J Clin Periodontol 2007; 34: 226–231 doi: 10.1111/j.1600-051X.2006.01045.x

Journal of Clinical Periodontology

Prognostic model for tooth survival in patients treated for periodontitis

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Faggion CM Jr., Petersilka G, Lange DE, Gerss J, Flemmig TF. Prognostic model for tooth survival in patients treated for periodontitis. J Clin Periodontol 2007; 34: 226–231. doi: 10.1111/j.1600-051X.2006.01045.x.

Abstract

Background: In patients with periodontitis, a quantitative prognostic assessment is needed in order to make evidence-based decisions about retaining teeth or extracting and replacing them with a dental prosthesis.

Methods: One hundred and ninety eight patients receiving active periodontal treatment in 1989 or 1990 and complying with supportive periodontal therapy (SPT) over an average of 11.8 ± 2.3 years were included in the study. A generalized linear model was established and fitted via generalized estimating equations to identify predictors for tooth loss during SPT.

Results: Of the 4559 teeth present at baseline, 166 (3.6%) were extracted during active treatment and 249 (5.5%) during SPT. Baseline findings of diabetes mellitus (OR = 4.17), reduced alveolar bone levels (OR = 1.04 for each 1% increment), increased tooth mobility (III *versus* 0: OR = 5.52), multiple roots (OR = 1.82), and non-vital pulp (OR = 2.24) were significant ($p < 0.05$) predictors for tooth loss during SPT. Based on these parameters, a prognostic model was constructed that provides estimates of tooth survival probability when periodontal therapy is rendered.

Conclusion: Using a multivariate approach, a prognostic model was developed that may be of value for clinical decision making.

Key words: periodontal disease; prognostic model; risk factor; tooth loss; tooth survival

Accepted for publication 14 November 2006

Treatment planning is probably one of the most important steps in the treatment of patients with oral diseases or conditions, especially when multiple concomitant problems exist in a patient. The clinician must decide which teeth to retain, which treatment to prescribe, and how to maintain or restore a functional and aesthetically pleasing dentition. For decision making, it is pivotal to assess each tooth's prognosis in order to choose the treatment modality with the greatest probability of success. Under- or overestimating the actual prognosis of a tooth may both result in increased and unnecessary costs. For example, if the prognosis is underestimated, a tooth, which could have been retained with a high probability by treating the existing disease and/or condition, may be extracted. The procedures required to replace the extracted tooth often incur higher costs than the treatment of the tooth's problem. On the other hand, overestimating the prognosis of a tooth may lead to rendering treatment to a tooth with a low probability of survival. If the tooth is lost some time after treatment, further therapies become necessary, resulting in additional costs. The combined costs may be greater than the cost for replacing the tooth in the first place.

Conflict of interest and source of funding statement

The authors declare that they have no conflict of interest.

There was no external source of funding for the study.

Prognosis is a prediction of the course of existing disease based on empirical data and should consider, among other factors, the seriousness of disease at treatment onset, the treatment prescribed, the clinician's skill, and the patient's compliance with the treatment protocol (Beck 1998). Using a univariate approach, several long-term studies have identified various prognostic factors in patients receiving treatment for periodontitis including tooth type, furcation involvement, alveolar bone loss, tooth mobility, and compliance (Hirschfeld & Wasserman 1978, McFall 1982, Goldman et al. 1986, Wilson et al. 1987, Wood et al. 1989, Axelsson et al. 1991).

Although these individual factors may aid the prognostic assessment, their relative weight is largely unknown so that the prognosis of a tooth, in which

several of these clinical findings are present, cannot be readily determined.

In clinical practice, rather vague terms such as good, fair, uncertain, questionable, poor, and hopeless are widely used for describing the perceived prognosis of teeth. However, to compare the prognosis of periodontally involved teeth with those of alternative therapies (McGuire & Nunn 1996, Lindh et al. 1998, Tan et al. 2004), qualitative information such as survival rate or life expectancy is required. Using tooth loss or survival rate as an outcome variable to assess the prognosis of a tooth may be more sensible than other clinical parameters frequently used to describe the periodontal condition (Hujoel & DeRouen 1995).

The purpose of this study was to develop a prognostic model to estimate quantitatively survival rates for teeth in patients receiving treatment for periodontitis.

Material and Methods

Study population

Three hundred and ninety-four patients having received active treatment for periodontitis between 1 January 1989 and 31 December 1990 at the Department of Periodontology, University of Münster, Germany, and complying with supportive periodontal therapy (SPT) for at least 5 years were included in the study. One hundred and eighty-one of the 394 subjects continued to receive SPT at the Department of Periodontology until the time of data collection, while 213 patients were lost to follow-up 5 years or more after active therapy. These 213 patients were contacted by mail and asked to identify their current dental provider and to consent to have the information pertinent to the present study retrieved from their dental records. Of these, 60 patients consented and 17 of the contacted 60 dentists provided the requested information for 17 patients, who were then included in the analysis. A final sample number of 198 patients, 181 from the Department plus 17 from private practitioners, were included in the statistical analysis. The sample population had a mean age of 47.58 ± 10.42 years at baseline examination, with 52.2% being females.

The study protocol was approved by the Ethics Committee of the Medical Chamber of Westfalia-Lippe and the University of Münster, Germany.

Data collection

Medical history

At baseline examination, patients completed a medical history questionnaire, with respect to diabetes mellitus, coronary heart diseases, infectious diseases, allergies, coagulation disorders, and radiation therapy in the head and neck region.

Clinical findings

The clinical findings at baseline were retrieved from the patients' charts, information regarding the teeth present, caries, dental restorations, probing depth on two sites per tooth (mesial and distal), tooth mobility (Lindhe & Nyman 1977), approximal plaque index (Lange et al. 1977), sulcus bleeding index (Muhlemann & Son 1971), and pulp testing.

Radiographic findings

Full-mouth radiographs at baseline using the paralleling technique (Langland & Sippy 1966) were available for assessment. Alveolar bone levels were determined on the inter-dental surfaces (mesial or distal) of each tooth. The distances between the cement–enamel junction and the most apical level of the alveolar crest (CEJ–AC) and the root apex (CEJ–RA) were measured using a vernier caliper and rounded to the nearest millimetre. Bone levels were determined by the fraction (CEJ–AC)/(CEJ–RA). This measure was performed instead of attempting to measure bone loss, which would have required estimating the physiologic position of the alveolar crest. Recorded data also included radiolucencies with the absence of a lamina dura around the apex consistent with a chronic periapical periodontitis, radiolucencies consistent with dental caries, radiopacities consistent with a root canal filling, and radiopacities consistent with dental restorations.

Assessment of pulp vitality

A tooth was considered having a non-vital pulp when it showed radiographic signs of a chronic apical periodontitis and/or a root canal filling and/or clinically, a negative pulp test was recorded.

Rendered treatment

During initial therapy, patients received repeated oral hygiene instructions, supragingival debridement, and coronal polishing. Patients then received subgingival debridement, and in 136 patients periodontal flap surgery was performed. Restorative and other dental treatments were rendered as needed. After completion of active periodontal therapy, patients were enrolled in an SPT program, which included reinforcement of oral hygiene instructions, supragingival scaling, and fluoride application. At the time of data collection, patients had received SPT over an average of 11.8 ± 2.3 years (range 1.91–15.67 years).

Assessment of tooth loss

Tooth loss was assessed during the active and SPT phase of therapy. A tooth was considered lost when it was noted to be extracted, marked missing on the periodontal chart, or not present on the follow-up radiograph.

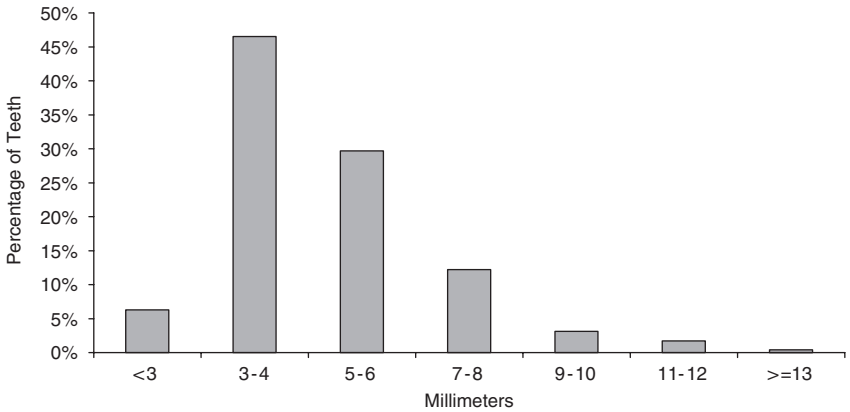

Fig. 1. Pocket probing depth at baseline: frequency distribution of the deepest pocket probing depth per tooth.

Statistical analysis

The assessed data were analysed using descriptive statistics. Furthermore, model-based inductive statistical analyses were performed using the SAS software package (Release 8.02) (Cary, NC, USA) and S-PLUS 6.1 (Seattle, WA, USA). In order to determine the predictive value of the assessed variables at baseline on tooth loss during SPT, a generalized linear model (logistic regression) was established and fitted via generalized estimating equations. The initial model included the following predictor variables: diabetes mellitus, coronary heart diseases, infectious diseases, allergies, coagulation disorders, probing depth, tooth mobility, tooth type, approximal plaque index, sulcus bleeding index, alveolar bone level, pulp vitality, and SPT frequency. Statistically significant prognostic variables were identified by means of a backward selection procedure. The backward selection procedure was performed based on *p*-values. Step by step, the predictor exhibiting the largest *p*-value was removed from the model, respectively. The procedure was stopped, when each predictors' *p*-value in the reduced model was less than 0.1. A Wald test was used to analyse the statistical significance of each parameter within the model. The results of the final model are presented as estimated odds ratios (OR) of each significant prognostic variable ($p < 0.05$). Graphical methods were applied to ensure that the final model adequately fitted the data. All statistical analyses were performed at the Department of Medical Informatics and Biomathematics, University of Münster, Germany.

Results

Baseline findings

Of the 198 patients, 27 patients reported a medical history of cardio-vascular disease, 16 an allergy against antibiotics, 15 a coagulation disorder, six diabetes mellitus, and two patients an infectious disease.

Overall, there were 4559 teeth present at baseline (average 23.02 ± SD 4.99 teeth per subject), out of which 2210 (48.5%) teeth were in the upper and 2349 (51.5%) in the lower jaw; 3173 (69.6%) teeth were single-rooted and 1386 (30.4%) were multi-rooted. Twenty-nine per cent (29.4%) of the teeth had a pocket probing depth of 5–6 mm and 17.1% of 7 mm or greater (Fig. 1). Eleven per cent (11.4%) of the teeth displayed a class I mobility, 7.5% a class II, and 2.0% a class III mobility. Patients showed a mean approximal plaque index of 75.7 ± 25.0% and a mean sulcus bleeding index of 41.3 ± 28.2. Radiographically, 28.1% of teeth had bone levels between 50% and 70% of the root length, and 10.8% demonstrated bone levels <50% (Fig. 2).

Tooth loss

Overall, 461 (10.24%) teeth were lost during the observation period of 1.9–15.7 years. During active therapy, 166 (3.64%) teeth were extracted and 249 teeth (5.46%) were lost during SPT (Fig. 3).

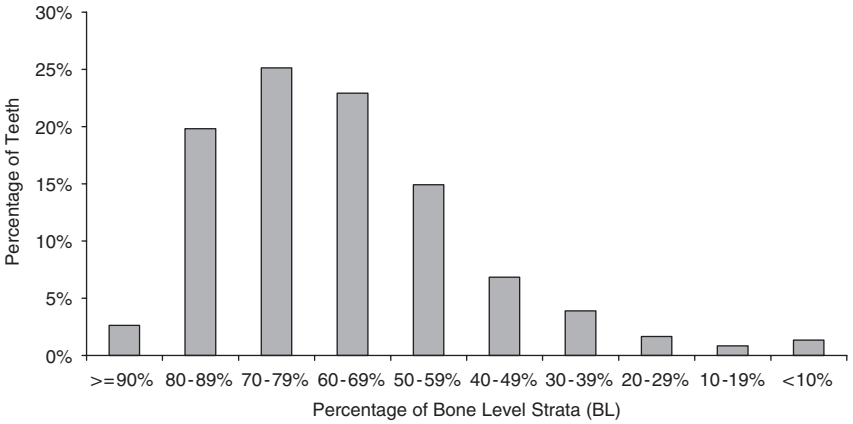

Fig. 2. Alveolar bone level at baseline: frequency distribution of the highest inter-dental radiographic bone levels (BL) per tooth.

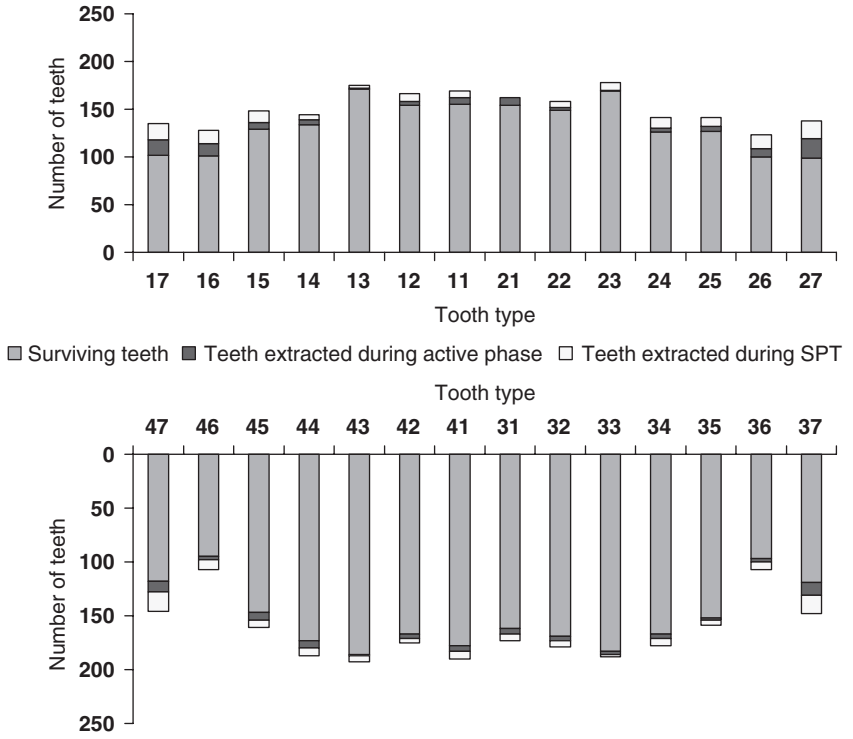

Fig. 3. Teeth present at baseline and lost over time: number of teeth present at initial examination and number of teeth extracted during active treatment or during supportive periodontal therapy (SPT).

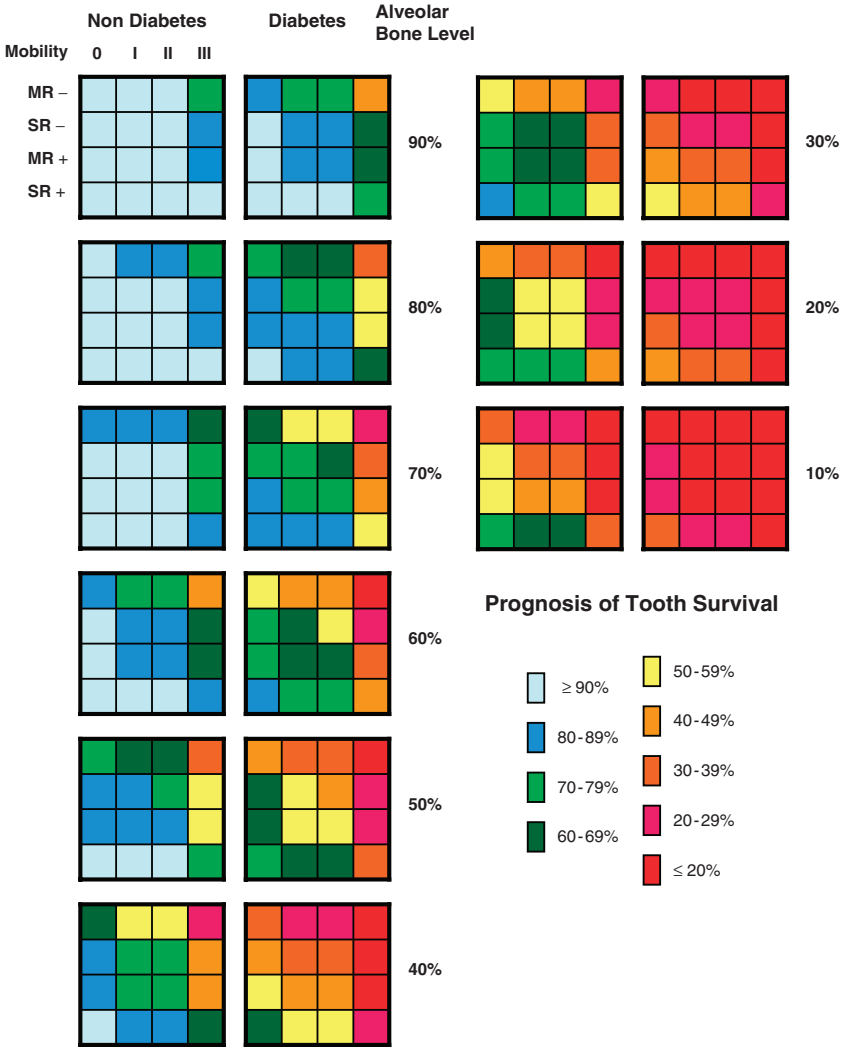

Fig. 4. Prognosis of tooth survival: probability of tooth survival using all possible combinations of variables found to be significant predictors. Each square represents a unique combination of predictors. The colour coding on the bottom right indicates the tooth survival probability over an average of 11.8 years. SR+, single-rooted and vital tooth; MR+, multi-rooted and vital tooth; SR −, single-rooted and non-vital tooth; MR −, multi-rooted and non-vital tooth.

Prognostic model for tooth loss during SPT

The logistic regression model revealed as significant ($p < 0.05$) predictors for tooth loss during SPT the diagnosis of diabetes mellitus [OR = 4.17, 95% confidence interval (CI) = 1.51–11.57]; the alveolar bone level (OR = 1.04, 95% CI = 1.03–1.06 for each 1% increment in reduced bone level); tooth mobility (class III *versus* class 0: OR = 5.52, 95% CI = 2.05–14.83); root type (multi- *versus* single-rooted: OR = 1.82, 95% CI = 1.10–3.02); and a non-vital pulp (OR = 2.24, CI = 1.38–3.64) at baseline examination. The R^2 of the final model was 0.14.

To facilitate the use of the prognostic model in clinical decision making, a graph was constructed over the full range of all variables with a significant prognostic value in a format described previously (http://www.nzgg.org.nz) (Fig. 4). Tooth survival rates (1 – tooth loss rates) are shown to allow for comparison with the outcome of alternative treatments, e.g. implant- or tooth-supported fixed partial dentures.

Discussion

In patients receiving treatment for periodontitis, few studies have used a multivariate approach to identify prognostic factors. Using a Cox proportional hazard regression analysis, McGuire & Nunn (1996) reported initial pocket probing depth [Risk ratio (RR) = 1.4 for each stratum], furcation involvement (RR = 1.3 for each stratum), mobility (RR = 2.1 for each stratum), alveolar bone loss (RR = 1.04 for each stratum), parafunctional habit without using a biteguard (RR = 2.2), and smoking (RR = 2.1) to be significantly associated with an increased risk for tooth loss in 100 patients receiving SPT for an average of 9.97 years. In another cohort of 100 patients receiving SPT for an average of 9.8 years, Fardal et al. (2004) identified male gender (OR = 2.8), age >60 years (OR = 4.0), and smoking (OR = 4.2) as significant predictors of tooth loss by logistic regression analysis. This logistic regression model also included non-significant variables such as frequency of maintenance, oral health status, and family history of periodontal disease as independent variables. Using a multiple regression model, König et al. (2002) found only smoking and antibiotic therapy to be statistically significantly associated with tooth loss in 167 patients over an average period of 11.7 years.

In the present study, root type, alveolar bone level, and tooth mobility have been identified as significant predictors for tooth loss. These clinical findings at baseline examination have been previously associated with an increased risk for tooth loss in subjects receiving treatment for periodontitis, supporting the prognostic value of these variables (Hirschfeld & Wasserman 1978, DeVore et al. 1986, Wang et al. 1994, McGuire & Nunn 1996, Dannewitz et al. 2006). Although a non-vital pulp and diabetes mellitus have been identified as risk factors for tooth loss in randomly selected populations (Paulander et al. 2004, Campus et al. 2005, Caplan et al. 2005), their prognostic value in patients receiving treatment for periodontitis has not yet been reported.

The population used in this study appears to be representative for those receiving treatment for periodontitis with regard to their initial disease severity and extent as well as treatment outcome, further supporting the validity of the prognostic model (Table 1; Hirschfeld & Wasserman 1978, McFall 1982, Wood et al. 1989, Tonetti et al. 2000, König et al. 2002, Fardal et al. 2004, Paulander et al. 2004).

Table 1. Summary results of comparative retrospective studies: demographics and long-term treatment outcome in patients having periodontitis.

	Hirschfeld & Wasserman (1978)	McFall (1982)	Wood et al. (1989)	Tonetti et al. (2000)	König et al. (2002)	Fardal et al. (2004)	Present study
Number of patients	600	100	63	273	142	100	198
Mean age	42	43.8	45 (24–67)	52 ± 14	46 ± 9	46 (25–69)	47.58 ± 10.42
Mean number of teeth present	15,666	2627	1607	5929	3353	2436	4559
Mean observation period (years)	22 (15–53)	19 (15–29)	13.6 (10–34)	5.6 (0.41–23.2)	10.5 (8–13)	9.8 (9–11)	11.8 (8–15)
Percentage of teeth extracted during active therapy (%)				4.8	4.98		3.6
Percentage of teeth extracted during SPT (%)	8.37	11.38	7.1	4.2	2.95		5.5
Mean annual tooth-loss rate	0.08	0.14	0.10	0.4	0.07	0.04	0.11

Values in parentheses indicate ranges.
SPT, supportive periodontal therapy.

A limitation of the present study is the lack of smoking information, which was not included in the medical history questionnaire taken at the time of baseline examination. It may be assumed that a considerable number of smokers were included in the study, as the overall smoking prevalence in Germany during the time of baseline examination, i.e., 1992, was 28.8% (http://www.cdc.gov/tobacco/who/germany.htm). Smoking has been repeatedly shown to be associated with a less favourable outcome following periodontal therapy (Garcia 2005, Labriola et al. 2005), and has been identified as a significant risk factor for tooth loss in patients with periodontitis undergoing therapy (McGuire & Nunn 1996, König et al. 2002, Fardal et al. 2004).

The current study extends on previous reports (Hirschfeld & Wasserman 1978, DeVore et al. 1986, Wang et al. 1994, McGuire & Nunn 1996, Dannewitz et al. 2006) by presenting a logistic regression model using findings from initial examination to estimate the survival rate of teeth receiving periodontitis therapy. The calculated survival rates may aid the decision-making process during treatment planning with respect to whether teeth should be retained or rather extracted and subsequently replaced by some type of restoration. Several long-term studies and systematic reviews have reported the survival rates of various restorative procedures. For example, in a recent systematic review, the 10-year probability of survival for conventional tooth-supported fixed partial dentures was 89.1% with a 95% CI between 81% and 93.8%, while the probability of success, i.e. restorations that remained unchanged and did not require any intervention, was 71% (95% CI = 47.7–85.2%) (Tan et al. 2004). In another systematic review, the 10-year survival rate of fixed partial dentures supported by implants was 86% (95% CI = 82.8–89.8%) (Pjetursson et al. 2004).

The logistic regression model based on clinical findings at baseline explains 14% of the variance in tooth loss ($R^2 = 0.14$). This can be interpreted as the prediction of tooth loss being improved by 14% compared with an alternative simple and undifferentiated prediction not considering any of the information given by prognostic variables. Forecasting tooth survival in an uncontrolled clinical environment is complicated by the fact that tooth loss rarely occurs by spontaneous exfoliation but is usually confounded by the provider's treatment decision. The reasons given for extraction include dental pain, caries, tooth mobility, tooth fracture, abscess or infection, periodontitis, fractured restoration, prosthetic reasons, root canal treatment failure, and the patient's propensity to choose extraction over other treatment alternatives (Gilbert et al. 2002). Many of these are not related to a disease process per se and, therefore, can hardly be predicted. Along the same line, Paulander et al. (2004) argue that the severity of periodontal disease may influence the dentist's/patient's decision to extract a tooth. Furthermore, decision making during treatment planning is determined by many other factors that go beyond survival rates and include, among others, the ability to achieve and maintain oral health, a functional dentition, and an aesthetically pleasing oro-facial appearance as well as considerations regarding the cost effectiveness of treatment alternatives.

In conclusion, there are multiple factors determining tooth prognosis in patients undergoing treatment for periodontitis. The developed prognostic model explains 14% of the variance in tooth loss in patients receiving periodontal treatment over a mean period of 11.8 years. Using baseline findings from the medical history as well as clinical and radiographic examination, the presented prognostic model provides survival rate estimates for teeth and may be of value for decision making during treatment planning.

Acknowledgements

The authors would like to express their gratitude to the private practitioners who so kindly gave them access to their patient charts. In addition, they want to acknowledge the invaluable help of Dr. J. Tunkel (Department of Periodontology, University of Münster, Germany) in preparing the application for the Ethics Committee.

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Clinical Relevance

Scientific rationale for the study: There is limited information on how the prognosis of periodontally involved teeth can be determined quantitatively. This information is needed if the long-term outcome of tooth retention by periodontal therapy is to be compared with alternative treatments aimed at replacing teeth.

Principal findings: Baseline findings identified as significant predictors of tooth loss during SPT were used to construct a logistic regression model for quantitatively estimating tooth prognosis.

Practical implications: The prognostic model, combined with data on expected survival rates of dental prostheses, may be useful in treatment planning.