Tooth Loss in 776 Treated Periodontal Patients

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Background: The most common form of periodontitis is a variably progressive dynamic pathologic process that causes attachment loss, destroys the alveolar bone supporting a tooth, and terminates with tooth loss. We evaluated the loss of teeth of treated periodontal patients categorized by severity and risk.

Methods: Each of nine periodontists evaluated 100 consecutive periodontal maintenance patients. The disease severity and risk level were determined from data at the initial examination. The number of teeth lost was determined from data at the initial and maintenance visits.

Results: A stepwise regression analysis showed that disease ($P = 0.0000478$) and risk ($P = 0.00129$) scores predicted the mean tooth loss rate. The adjusted R^2 statistic was 88.56%. The ordinal logistic regression model showed that only the disease score ($P < 0.0005$) was significantly associated with the probability of patients losing a specific number of teeth.

Conclusions: Categorizing a patient by severity may be beneficial in the management of the periodontal patient. The disease score can be used to establish a criterion and target for care. For example, treatment can result in nearly no lost teeth when the severity is low, and this benefit is lost when the severity is high. The disease score provides an objective means to quickly determine severity. An increase in the disease score provides evidence that a new treatment plan is needed. Therefore, the effect of the routine use of the disease score could result in fewer patients with severe disease and reduce the number of teeth lost. *J Periodontol 2010;81:244-250.*

KEY WORDS

Dental care; outcome assessment; periodontal diseases; tooth loss.

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The most common form of periodontitis is a variably progressive dynamic pathologic process that causes attachment loss, destroys the alveolar bone supporting a tooth, and terminates with tooth loss.[1-4] A goal of periodontal therapy is to stop the loss of bone and thereby preserve the natural dentition.[5] As shown in Table 1, several studies[6-19] reported tooth loss in periodontal patients. The 929 subjects of the six studies[6-11] that reported tooth loss during the active and maintenance phases of periodontal treatment had moderate to severe periodontitis. The mean tooth loss rate (MTLR; number of teeth lost per subject per year) was 0.01,[6] 0.13,[7] 0.16,[8] 0.22,[9] 0.24,[10] and 0.28.[11] One factor for the variation of MTLR is the distribution of disease severity within each study population, as tooth loss parallels the severity of periodontitis.[20] For example, subjects with moderate to severe periodontitis of a dental population that predominantly did not receive periodontal treatment had an MTLR of 0.19. However, when they were grouped into six categories of severity represented by disease score categories 4 to 9, the MTLR for each category was 0.12, 0.16, 0.25, 0.32, 0.51, and 0.61, respectively.[21] We conjectured that the MTLR during periodontal treatment would parallel disease severity determined at the initiation of treatment.

In addition to severity, the risk for future periodontal deterioration is a factor of tooth loss by its effect on the rate of

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Table 1.

Tooth Loss and Periodontal Treatment

Study	Total Subjects	Mean Study Years	Total Tooth Loss	Mean Tooth Loss	MTLR	Percentage of Subjects With Loss of: No Teeth	1 to 3 Teeth	4 to 6 Teeth	7 to 9 Teeth	10+ Teeth
Active and maintenance phases										
Axelsson et al.[6]	317	15	71	0.22	0.01	81.4	18.3	0.3	0	0
McGuire[7]	100	10	131	1.31	0.13					
Goldman et al.[8]	211	22.2	771	3.65	0.16	62.1	28	10		
McLeod et al.[9]	114	12.5	308	2.7	0.22	84.2	13.2	2.6		
Becker et al.[10]	95	6.6	150	1.58	0.24					
Checchi et al.[11]	92	6.7	170	1.85	0.28					
Maintenance phase only										
Nabers et al.[12]	1,535	12.9	444	0.29	0.02	89.3	←——10.7——→			
Lindhe and Nyman[13]	61	14	30	0.49	0.04					
Oliver[14]	442	10.1	320	0.72	0.07					
Wilson et al.[15]	162	5	60	0.37	0.07	86.4	←——13.6——→			
Hirschfeld and Wasserman[16]	600	22	1,312	2.19	0.1	50	33.2	←—12.6—→		4.2
Wood et al.[17]	63	13.6	115	1.83	0.13	←85.7→		←—11.1—→		3.2
McFall[18]	100	19	299	2.99	0.16	← 77 →		←——15——→		8
Tonetti et al.[19]	273	5.6	297	1.09	0.19	55.7	35.2	5.5	2.6	1.1

Arrows represent range of number of teeth lost.

disease progression.[22] Although the effect of risk on tooth loss was reported for a dental population that predominantly did not receive periodontal treatment,[21] to our knowledge, no reports exist that describe the effect of objectively determined and validated periodontal risk on tooth loss during periodontal treatment.

Page and Martin[23] described a disease score as a quantification of periodontal disease severity and extent that ranges from 1 for health to 100 for the most severe disease. The method combines the quantified value for each sextant's disease severity based on probing depth, radiographic bone height from the cemento-enamel junction, and bleeding on probing. The accuracy and validity of the disease scores were demonstrated by statistical analysis of the strength of agreement of disease scores with actual periodontal status determined using values of alveolar bone height obtained from digitized radiographs. Page et al.[22,24] described a risk score as a quantification of the risk for periodontal disease during the natural history of disease. The method is based on 11 risk factors.[22,24] The accuracy and validity of the risk scores were demonstrated by statistical analysis of actual bone loss from digitized radiographs and tooth loss from clinical records during a study period of 15 years. These two methods established a numeric means to categorize patients by disease severity and risk level.

The purpose of this study is to report tooth loss during periodontal treatment where patients were categorized at the inception of treatment by disease severity and risk level.

MATERIALS AND METHODS

Periodontists who began using novel commercially available technology‖ in 2003 were asked to participate. These periodontists used the technology to provide the developers with information about the technology. The periodontists used the technology for patients who were treated and presenting for maintenance care to determine disease and risk scores (i.e., disease severity and risk level, respectively) for these patients from information in the records from the initial examination and current maintenance appointments. Of the periodontists who were asked to participate, nine (JAM; PAL; Willard Carter, currently retired, North Venice FL; Robert Gottlieb, Kenmore, WA; Carole Hildebrand, Philadelphia, PA; Randy Nolf, Stroudsburg, PA; Jeff Peck, Utica, NY; A. Robert Romans, Jacksonville, FL; and Anthony Polimeni, Huntingdon, NY) agreed. The study population was comprised of 100 consecutive patients of each of the nine periodontists presenting for maintenance care who had the requisite information[23] in their charts. The Tufts Health Sciences Campus Institutional

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Review Board approved the study as an exempt study and granted a waiver of informed consent. Patients were treated between 1971 and 2003. The required information consisted of periodontal charting done during the initial diagnostic appointment and current maintenance appointment and full-mouth periapical radiographs or full-mouth bitewing radiographs taken ≤12 months prior to the initial diagnostic appointment and current maintenance appointment. Additionally the patient must not have received periodontal surgery during the 2 years prior to the initial diagnostic appointment, and one or more periodontal pockets measuring ≥5 mm must have existed at the initial diagnostic appointment. The treatment performed in the periodontists' offices was reported for the interval between the two appointments. Treatment interventions reported were periodontal maintenance procedures, quadrants of scaling and root planing, quadrants of surgery to reduce or eliminate pockets, periodontal surgical procedures not specifically intended to change probing depths, sites treated with local chemotherapy, and weeks of systemic chemotherapy. The number of non-third molar teeth that were extracted was also reported, regardless of the clinician providing the service and the reason for the extraction.

Disease severity was determined for each patient using the method reported by Page and Martin[23] and expressed as a disease score with a range of 1 (health) to 100 (severe periodontitis) (Table 2). The risk level was determined for each patient using the method reported by Page et al.[22,24] and expressed as a risk score with a range of 1 (very low) to 5 (very high). Patients were grouped based on their disease and risk scores into a two-factor matrix in which nine categories of disease scores, as defined in Table 2, were used to establish a 45-cell matrix of disease severity and risk. Patients were excluded from the analysis if the time between the initial diagnostic appointment and current periodontal maintenance appointment was <3 years or if the number of patients for a cell in the 45-cell matrix was less than five. The distribution of the 776 patients that met these conditions is shown in Table 3. The age range of the study subjects was 19 to 84 years. The mean patient age was 46.0 ± 10.5 years for all 776 patients and 48.7 ± 6.8 years for the matrix cells. The MTLR was calculated for each cell of the matrix, each disease score category, each risk score, and the entire study population (Table 4). The proportion of patients with a specific number of teeth lost was calculated for each combination of disease score category and risk score; the distribution is shown in Figure 1. The proportion of patients with a specific number of teeth lost for the entire study population is also shown in Figure 1.

Statistical Analyses

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

RESULTS

The distribution of the population in this study by disease severity and risk level (Table 3) included 98.5% categorized as having moderate or severe periodontitis (i.e., disease score categories 4 to 9). Patients were fairly evenly distributed among disease score categories 5 to 9, and each included at least 100 patients. A total of 91.5% of the patients were categorized as high or very high risk (i.e., risk scores 4 and 5) with more than half of all patients categorized as very high risk. Fourteen cells of the 45-cell matrix represented five or more patients. Twelve cells representing patients with disease score categories 4 to 9 and risk scores 3 to 5 ranged from 19 to 173 patients. The cell for disease score category 3 and risk score 2 represented five patients. The cell for disease score category 3 and risk score 3 represented seven patients.

A total of 980 teeth were lost during the mean study period of 13.2 ± 7.0 years (range: 3.0 to 32.5 years). The mean tooth loss was 1.26 ± 2.53 per patient. The entire study population's MTLR was 0.11 ± 0.26. As shown in Table 4, MTLR increased in rank order for disease score and risk score categories. Within the matrix, MTLR increased in rank order for each risk score with one exception, the cell of risk score 4 combined with disease score category 8. However, for each disease score category, the rank order was maintained for disease score categories 3 to 5, but they were in reverse order for disease score categories 6 to 9. The MTLR for risk score 4 combined with disease score categories 6 to 9 and risk score 5 combined with disease score categories 6 to 9 had equivalent values of 0.14. This means that the MTLR for disease score categories ≥6 was 0.14. In contrast, the MTLR for the cells of risk scores ≤4 combined with disease score categories ≤5 were each ≤0.03, and the MTLR for this group of six cells was 0.03. This means that the MTLR for disease score categories ≤5 was 0.03.

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

Table 2.

Disease Score Categories[21]

Periodontal Disease Severity	Disease Score*	Disease Score Category	Description†
Healthy or gingivitis	1 to 3	1	No sextant has periodontitis
Mild periodontitis	4 to 7	2	≥1 sextants has mild periodontitis
	8 to 10	3	≥40% of the sextants have mild periodontitis
Moderate periodontitis	11 to 26	4	≥1 sextants has moderate periodontitis
	27 to 36	5	≥40% of sextants have moderate periodontitis
Severe periodontitis	37 to 64	6	1 sextant has severe periodontitis
	65 to 82	7	≥20% of sextants have severe periodontitis
	83 to 92	8	≥40% of sextants have severe periodontitis
	93 to100	9	>50% of sextants have severe periodontitis

* The disease score is a quantification of severity and extent of periodontal disease based on the number of sextants at each severity level, which is determined by probing depth (PD), alveolar bone loss, and bleeding on probing.[23]

† The severity of periodontitis for a sextant is determined by the deepest pocket, greatest bone loss, and bleeding on probing for the sextant. We defined mild periodontitis as PD <5 mm plus the radiographic distance of the bone crest to the cement-enamel junction (RBH) as 2 to 4 mm or PD 5 to 7 mm plus RBH <2 mm. Moderate periodontitis was defined as the combination of PD <5 mm and RBH >4 mm, PD 5 to 7 mm and RBH 2 to 4 mm, or PD >7 mm and RBH <2 mm. Severe periodontitis was defined as PD 5 to 7 mm and RBH >4 mm or PD >7 mm and RBH ≥2 mm.[23]

Figure 1 illustrates the variation in tooth loss using the MTLR (black line) and the percentage of patients who lost a specific number of teeth (bars) for risk and disease score categories. Furthermore, Figure 1 shows the variation of combined risk and disease score categories from the population's mean. Although 61% of the entire study population lost no teeth, no patients with risk score 2 combined with disease score category 3 lost any teeth. For risk scores ≥3, the range for the percentage of patients with no tooth loss was 26% to 83%. Twenty-eight percent of the entire study population lost one to three teeth, and the range for risk scores 3 to 5 was 17% to 42%. Seven percent of the entire study population lost four to six teeth, and this magnitude of tooth loss was nearly totally associated with severe periodontitis (i.e., disease score categories ≥6). Two percent of the entire study population lost seven to nine teeth, and this magnitude of tooth loss was only associated with risk scores 4 and 5. Two percent of the entire study population lost 10+ teeth, and this was only associated with disease score categories 8 and 9.

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

The regression analysis showed that the combination of the disease score and risk score could be used to accurately predict the MTLR when treatment was applied. The *P* values for the disease score and risk score were 0.0000478 and 0.00129, respectively. The adjusted R^2 statistic was 88.56%, and the overall regression model was significant at a 0.05 significance level. Only one observation had a relatively large standardized residual. This observation corresponded to risk score 4 and disease score category 8, which had an unusually large MTLR.

The ordinal logistic regression model showed that only the disease score was significantly associated with the probability of patients losing a specific number of teeth. This model's *P* values for disease and risk scores were <0.0005 and 0.807, respectively. The high *P* value for the risk score appears to be evidence that periodontal treatment reduces and minimizes the risk that periodontal disease will progress, making risk irrelevant to predict the number of teeth a patient may lose when treatment is applied. The measures of association indicated the relationship between the observed responses and the predicted probabilities; 67% of the pairs were concordant, whereas 30% were discordant. Thus, there was a better chance for a pair to be concordant than discordant, indicating the good predictive ability of the model.

DISCUSSION

The periodontitis-treated population of our study was comprised of patients referred to periodontists. A total of 98.5% of our study population had moderate to severe periodontitis, which is consistent with the report by Cobb et al.[25] and the reports listed in Table 1.[6-19] Six studies[6-11] listed in Table 1 for the active and maintenance phases of periodontal treatment were very similar to our study. For example, the MTLR (0.11 ± 0.26) and study years (13.2 ± 7.0) for our study were within the ranges reported for the studies[6-11] (i.e., MTLR range = 0.01 to 0.28; range of study years = 6.6 to 22.2 years). Our study population (N = 776) represented the treatment of nine

Table 3.

Distribution of Patients by Risk Score and Disease Score Category

	Disease Score Category										
	Healthy or Gingivitis	Periodontitis									
		Mild		Moderate		Severe					
Risk Score	1	2	3	4	5	6	7	8	9	Total	%
Very low (1)	0	0	0	0	0	0	0	0	0	0	0.0
Low (2)	0	0	5	0	0	0	0	0	0	5	0.6
Moderate (3)	0	0	7	24	30	0	0	0	0	61	7.9
High (4)	0	0	0	45	117	46	34	19	23	284	36.6
Very high (5)	0	0	0	0	0	97	74	82	173	426	54.9
Total	0	0	12	69	147	143	108	101	196	776	
%	0.0	0.0	1.5	8.9	18.9	18.4	13.9	13.0	25.3		

Table 4.

MTLR

	Disease Score Category									
	Healthy or Gingivitis	Periodontitis								
		Mild		Moderate		Severe				
Risk Score	1	2	3	4	5	6	7	8	9	Mean
Very low (1)										
Low (2)			0.00*							0.00
Moderate (3)			0.01	0.02	0.03					0.03
High (4)				0.03	0.03	0.07	0.09	0.29	0.24	0.08
Very high (5)						0.06	0.08	0.12	0.22	0.14
Mean			0.01	0.03	0.03	0.06	0.08	0.15	0.22	0.11

* The MTLR was reported by the statistician as 0.00 (the 5 subjects lost 0 teeth).

periodontists, which was significantly higher than for the studies[6-11] considered individually (i.e., N range = 92 to 317) but similar when the studies[6-11] were pooled (N = 929). There was an insufficient amount of data regarding the proportion of subjects who lost a specific number of teeth to compare with our study.

Without treatment, periodontal disease is progressive. The mean tooth loss increases, and a greater proportion of a population experiences more severe tooth loss (e.g., four to six teeth lost and seven to nine teeth lost).[21,22,24] The progressiveness of periodontal disease is determined by the risk level.[22] Periodontal treatment suppresses the actualization of risk resulting in a lower rate of disease progression. Tooth loss during the active phase of periodontal treatment is predicted by disease severity at the inception of treatment. Disease severity at the inception of treatment is predicted by the risk level during the time period preceding treatment.[21] Therefore, as shown in the present study, MTLR was predicted by the disease score (P value = 0.0000478) and risk score (P value = 0.00129). The consolidated data of the eight[12-19] maintenance-only studies listed in Table 1 had an MTLR of 0.07, which is less than the MTLR of 0.12 for the six active- and maintenance-phase studies.[6-11] The lower MTLR for the maintenance-only period was due to the suppression of risk actualization, which slows disease progression. We hypothesize that the proportion of a treated population that loses a specific number of teeth is determined primarily at the inception of treatment, and the duration of the maintenance period diminishes the predictive influence of risk. This is our interpretation of $P < 0.00005$ for the disease score and $P = 0.807$ for the risk score for the probability of patients losing a specific number of teeth.

Table 4 and Figure 1 illustrate that periodontal treatment, when applied before the disease is categorized as severe (i.e., disease score categories 6 to 9), can result in almost no tooth loss (i.e., MTLR ≤0.03), and furthermore, the likelihood that a patient will experience any tooth loss is <30%. Delaying treatment until periodontitis becomes severe can result in a greater number of teeth lost and a higher likelihood of losing several teeth. For example, as illustrated in Table 4, patients with severe periodontitis had an MTLR two to 14 times higher compared to patients with moderate periodontitis. Furthermore, as illustrated in Figure 1, the likelihood of tooth loss may increase from ~20% to ~70%.

The present study shows that the distribution of disease severity of a population affected the MTLR and

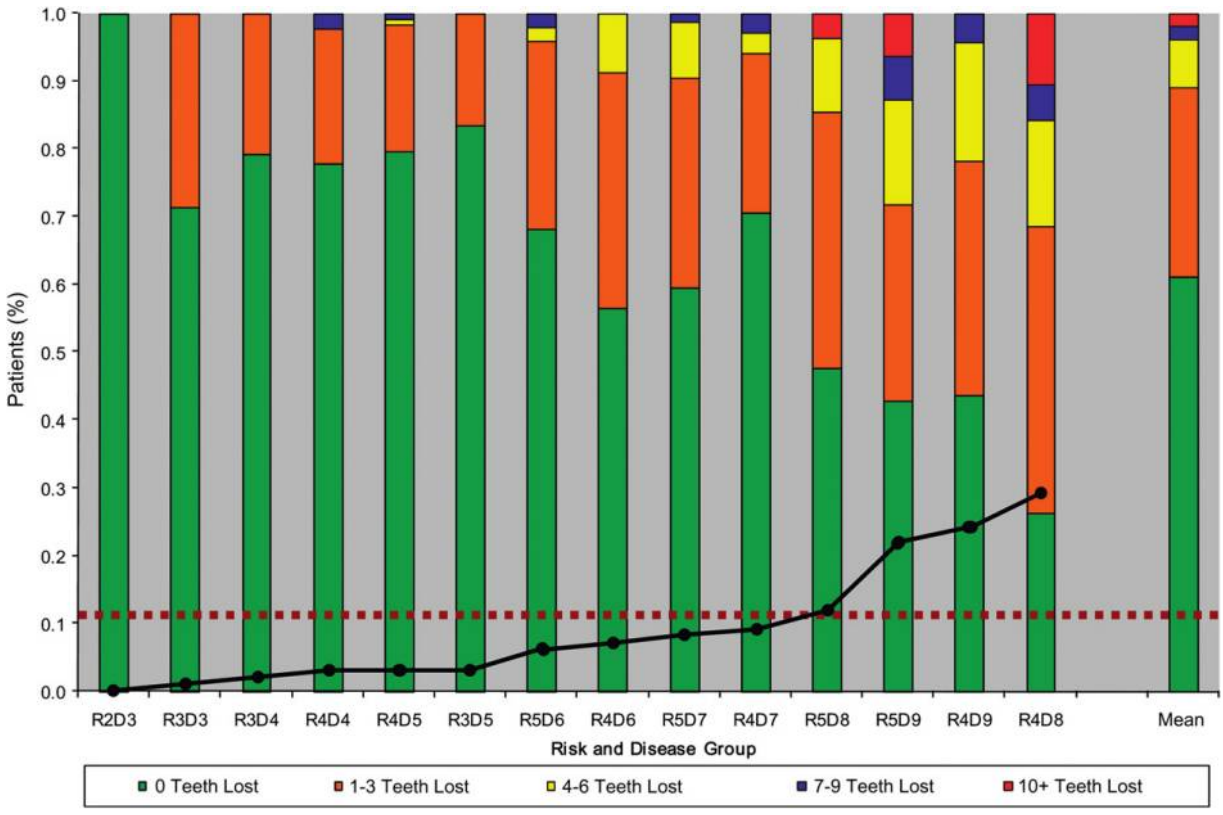

Figure 1.
Tooth loss for combinations of risk score and disease score category. Each bar corresponds to the risk and disease group listed on the x axis; the number following "R" is the risk score, and the number following "D" is the disease score category. The bar labeled "Mean" represents the entire study population. Each bar consists of the percentage of patients in the risk-disease group that lost a specific number of teeth. Each point on the solid black line is the MTLR for the respective risk-disease group. This value also appears in Table 4. The horizontal dashed red line is the MTLR for the entire study population. The y axis serves a dual purpose: the percentage of patients in decimal fraction (e.g., 0.2 means 20%) for the bar length and the MTLR in standard decimal format for the dashed red line and each point on the solid black line.

distribution of subjects with a specific number of teeth lost. This effect indicates that comparing tooth loss for periodontitis-affected populations is more accurate when there are more periodontal disease categories than healthy, gingivitis, mild, moderate, and severe periodontitis. Our method of categorizing patients by up to 100 categories of disease severity and five levels of risk offers a means to increase comparative accuracy.

Although our study population was fairly large, it was much too small to fully populate all 45 cells of the matrix, and hence, statistical analysis was restricted to 14 combinations of risk and disease severity. A much larger population would be needed for a statistical analysis of all 45 combinations of risk and disease severity. In the present study, the MTLR and percentage of patients who lost a specific number of teeth were based solely on data from the present study population. Thus, valid and accurate values for other dental populations require additional studies of much larger populations. Future studies may result in different interpretations from those presented here.

CONCLUSIONS

Our method of categorizing patients by periodontal disease severity and risk level may be beneficial for the management of patients with present or past periodontal disease. The scores can be used to establish a criterion and target for care. For example, treatment can result in nearly no lost teeth when severity is low, and this benefit is lost when severity is high. The disease score provides an objective means to quickly determine severity. An increase in the disease score provides evidence that a new treatment plan is needed. Therefore, the effect of the routine use of disease and risk scores could result in fewer patients with severe disease and reduce the number of teeth lost.

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at PreViser. Dr. Loeb owns stock in PreViser and serves as its chief executive officer. Drs. Martin and Loeb have also received consulting fees from PreViser. Dr. Page owns equity in PreViser. Dr. Levi reports no conflicts of interest related to this study.

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