1 test</td>
<td>2.463</td>
<td>2.186</td>
<td>0.2599</td>
</tr>
<tr>
<td>Mean CEJ-BD(_{T0})/IL-1 polymorphism</td>
<td>-0.373</td>
<td>0.452</td>
<td>0.4093</td>
</tr>
<tr>
<td>Tooth level</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$TM_{T0}$</td>
<td>0.575</td>
<td>0.650</td>
<td>0.3764</td>
</tr>
<tr>
<td>$PR_{T0}$</td>
<td>0.684</td>
<td>0.593</td>
<td>0.2487</td>
</tr>
<tr>
<td>$MT_{T0}$</td>
<td>2.735</td>
<td>0.582</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>BC-BD(_{T0})</td>
<td>-0.293</td>
<td>0.141</td>
<td>0.0377</td>
</tr>
<tr>
<td>$PD_{T0}$</td>
<td>0.081</td>
<td>0.207</td>
<td>0.6956</td>
</tr>
<tr>
<td>CEJ-BD(_{T0})</td>
<td>0.051</td>
<td>0.162</td>
<td>0.7529</td>
</tr>
<tr>
<td>BD-RA(_{T0})</td>
<td>-0.868</td>
<td>0.147</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

Statistically significant values are shown in bold.
and $T_2$. The number of lost teeth is less than that seen in previous studies; Wood et al.\textsuperscript{10} observed a 5.0% tooth loss, whereas Hirschfeld and Wasserman\textsuperscript{11} observed a 7.1% tooth loss for periodontal reasons. The stringent maintenance program applied in the present study can possibly explain the low number of lost teeth. The maintenance phase is a critical factor in the long-term conservation of periodontally treated teeth.\textsuperscript{12}

The analysis at the patient level showed that none of the considered variables proved predictive for tooth loss. Patient age, often considered in periodontal literature as one of the parameters to be used in prognoses for periodontally affected teeth, did not prove predictive for tooth loss. This observation reinforces the recently proposed concept of disease severity being independent from the patient’s age.\textsuperscript{13}

In addition, gender did not prove predictive for tooth loss. Males often have been associated with more severe periodontal disease when either attachment loss or bone height is considered, attributing this to different oral hygiene habits (with males generally practicing poorer oral hygiene), rather than to any biologic basis.\textsuperscript{14-16}

In this sample, this behavior cannot be related to tooth loss even though the result is extremely close to statistical significance.

At the tooth level, the molar teeth variable $MT_{T0}$ was found to be strongly associated with tooth loss. On the basis of this finding, affected molar teeth seem to be more prone to be lost in the future as opposed to non-molar teeth. An example of the statistical model is shown in Figure 1. The example refers to a hypothetical case, such as a female patient aged 45 (mean CEJ-BD$_{T0}$ = 4 mm), showing a mobile tooth, without a crown restoration, and with 4 mm PD and 4 mm residual supporting bone. During the 10-year maintenance period, the probability of losing the tooth is $\sim$85% in the case of molar teeth and 25% in the case of non-molar teeth. These results obtained with our statistical model agree with those obtained by König et al.\textsuperscript{17} on 142 patients. These authors found that the survival rate of molars was worse than for non-molars.

BC-BD$_{T0}$ did prove predictive for tooth loss: with the same amount of residual supporting bone, the greater the infrabony component, the lower the probability of tooth loss over time. These results match with those obtained in a previous study.\textsuperscript{1} In addition, deep infrabony defects tend to respond better to regenerative procedures.\textsuperscript{18}

BD-RA$_{T0}$ was found to be an important prognostic factor for tooth loss, whereas the amount of bone loss was not. The greater the amount of residual supporting bone, the lower the risk of tooth loss. Therefore, x-ray examination may be helpful in predicting tooth loss (Fig. 2).

These results seem to indicate that some clinical variables commonly used for diagnosis (PD, age, and mobility) are ineffective in prognosticating tooth loss,\textsuperscript{19} as reported in an article by McGuire and Nunn\textsuperscript{20} where the authors concluded that “the considered clinical parameters on tooth survival are only partially reflected in the assigned prognosis initially.”

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**Figure 1.**
An example of the multilevel model used for predicting tooth loss. A 10-year prognostic evaluation of tooth loss in a patient with 4 mm residual supporting bone at baseline. Molar teeth = 85% probability to be lost; non-molar teeth = 25% probability to be lost. X-axis: BDRA = residual supporting bone (mm); y-axis: probability of tooth loss (%).

**Figure 2.**
Tooth loss: prognostic evaluation of two periodontally diseased teeth showing the same amount of bone loss (A). The prognosis for the central incisor seems to be better than the prognosis for the lateral incisor because of the relative greater amount of residual supporting bone (B > C).
CONCLUSION
This study shows that molar teeth, the infrabony component of the defect, and residual supporting bone may be considered prognostic factors for predicting tooth loss.

ACKNOWLEDGMENT
The authors thank Mrs. Julia Weiss, professional translator, for her help in reviewing the English language of the manuscript.

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Accepted for publication June 17, 2006.