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The clinical course of chronic periodontitis

IV. Gingival inflammation as a risk factor in tooth mortality

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Abstract

Aim: The purpose of this study was to assess the long-term influence of gingival inflammation on tooth loss.

Material and Methods: The data originated from a 26-year longitudinal study of Norwegian males, who practiced adequate daily oral home care and received ''state-of-the-art'' dental care. The initial examination in 1969 included 565 individuals aged between 16 and 34 years. Subsequent examinations took place in 1971, 1973, 1975, 1981, 1988 and 1995. Thus, the study covers the age range of 16–59 years. The teeth were divided into three tooth groups (I–III) reflecting the history of inflammation of the surrounding gingiva (gingival index (GI) scores) over 26 years: (I) teeth with surrounding gingival units scoring a minimum of one site with GI = 0 and a maximum of three sites with GI = 1, (II) teeth with surrounding gingival units scoring a minimum of one site with GI = 1 and a maximum of three sites with GI = 2 over the observation periods and (III) teeth with surrounding gingival units always scoring a minimum of GI = 2 (bleeding on probing) at all sites over the observation period.

Results: At baseline (1969), out of possible 15,820 teeth (565 × 28), 15,383 teeth were present. Four hundred and thirty-seven teeth had already been missing for unknown reasons. By 1995, 13,159 teeth were reexamined, i.e. over the 26-year observation period only 126 (0.95%) teeth were lost. Only 16 (0.28%) of 5793 teeth belonging to GI-Severity Group I were lost. In the GI-Severity Group II, however, 78 (2.28%) out of 3348 teeth were lost, and 13 (11.21%) of 103 teeth with GI-Severity Group III were lost. Teeth with GI-Severity Group III yielded an odds ratio for tooth loss that was 46 times higher than that of teeth with GI-Severity Group I, and five times higher than that of teeth with GI-Severity Group II over 26 years. Furthermore, teeth with the GI-Severity Group II had a nine times higher risk for tooth loss than teeth with the GI-Severity Group I.

The GI-Severity Group I retained 99.5% of the teeth after a tooth age of 51 years. The GI-Severity Group II retained 93.8% of the teeth after a tooth age of 50 years. However, in the GI-Severity Group III, 63.4% of the teeth were retained for a tooth age of 47 years.

Conclusions: Teeth surrounded with inflammation-free gingival tissues were maintained for a tooth age of 51 years, while teeth consistently surrounded with inflamed gingivae yielded a 46-times higher risk to be lost. Only two-thirds of such teeth were maintained throughout the 26-year observation period. This documents the role of gingival inflammation as a risk factor for future tooth loss.

Key words: gingival health, longitudinal study, risk factors, severity levels, tooth loss

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To retain the dentition in good health and function, major efforts for the prevention and therapy of the two most common oral diseases, caries and periodontitis, have been advocated. The success or failure of such programs is usually measured by the number of teeth retained at various stages of adult life.

Numerous studies of industrialized populations have reported that caries and its sequelae constitute the main reason for tooth loss, although more recent reports have emphasized the significant contribution of periodontal disease to tooth loss in adults (Johansen 1970, Klock & Haugejorden 1991, McCaul et al. 2001, Trovik et al. 2000).

The number of teeth present or tooth loss represents a true outcome variable in evaluating oral care programs, and only a few longitudinal studies have assessed the secondary or surrogate criteria associated with tooth loss (Hujoel et al. 1998, Neely et al. 2001). One recent study (Schätzle et al. 2003) showed that different severities of gingivitis yielded different risks for periodontal attachment loss. In that study, it was demonstrated that sites that always bled on probing throughout a 26-year observation period resulted in up to 70% more attachment loss than sites that never showed signs of inflammation.

The primary objective of this report was to assess the relationship between clinical signs of gingival inflammation and tooth loss based on a long-term prospective cohort study.

Material and Methods

Source of data

The information presented in this paper was obtained from a longitudinal study of the initiation and progression of periodontal disease conducted in Oslo, Norway, between 1969 and 1995. The study population has been described previously (Löe et al. 1978a–c, 1986, Ånerud et al. 1991). The initial examination in 1969 included 565 individuals aged between 16 and 34 years. Subsequent surveys took place in 1971, 1973, 1975, 1981, 1988 and 1995. Four hundred and eighty-seven individuals could be reexamined at least once. At the last examination in 1995, 223 individuals participated. Fifty-four persons participated in all seven surveys. Thus, the study covers the age range of 16–59 years. The group was randomly selected by the Norwegian Bureau of Statistics. The participants were all born and raised in the City of Oslo, Norway, and had received systematic dental care since early childhood. In response to questionnaires at the start of the study and at subsequent examinations, all participants reported seeing their dentist on a regular basis, owning a tooth brush and brushing their teeth at least once a day.

Table 1. Number of patients examined at each survey during 26 years

Age group (years)	Survey 1	Survey 2	Survey 3	Survey 4	Survey 5	Survey 6	Survey 7	Patients per age group
<20	143	65	0	0	0	0	0	208
20–24	224	149	117	51	0	0	0	541
25–29	161	116	102	88	45	0	0	512
30–34	36	45	65	89	92	0	0	327
35–39	1	6	8	16	74	77	0	182
40–44	0	0	0	1	17	82	30	130
45–49	0	0	0	0	0	41	104	145
50–54	0	0	0	0	0	0	66	66
55–59	0	0	0	0	0	1	23	24
patients per survey	565	381	292	245	228	201	223	2135

Mean observation period: 16.6 years.
Patients in two and more surveys: 487.

The average observation period of a patient was 16.6 years. For evaluation, the subjects were divided into nine age cohorts: <20, 20–24, 25–29, 30–34, 35–39, 40–44, 45–49, 50–54, 55–59 years of age (Table 1).

Clinical parameters

At each appointment, the participants answered questions regarding their personal dental care and smoking habits. The oral cavity at large was inspected and missing teeth were recorded at each appointment.

Tooth loss during the 26-year follow-up period was identified when a tooth was present in 1969 and missing at any of the subsequent examinations. Information on the date or the reason for tooth loss was not collected. Third molars were not included in the evaluation at any time.

The examinations were performed in well-equipped clinical facilities at the Faculty of Odontology, University of Oslo, Norway.

For the purpose of the current analysis, the clinical examination included scoring of the gingival index (GI) (Löe & Silness 1963) on mesial and buccal surfaces of all teeth except third molars (Löe et al. 1978a). From Survey 5 (1981) onwards, the GI scores were also performed on the distal and lingual surfaces of all teeth.

For tooth-specific calculations, three tooth groups reflecting the history of inflammation of the surrounding gingivae (GI scores) over 26 years were established. For this reason, the minimal and maximal GI value of all sites was determined.

GI-Severity Group I

Teeth with surrounding gingival units scoring a minimum of one site with GI = 0 and a maximum of three sites with GI = 1 over the observation period (mean tooth GI between 0 and 0.75).

GI-Severity Group II

Teeth with surrounding gingival units scoring a minimum of one site with GI = 1 and a maximum of three sites with GI = 2 over the observation period (mean tooth GI between 1 and 1.75).

GI-Severity Group III

Teeth with surrounding gingival units always scoring a minimum of GI = 2 (bleeding on probing) at all sites over the observation period (mean tooth GI $\geqslant$2).

All other teeth not fulfilling these criteria (e.g. teeth with one site scoring GI = 2 and three sites scoring GI = 0 at any time) were not considered for further evaluation (Tables 2a and b). Hence, 3934 teeth not meeting any of the above criteria were excluded from further analysis. This represents 29.8% of the original 13,285 teeth included in this cohort.

Tooth mortality rates were defined as the number of teeth lost during the observation period divided by the number of years of observation per subject (e.g. two teeth lost over 26 years in subject X = Tooth mortality rate of 2/26 = 0.077 for subject X; one tooth lost over 6 years in subject Y = Tooth mortality rate of 1/6 = 0.167 for subject Y).

For tooth loss survival analysis, the time points of permanent tooth emergence were considered. This was based

Table 2a. Number of retained and lost teeth by GI-severity levels (only selected teeth)

GI-Severity Group I (GI_Min = 0 and GI_Max < 1)				GI-Severity Group II (GI_Min = 1 and GI_Max < 2)				GI-Severity Group III (GI_Min ⩾ 2)			
teeth retained		teeth lost		teeth retained		teeth lost		teeth retained		teeth lost	
N	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%
5793	99.72	16	0.28	3348	97.72	78	2.28	103	88.79	13	11.21

Three thousand nine hundred and thirty four did not fulfill the selection criteria, 19 (0.48%) of them were lost.
GI, gingival index.

Table 2b. Cumulative number of lost teeth by GI-severity levels and age groups (only selected teeth)

Age group (years)	Teeth lost					
	GI-Severity Group I (0 ⩽ GI < 1)		GI-Severity Group II (1 ⩽ GI < 2)		GI-Severity Group III (GI ⩾ 2)	
	N	%	*N*	%	*N*	%
< 20	1	6.25	1	1.28	1	7.69
20–24	6	37.50	12	15.38	0	0.00
25–29	2	12.50	20	25.64	3	23.08
30–34	4	25.00	13	16.67	5	38.46
35–39	0	0.00	12	15.38	1	7.69
40–44	1	6.25	9	11.54	0	0.00
45–49	2	12.50	7	8.97	3	23.08
50–54	0	0.00	4	5.13	0	0.00
55–59	0	0.00	0	0.00	0	0.00
total	16	14.95	78	72.90	13	12.15

GI, gingival index.

Table 3. Age of permanent tooth emergence in Danish boys (Helm & Seidler, 1974)

Tooth	Mean age of emergence (years)	SE	SD
Maxilla			
I1	7.18	0.024	0.74
I2	8.21	0.030	0.87
C	11.45	0.036	1.21
P1	10.59	0.038	1.46
P2	11.43	0.041	1.47
M1	6.25	0.028	0.71
M2	12.39	0.041	1.26
Mandible			
I1	6.19	0.027	0.66
I2	7.38	0.029	0.90
C	10.54	0.032	1.13
P1	10.68	0.040	1.48
P2	11.53	0.041	1.44
M1	6.21	0.028	0.68
M2	11.90	0.041	1.30

on the data published for Danish males by Helm & Seidler (1974) (Table 3), which are in agreement with the timing of incisor tooth eruption for Norwegian males (Alstad 1973). Hence, the tooth age was calculated as the time period between the mean age for tooth eruption and the midpoint of the two last surveys, when the tooth was still present and the survey during which tooth loss was observed.

Data analysis

The Statistical Analysis System Package (SAS Institute Inc., Cary, NC, USA) was used to calculate frequencies, mean values, standard deviations and standard errors for all parameters.

For the calculations of the odds ratio, the logistic regression models (PROC LOGISTIC, SAS) were used to model the binary tooth loss variable as a function of gingival inflammation severity class and age.

For the calculations of the survival analysis the PROC LIFETEST (Kaplan–Meier cumulative survival distributions), SAS, was used to model the tooth loss variable as a function of gingival inflammation severity class and age. The level of significance was set at $\alpha = 0.05$.

Results

Out of 15,820 possible (565 × 28) teeth, 15,383 teeth were present at baseline in 1969. Four hundred and thirty-seven teeth were missing prior to the start of the study. A total of 487 patients with 13,285 teeth in 1969 were followed for at least two subsequent surveys (Table 2a).

Of the 487 subjects, 412 (85%) did not lose any teeth. Over the 26-year observation period, 75 (15%) of the reexamined individuals had lost a total of 126 teeth (0.95%): 49 subjects lost one tooth, 12 subjects lost two teeth, eight subjects lost three teeth, three subjects lost four teeth, two individuals lost five teeth and one subject lost seven teeth. The mean number of teeth lost per subject was 0.26. The mean number of teeth lost in the 75 subjects with tooth loss was 1.68 (Table 4).

Most teeth lost were molars (62%), followed in proportion by premolars (27%) and incisors (10%). Canines were the most rarely lost teeth. Only two canines (<2%) out of the 126 teeth were lost. Less than 3% of the missing teeth were lost before the age of 20 years. Of the total tooth loss, 67% were lost between age 20 and 39 years. Thereafter, in the fifth decade of life, a decrease in tooth loss was observed. Finally, in the age cohort of 50–59-year-old subjects, again, 3% of the teeth were lost (Table 5).

Based on the history of gingival inflammation only, 16 out of 5809 (0.28%) teeth with a GI ⩾0 and <1 (GI-Severity Group I) were lost. In the group of teeth yielding GI scores ⩾1 and <2 (GI-Severity Group II), 78 (2.28%) out of 3426 teeth were lost. Finally, 13 (11.21%) of 116 teeth scoring GI > 2 (GI-Severity Group III) were lost (Table 2a).

Table 4. Number of lost teeth by individual (all teeth)

Lost teeth	Individuals	
	N	%
1	49	65.33
2	12	16.00
3	8	10.67
4	3	4.00
5	2	2.67
6	0	0.00
7	1	1.33
total	75	100.0

Four hundred and twelve or 85% of the subjects lost no teeth.

Table 5. Tooth loss by age groups and tooth groups (all teeth)

Age group (years)	Incisors				Canines				Premolars				Molars				Total lost teeth	
	retained		lost		retained		lost		retained		lost		retained		lost			
	N	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%
< 20			0	0.00			0	0.00			1	2.94			2	2.56	3	2.38
20–24			4	33.33			1	50.00			3	8.82			10	12.82	18	14.29
25–29			0	0.00			0	0.00			4	11.76			21	26.92	25	19.84
30–34			5	41.67			0	0.00			5	14.71			15	19.23	25	19.84
35–39			1	8.33			1	50.00			5	14.71			9	11.54	16	12.70
40–44			2	16.67			0	0.00			8	23.53			10	12.82	20	15.87
45–49			0	0.00			0	0.00			7	20.59			8	10.26	15	11.90
50–54			0	0.00			0	0.00			1	2.94			3	3.85	4	3.17
55–59			0	0.00			0	0.00			0	0.00			0	0.00	0	0.00
	3861	99.69	12	0.31	1939	99.90	2	0.10	3681	99.08	34	0.92	3790	97.94	78	2.06	126	100.00

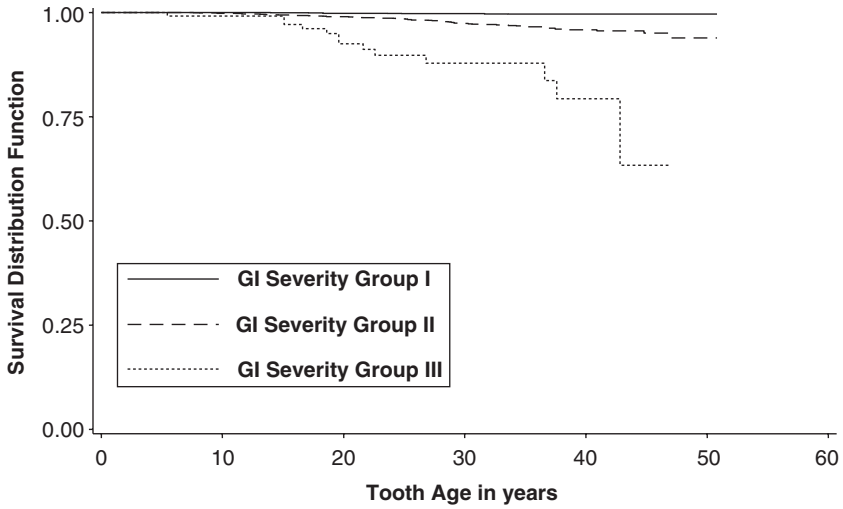

Fig. 1. Survival distribution function for different gingival inflammation severity levels.

The odds ratio for tooth loss was 8.5 (95% confidence limits (CL): 4.94–14.60) for the GI-Severity Group II and 45.8 (95% CL: 21.29–97.77) for the GI-Severity Group III (bleeding on probing) compared with GI-Severity Group I. The odds ratio for tooth loss in the GI-Severity Group III was 5.4 (95% CL: 2.90–10.06) compared with teeth in the GI-Severity Group II.

Age as a risk factor for tooth loss did not reach statistical significance.

Figure 1 depicts a Kaplan–Meier cumulative survival distribution for the three defined GI-Severity Groups. Before a tooth age of approximately 15 years, tooth loss was extremely rare. After a tooth age of 20 years, it is evident that the GI-Severity Group III yielded a significantly increased cumulative tooth loss when compared with both GI-Severity Groups I and II. On the basis of tooth age, the mean tooth survival time in this study, for the GI-Severity Group I was 33.6 years (SE: 0.0129). For the GI-Severity Group II, it was 45.9 years (SE: 0.10) and for the GI-Severity Group III, it was 39.4 years (SE: 0.94), respectively.

The GI-Severity Group I still retained 99.5% of the teeth after a tooth age of 51 years. The GI-Severity Group II retained 93.8% of the teeth after a tooth age of 50 years. However, in the GI-Severity Group III, 63.4% of the teeth were retained for a tooth age of 47 years.

Discussion

The purpose of this study was to determine the long-term influence of clinical signs of gingival inflammation as a risk factor for tooth loss. During the 26-year observation period, only 15% of the subjects lost teeth. Tooth loss amounted to only 126 teeth (0.96%) out of 13,285. This corresponded to an annualized tooth loss of 0.016 teeth/year and individual, reflecting an extremely low overall tooth loss through 60 years of life of a patient population and confirming earlier assessments of tooth longevity in the same population (Löe et al. 1978c).

In contrast to the present study, a sixfold higher tooth mortality rate was reported based on a 10-year follow-up study of 273 Swedish adults (0.1 teeth/person/year) (Holm 1994). Furthermore, a 10-fold higher mortality rate resulted from the analysis of a US cohort (0.17/person/year) followed for 5 years (Machtei et al. 1999). The reason for these higher mortality rates may be explained by the age range of the respective cohorts.

The mortality rate also appears to be elevated (0.3–2.0 teeth/person/year) in patients treated for periodontitis (McGuire & Nunn 1996). A much higher tooth mortality rate was reported in the longitudinal study on the natural history of periodontal disease in Sri Lankan tea laborers in whom a subset of subjects (8%) with rapidly progressing disease lost 2.33 teeth/year and individual (Löe et al. 1986). As a consequence, most of these patients were edentulous by the age of 40 years.

In the present study, the total number of teeth lost was fairly evenly distributed, varying between 13% and 20% of the total tooth loss in all 5-year age cohorts from 20 to 50 years of age. Before the age of 20 and between 50 and 60 years of age the tooth loss was very low. The majority of teeth lost were molars followed by premolars, while anterior teeth were rarely lost. The fact that approximately 2% of the molars and 1% of the premolars were lost throughout the observation period, while anterior tooth loss did not even

reach one in three hundred teeth shows that posterior teeth are at a substantially higher risk for loss.

It is remarkable that the GI-Severity Group I, where no bleeding on probing was ever scored throughout the observation period, yielded a cumulative tooth survival of 99.5% at a tooth age of 51 years. This suggests that clinically healthy gingiva is a prognostic indicator of tooth longevity. This is also supported by a short-term prospective study on elderly subjects (above the age of 65 years). In this study, subjects with a complete dentition (28 teeth) did not lose any teeth at all over the 4-year observation period (Persson et al. 2003). The absence of bleeding on probing, indeed (Joss et al. 1994) may represent periodontal stability and indicate prognostically that teeth will be retained.

In contrast to the GI-Severity Group I (with absence of bleeding on probing), the GI-Severity Group III demonstrated a cumulative tooth survival rate of only 63% after 47 years of tooth age. In other words, one-third of the teeth (37%) that always bled on probing were lost after a tooth age of 40 years, corresponding to a patient age of at least 50 years. At a patient age of 40 years, corresponding to a tooth age of 30 years, the cumulative tooth survival rate was still 88%. Hence, during a 10-year period, in the fifth decade of life, the tooth survival rate dropped from 88% to 63%. The fact that the GI-Severity Group II demonstrated a cumulative tooth survival rate of 94% after 51 years of tooth age supports the concept that occasionally, bleeding tooth sites provide a much smaller risk for tooth loss than regularly bleeding gingivae. Again, this may confirm the relative predictive role of bleeding on probing for attachment loss studied retrospectively (Lang et al. 1986) and prospectively (Lang et al. 1990, Joss et al. 1994) in periodontal maintenance patients.

In the present study, the risk to lose a tooth showed a wide range of odds ratios. Teeth always surrounded by healthy or occasionally slightly inflamed gingivae (GI-Severity Group I) had an eight times lower likelihood to be lost when compared with teeth consistently surrounded by slightly inflamed gingivae and occasional bleeding (GI-Severity Group II). However, teeth with gingival tissues that always bled on probing (GI-Severity Group III) had a 46 times higher likelihood to be lost than teeth always surrounded with healthy gingivae (GI-Severity Group I). Finally, teeth of the GI-Severity Group II showed only a five times lower likelihood for tooth loss than teeth of the GI-Severity Group III. Again, this odds ratio clearly positions regularly bleeding gingivae into the category of a risk factor for tooth loss. Similar suggestions were made by Burt et al. (1990), who identified gingival inflammation as the most prominent risk indicator for partial tooth loss. In their study, however, gingival inflammation was only assessed at baseline, which may explain the relatively low odds ratio (Burt et al. 1990).

The fact that well-maintained teeth with healthy, non-bleeding gingivae were practically maintained for half a century, i.e. a tooth age of 51 years as indicated in the present analysis, clearly positions the natural tooth as a predictable and fully functional chewing element. In recent years, reconstructions supported by endosseous implants have yielded high predictability and are documented for successful function with high survival rates of over 90% after 5–10 years (for a review, see Berglundh et al. 2002). Nevertheless, a recent study has identified a threefold increased risk for implant loss in patients who were previously treated for advanced periodontitis and who had lost their teeth because of periodontitis when compared with patients without a history of periodontitis (Karoussis et al. 2003). Although this 10-year prospective cohort study yielded survival of implants after 10 years of 90.5% and 96.5%, respectively, for patients with or without a history of periodontitis, it has to be realized that tooth survival rates revealed in the present study surpass by far those for oral implants. Consequently, the maintenance of the natural dentition in a healthy condition with uninflamed gingivae still constitutes the primary goal for the maintenance of a functional dentition throughout life.

In conclusion, this study has clearly shown that tooth loss is a rare phenomenon in a population with regular professional and personal oral care. A limited subset of 15% of the study population lost teeth during the observation period of 26 years, and only 1% of the entire population lost more than three teeth. While teeth surrounded with inflammation-free gingiva were maintained for a tooth age of 51 years, teeth consistently surrounded with inflamed gingiva yielded a 46-times higher risk to be lost. This confirms the role of gingival inflammation as a significant risk factor for future tooth loss.

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