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Loss of molars in periodontally treated patients: a retrospective analysis five years or more after active periodontal treatment

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Abstract

Objectives: Evaluation of tooth loss in molars and prognostic factors for molar survival.

Material and Methods: Five hundred and five molars in 71 patients (mean age 46 years; 40 females) were evaluated. The following inclusion criteria were required: periodontal therapy of at least one molar, at least 5 years of supportive periodontal therapy, and baseline assessment of furcation involvement (FI).

Results: At baseline 200 of 505 molars exhibited no FI, 116 degree I, 122 degree II, and 67 degree III FI. Twenty-seven molars did not receive periodontal treatment; 127 molars were subjected to non-surgical therapy, and 227 to flap surgery. Tunnel preparation was performed on 14 molars, root resection on 20, regenerative therapy on 57 teeth, and 33 molars were extracted. During the average follow-up period of 107 months 38 molars were lost additionally. Molars with degree III FI had the highest mortality. A multi-level proportional hazard model revealed smoking, baseline bone loss, number of molars left, and degree III FI as risk factors influencing the retention time of molars.

Conclusion: Overall periodontal therapy results in a good prognosis of molars. Degree III FI leads to a significant deterioration of prognosis. Beyond FI smoking, baseline bone loss, and number of molars left influence molar survival.

Key words: furcation involvement; long-term stability; molar; periodontal treatment; tooth loss

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Furcation involved molars respond less favourably to periodontal therapy than molars without furcation involvement (FI) or single rooted teeth and are at greater risk for further attachment loss compared with other teeth (Nordland et al. 1987, Loos et al. 1989, Wang et al. 1994). This problem was also described by Kalkwarf et al. (1988) who reported the success of different surgical and non-surgical treatment modalities on 158 molars. During the 2-year observation period the horizontal defect in the furcation area increased independently of the performed therapy.

Numerous factors contribute to a more severe disease progression in furcation involved molars, recurrent periodontal infection, and as a result an inferior long-term prognosis of these teeth (McGuire & Nunn 1996). These factors include morphological features such as enamel projections (Al-Shammari et al. 2001) and accessory pulpal canals into the furcation, anatomy which impedes accessibility for individual oral hygiene in the molar region (Lang et al. 1973), and professional root debridement (Fleisher et al. 1989).

Hirschfeld & Wassermann (1978) examined retrospectively the periodontal conditions of 600 patients who had been previously treated for 15–55 years. Over the 22-year average period of maintenance 7.1% of all teeth were extracted because of periodontal causes, but 31% of the teeth with FI. Corresponding results were reported by McFall (1982), who observed an overall tooth loss of 10% and 57% of teeth with probable FI over a maintenance period of 19 years.

Depending on tooth type, degree of FI, and individual factors (age, course of periodontal destruction, compliance, and prosthetic considerations) different surgical and non-surgical modalities may be considered for furcation therapy (Al-Shammari et al. 2001). Indication and application for scaling and root planing (SRP; Cattabriga et al. 2000),

resective techniques (tunnel preparation, hemisection, root amputation; DeSanctis & Murphy 2000, Rüdiger 2001), guided tissue regeneration (GTR; Sanz & Giovannoli 2000, Eickholz et al. 2001), enamel matrix derivative (Jepsen et al. 2004) and bone substitutes (McClain & Schallhorn 2000) have been discussed in detail in the literature.

The aim of the present study was to evaluate tooth loss of molars in relation to their degree of FI and treatment modality. Further, prognostic factors for the survival of molars in patients consecutively maintained over a period of at least 5 years after active periodontal therapy should be identified.

Material and Methods

Patients

In this restrospective study patients were consecutively recruited until at least 500 molars were collected for analysis. Patients with periodontal treatment of at least one of the present molars and not less than 5 years of supportive periodontal therapy (SPT) were included in the study. Periodontally treated patients without molars or patients with periodontal treatment only at non-molar teeth were excluded. All patients underwent periodontal treatment between 1992 and 1995 by one of the authors (P. E.) at the Section of Periodontology of the Department of Conservative Dentistry of the University Hospital of Heidelberg and were on a regular SPT programme after active (antiinfectious and corrective) periodontal therapy (APT).

The patients were categorized according to the classification of Periodontal Disease and Conditions of the American Academy of Periodontology (Armitage 1999). However, to achieve a more accurate discrimination between aggressive and chronic periodontitis only patients with the radiographic evidence of 50% or more bone loss in at least two permanent teeth at the age of 35 or younger were diagnosed as aggressive periodontitis.

Patients were asked actual and past smoking habits and packyears were calculated (number of cigarettes/day/20 × years) to assess their lifetime smoking exposure. Patients who reported smoking more than 10 cigarettes/day were classified as actual smoker. Former smokers were subjects who had previously been smokers but had stopped their habit before the beginning of the periodontal therapy. Patients who smoked up to 10 cigarettes/day or had never smoked were identified as non-smokers.

Examinations and therapy

APT was performed similarly for all patients. The APT consisted of oral hygiene instructions, professional tooth cleaning, and subgingival SRP as a conservative, non-surgical therapeutical approach (antiinfectious periodontal therapy). SRP was performed only once during the APT at every tooth with probing pocket depth (PPD) of 4 mm and more. Three to 6 months later outcome of antiinfectious periodontal therapy was re-evaluated and if necessary, further surgical therapy was rendered. Depending on tooth type and the extent of periodontal destruction different surgical procedures were chosen. Surgical intervention included access flap surgery, GTR, tunnel preparation, resective procedures, and tooth extraction (corrective periodontal therapy).

The horizontal extent of FI was assessed clinically at the beginning of periodontal therapy in every molar by a well-trained periodontist. In case of further surgical therapy FI was measured intra-surgically after elevation of the soft tissue flap but prior to soft or hard tissue instrumentation. The measurements were done with a curved, scaled Nabers probe (Q-2N [SS+SSC] Nabers colour coded, Hu-Friedy, Chicago, IL, USA) and the defect characterized according to the following classification (Hamp et al. 1975, Eickholz & Staehle 1994):

Degree 0: the furcation is not probable.
Degree I: horizontal loss of periodontal tissue support up to 3 mm.
Degree II: horizontal loss of support exceeding 3 mm, but not encompassing the total width of the furcation area.
Degree III: horizontal 'through-and-through'-destruction of the periodontal tissue in the furcation.

In case of different degrees of FI within one tooth, the molar was characterized for the analysis by the most severe furcation defect. For this retrospective investigation the FIs charted before treatment or during periodontal surgery were documented. Further, the records at each appointment in the SPT phase were compared carefully to check for any tooth loss of molars and non-molar teeth and for the reasons of extraction during the SPT.

Radiographic bone loss at the beginning of the APT was measured possibly at every molar ($n = 486$, excluding all molars without the radiographic information of bone loss at the baseline) using a Schei ruler to assess the percentage of bone loss in 20% steps (Schei et al.1959) and classified in five categories ($I \leqslant 20\%$, $II \leqslant 40\%$, $III \leqslant 60\%$, $IV \leqslant 80\%$, and $V > 80\%$).

After completion of APT all patients were assigned to SPT on a regular basis and followed up for at least 5 years. The maintenance regime was scheduled according to the patient's individual periodontal risk at 3, 6 months or annual intervals. SPT included clinical measurements, assessment of the plaque control record (PCR; O'Leary et al. 1972) and if necessary re-instrumentation of sites with PPD of 4 mm and bleeding on probing and of 5 mm and more.

Data analysis

For descriptive analysis of the data the mean and standard deviations of the respective variables were calculated. To assess the association of jaw and FI, we used the Cochran–Mantel–Haenszel test.

In order to identify prognostic factors for the survival of molars a proportional hazard model for time-to-event data using a patient-specific γ distribution for shared frailty was applied. The consideration of a patient-specific risk is important, lest the dependency between different molars of the same patient would be neglected, resulting in biased estimates for the relative risks (Henderson & Omar 1999). The shared frailty term is used to model this dependency. The following factors were used in the multi-level proportional hazard regression analysis: logarithm of packyears, age, number of molars left (all patient specific), degree III FI, baseline bone loss (both molar specific). Baseline bone loss was used as a metric variable, giving equidistant interpretation to this variable. As most of the extracted third molars displayed no FI the decision for extraction of these teeth was basically not related to FI but substantiated by other factors. Hence, the regression model was calculated excluding third molars and molars without information about baseline bone loss ($n = 428$). Statistical analysis was performed using R 2.0.0 (R Foundation for Statistical

Computing, Vienna, Austria) on the Darwin operating system (Mac OS X) on a PowerPC architecture. Specifically, we used the coxph() function from the survival package, version 2.13-2, for the main analysis.

Results

Patient and tooth characteristics

Seventy-one patients (40 females) with 505 molars at the beginning of the periodontal therapy were recruited. The average age of the patients at the beginning of periodontal therapy was 46 ± 11 years (ranging from 16 to 70 years). The study population included nine patients with aggressive periodontitis (median age of 28 years, with a 25th percentile of 23.5 years and 75th percentile of 34 years, ranging from 16 to 34 years) and 62 subjects with chronic periodontitis (mean age of 49 ± 9 years, ranging from 27 to 70 years). The fractions of active smokers, former smokers, and non-smokers were 43.7% ($n = 31$), 26.8% ($n = 19$), and 29.5% ($n = 21$), respectively. Active smokers had a mean of 21.3 ± 17.9 packyears and former smokers of 15.2 ± 16.8 packyears. The median of the PCR of all patients during the complete SPT was 21.3% (ranging from 4.2% to 58.5%, 25th percentile of 16.3% and 75th percentile of 27.2%). The mean number of appointments during the SPT for all patients was 17 ± 5 (ranging from four to 32 appointments). The median observation period was 107 months (between 62 and 145 months).

The total number of teeth at the beginning of the periodontal therapy was 1824 including 505 molars, with an average of 25.7 teeth in each patient at the initial examination. Only 4% ($n = 3$) of the patients exhibited all 12 molars, while 46% of the patients ($n = 33$) had at least eight molars remaining. Two hundred and fourty-three (48.1%) were maxillary molars and 262 (51.9%) were mandibular molars. Third (13.9%) molars had a lower frequency of presence than first (38.2%) and second molars (47.9%; Table 1).

Table 1 shows the status of molars with regard to the maximum FI: 200 out of the 505 molars had no probable furcation entrances (degree 0; 39.6%), 116 exhibited a FI of degree I (23%), 122 of degree II (24.1%) and 67 molars had degree III (13.3%). Seventy-two percent of the total number of 243 maxillary molars revealed FI but only 49.6% of the molars in the mandible. This difference was statistically significant ($p = 6 \times 10^{-8}$).

Table 1. Number of molars at the beginning of active periodontal therapy with regard to the maximum furcation involvement

FI (degree)	Maxillary molars ($n = 243$)			Mandibular molars ($n = 262$)			Total number
	first	second	third	first	second	third	
0	15	34	19	37	61	34	200
I	24	30	5	24	25	8	116
II	38	37	2	19	25	1	122
III	21	17	1	15	13		67
Total number	98	118	27	95	124	43	505

Table 2. Radiographic bone loss at the beginning of the active periodontal therapy (number of molars that could be assessed radiographically/total number of molars)

FI (degree)	Bone loss	Maxillary molars ($n = 235/243$)			Mandibular molars ($n = 251/262$)			Total number (486/505)
		first (96/98)	second (118/118)	third (21/27)	first (93/95)	second (121/124)	third (37/43)	
0 (186/200)	I	2	2	1	7	16	3	31
	II	9	16	6	22	31	14	98
	III	4	11	7	4	8	11	45
	IV		2	1	1	2		6
	V		3		1	1	1	6
I (113/116)	I	1	3		2	1		7
	II	10	14	2	16	13	3	58
	III	7	8	1	5	9	2	32
	IV	4	3		1	1	2	11
	V	2	2			1		5
II (121/122)	I	2			3	2	1	8
	II	7	12		9	8		36
	III	15	17	1	3	12		48
	IV	8	7	1	4	3		23
	V	5	1					6
III (66/67)	I				1	1		2
	II	3	2		4	7		16
	III	9	6		5	2		22
	IV	5	4		3	2		14
	V	3	5	1	2	1		12
Total number (486/505)	I	5	5	1	13	20	4	48
	II	29	44	8	51	59	17	208
	III	35	42	9	17	31	13	147
	IV	17	16	2	9	8	2	54
	V	10	11	1	3	3	1	29

Radiographic bone loss was assessed in 20% steps: I ≤ 20%, II ≤ 40%, III ≤ 60%, IV ≤ 80%, and V > 80%.

Table 1 also presents the frequency of different degrees of FI for the first, second, and third molars in the maxilla and the mandible. FI of degree II or III was significantly more frequent in the maxilla (47.7%) compared with the mandible (27.9%; $p = 5 \times 10^{-6}$).

At the beginning of periodontal therapy 9.9% of all molars showed a radiographic bone loss of ⩽20%, 42.8% of ⩽40%, 30.2% of ⩽60%, 11.1% of ⩽80%, and 6% of more than 80% (Table 2).

Active periodontal therapy

Table 3 depicts the frequencies of the various therapeutic procedures, their distribution related to molar type, and FI, respectively. Thirty-three molars (6.5%) out of 505 were extracted during the active therapy.

Twenty-seven molars did not receive any periodontal treatment (5.3%). Twenty-two (81.5%) of them were without FI. Of the remaining teeth, 127 molars were scaled and root planed only (SRP; 25.1%). After the re-evaluation of the outcome of the antiinfective therapy further surgical treatment was necessary in 351 molars (in addition to

Table 3. Treatment of molars in active periodontal therapy (APT)

FI (degree)	Therapy	Maxillary molars ($n = 243$)			Mandibular molars ($n = 262$)			Total number (505)
		first (98)	second (118)	third (27)	first (95)	second (124)	third (43)	
0 (200)	None	3	3	5	4	3	4	22
	SRP	5	8	3	15	33	9	73
	Flap surgery	7	18	9	13	25	15	87
	GTR		1		3			4
	Tunnel preparation							
	Root resection				1			1
	Extraction		4	2	1		6	13
I (116)	None				1	2	1	4
	SRP	6	10	3	7	4	2	32
	Flap surgery	14	17	1	14	15	3	64
	GTR	2	2		2	2	1	9
	Tunnel preparation							
	Root resection	2				1		3
	Extraction		1	1		1	1	4
II (122)	None							
	SRP	9	5	1	2	1		18
	Flap surgery	14	22	1	10	14	1	62
	GTR	10	7		6	9		32
	Tunnel preparation					1		1
	Root resection	5	1		1			7
	Extraction		2					2
III (67)	None					1		1
	SRP	2			2			4
	Flap surgery	7	3			4		14
	GTR	4	4		2	2		12
	Tunnel preparation		1		9	3		13
	Root resection	5	2			2		9
	Extraction	3	7	1	2	1		14
Total number (505)	None	3	3	5	5	6	5	27
	SRP	22	23	7	26	38	11	127
	Flap surgery	42	60	11	37	58	19	227
	GTR	16	14		13	13	1	57
	Tunnel preparation		1		9	4		14
	Root resection	12	3		2	3		20
	Extraction	3	14	4	3	2	7	33

SRP, scaling and root planing; GTR, guided tissue regeneration.

the preceding SRP during antiinfective therapy). Two-hundred and twenty-seven teeth were subjected to flap surgery (45%). Tunnel preparation was performed in 14 molars (2.8%), root resection in 20 (4%) and regenerative therapy in 57 teeth (11.3%).

Fifty-seven and a half percentage of the molars ($n = 73$) in the SRP group had no FI, 126 teeth (55.5%) treated with flap surgery had FI of degree I or II and only 14 teeth FI degree III (6.2%). Forty-four molars (77.2%) in the GTR group displayed a furcation defect of degree II or III. Tunnel preparation was performed in 13 molars with a through-and-through defect and in only one molar with degree II FI. Nine of the molars treated with root resection displayed an FI of degree III, seven of degree II, three of degree I and one molar had no furcation defect (Table 3).

Figure 1 displays the fraction of the seven different treatment modalities in the first, second, and third molars. While in first and second molars all treatment options were executed in third molars neither tunnel preparation nor root resection were performed. But third molars exhibited the highest percentage of extractions (15.7%) based on their total number.

Tooth loss

Thirty-three molars (6.5%) were extracted during the active periodontal therapy (Table 3) in 19 out of the 71 patients. Maxillary molars accounted for the loss of 22 teeth, while 11 mandibular molars were lost. Thirteen of the extracted molars in the active periodontal therapy had no probable furcation (degree 0), four had a degree I FI, two had a degree II, and 14 had a through-and-through furcation defect (Table 3).

In the course of SPT an additional 38 molars (7.5% of the initial 505 molars) were lost in 26 of the 71 patients. The mean loss of molars per patient was 0.06 teeth/year during SPT. Maxillary molars accounted for loss of 21 teeth, while 17 mandibular molars were extracted (Table 4). Eight of the 38 molars had been treated with root resection previously in the course of APT, 40% of the 20 teeth in the root resection group were lost during SPT (Table 4). Tooth loss of molars with degree III FI during SPT occurred predominantly in the maxilla (nine of 12 molars). Twenty-seven (71%) of the 38 molars were lost within the first 5 years of SPT.

Table 5 presents the reasons for extraction of molar teeth in the SPT. Twelve molars (31.6%) were extracted because of periodontal problems, there of 5 third molars and 5 molars with FI degree III. Endodontic lesions or combined periodontal–endodontic lesions were responsible for the extraction of 8 molars in each case (21.5%). The remaining 10 molars were extracted because of root fracture ($n = 3$, 7.9%), caries ($n = 2$, 5.2%), and prosthetic treatment ($n = 2$, 5.2%). In three cases the reason was not documented in our charts because the extraction was carried out alio loco.

While a total of 71 molars were extracted (14.1% of the 505 molars), 37 non-molar teeth were lost in the same interval (2.8% of all non-molar teeth present at the beginning of the periodontal therapy ($n = 1319$); APT: 25, SPT: 12). Extraction of the 71 molars were carried out in only 33 of the 71 studied patients, thereof 38 molars (53.5%) in only 11 patients (15.5%). This group was identified as 'down hill' patients (patients with extraction of three molars and more during APT or SPT) and Table 6 depicts characteristics of these patients. Among the 11 patients two were diagnosed with aggressive periodontitis, six patients had an average PCR over the median of 21.3%, three were non-smokers, and the remaining eight patients had an average of 23.5 ± 15 packyears. In the group of 33 patients with molar extractions 23 non-molar teeth were lost but only six non-molar teeth (16.2%) in the 'down hill' group (Table 6).

As the failure rate of teeth after root resection in the present investigation appeared to be extremely high (40%), we tried to retrace the indication for root

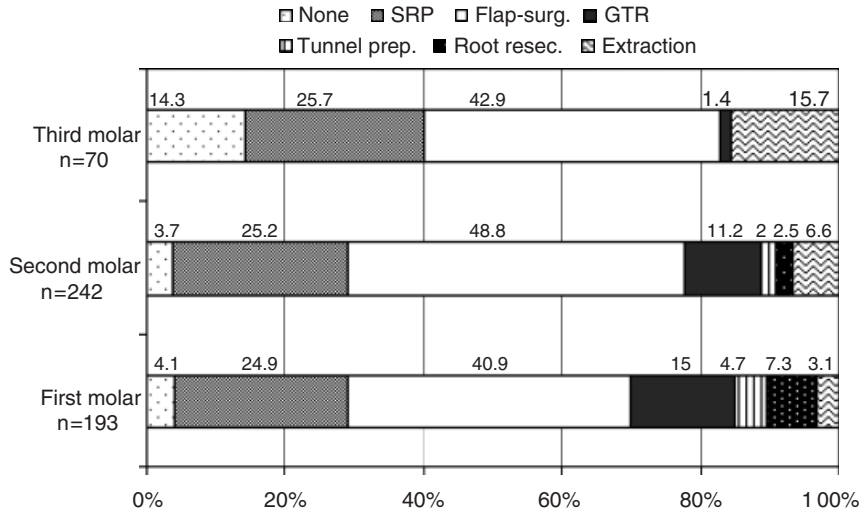

Fig. 1. Different treatment modalities in the first, second, and third molars.

Table 4. Tooth loss during supportive periodontal therapy (SPT)

FI (degree)	Therapy in APT	Maxillary-molars ($n = 21$)			Mandibular-molars ($n = 17$)			Total number
		1st	2nd	3rd	1st	2nd	3rd	
0	None		1	3			1	13
	SRP					3	1	
	Flap surgery				1		3	
I	None					1		9
	SRP					1		
	Flap surgery	1	2		1	1		
	Root resection	2						
II	SRP	1						4
	Flap surgery					1		
	Root resection	2						
III	SRP	2			1			12
	Flap surgery	1				2		
	Root resection	3	1					
	GTR		1					
	Tunnel preparation	1						
Total number		13	5	3	3	9	5	38

SRP, scaling and root planning; GTR, guided tissue regeneration.

Table 5. Reasons for extraction of molars in the supportive periodontal therapy (SPT)

Case	Molars (total)	Molars with degree III FI	Third molars
Perio	12	5	5
Perio-endo-lesions	8		
Endo	8		1
Root fracture	3		
Caries	2		1
New prosthodontics	2		
alio loco/ with unknown case	3		
Total	38		

resection and the following extraction (endodontic or periodontal) in these molars. All together eight molars were extracted in seven patients including three members of the 'down hill' group. All teeth were located in the maxilla. These molars had an average baseline bone loss of about 60% (3.5, from category 2–5). In two patients root resection was performed for periodontal indication to maintain the existing fixed prosthodontic construction and teeth had to be extracted because of increased mobility and periodontal problems. Only in one case root resection was carried out because of primarily endodontic reasons (complications during the revision of a root canal filling). In one female patient two molars were already extracted 4 months after root resection. In this case the indication for a resective procedure was clearly overextended to maintain the distal teeth in the maxilla. In the remaining three cases extraction was necessary because of root fracture, an acute periapical lesion, and a combined endodontic–periodontal lesion. These teeth could be retained an average of 50 months after the root resection (3–117 months).

Prognostic factors for the survival of molars

The results of the proportional hazard model are shown in Table 7. Degree III FI influences the retention time of molars most negatively with a hazard ratio of 3.25 ($p = 7.3 \times 10^{-4}$), followed by baseline bone loss (2.55 per category; $p = 5.4 \times 10^{-9}$), and packyears (1.4; $p = 1.9 \times 10^{-2}$). The retention time is also affected by the numbers of molars left (0.77 per missing molar; $p = 6.2 \times 10^{-2}$), whereas age failed to show significant influence (1.03 per year; $p = 6.2 \times 10^{-2}$).

Discussion

Prevalence and assessment of FI

The present investigation demonstrated a significantly higher prevalence of furcation involved molars in the maxilla compared with the mandible. This observation is in agreement with findings reported previously (Hirschfeld & Wassermann 1978, McFall 1982, Svärdström et al. 1996). Hirschfeld & Wasserman (1978) and McFall (1982) studied tooth loss in a population of 600 and 100 periodontal-treated patients over a period of 22 and 15 years, respectively. Their results revealed a prevalence of 25.1% and 38.7%, respectively, furcation involved molars in the maxilla and 15.9% and 29%, respectively in the mandible. Our data, however, showed a clearly higher proportion of furcation involved molars in the upper jaw compared with the mandible. This difference might be explained by the fact that in a

Table 6. Characteristics of the eleven 'down hill' patients who lost 53.5%of the totally extracted 71 molars

Patient number	Age (years)	Diagnosis	Number of **extracted molars** and *non-molar teeth*	Packyears	PCR
1/18	65	Chronic	**3** (APT = 1, SPT = 2), *1*	0	18
2/19	52	Chronic	**4** (APT = 3, SPT = 1), *2*	8	19
3/31	33	Aggressive	**3** (SPT), *0*	20	15
4/36	48	Chronic	**3** (SPT), *0*	0	22
5/38	53	Chronic	**3** (APT), *1*	0	29
6/45	43	Chronic	**3** (SPT), *1*	10	17
7/46	34	Aggressive	**5** (APT = 3, SPT = 2), *1*	29	27
8/47	37	Chronic	**4** (APT = 1, SPT = 3), *0*	30	25
9/59	41	Chronic	**3** (APT = 2, SPT = 1), *0*	38	20
10/61	46	Chronic	**4** (APT = 2, SPT = 2), *0*	48	29
11/69	51	Chronic	**3** (APT = 2, SPT = 1), *0*	5	28

APT, active periodontal therapy; SPT, supportive periodontal therapy.

Table 7. Proportional hazard model

	Coefficient	SE	*p*-value	Hazard ratio	Confidence interval (95%)
Packyears (logarithm)	0.33	0.14	1.9×10^{-2}	1.40	1.06–1.84
Baseline bone loss	0.94	0.16	5.4×10^{-9}	2.55	1.86–3.49
Degree III FI	1.18	0.35	7.3×10^{-4}	3.25	1.64–6.44
Age (years)	0.03	0.02	2.4×10^{-1}	1.03	0.98–1.08
Number of molars left	− 0.26	0.14	6.2×10^{-2}	0.77	0.59–1.01

Dependent variable: time of tooth retention (months), $n = 71$ patients, 428 molars (excluding third molars and molars without information about baseline bone loss).

number of molars FI was assessed during surgical procedures after elevation of the soft tissue flaps.

The clinical assessment of proximal furcation defects is difficult, in particular when neighbouring teeth are present and hamper probing (Eickholz & Staehle 1994). A clinical (Pontoriero et al. 1989) or radiographic (Goldman et al. 1986) assessment of FI depending on the probe used and the furcation location may lead to an underestimation of the defect (Zappa et al. 1993, Eickholz & Kim 1998, Eickholz & Hausmann 1999). However, in a previous study evaluating the reproducibility and validity of furcation measurements, Eickholz (1995) could demonstrate that there was no statistically significant difference between furcation classes assessed presurgically and intra-surgically if a curved colour-coded probe was used as in the present study. Use of a pressure controlled or straight probe for furcation diagnosis leads to underestimation of class III FI (Eickholz & Kim 1998).

Svärdstrom et al. (1996) also reported a higher prevalence of FI in the maxillary molars (especially at the distal aspect of first and second molars) than in the mandible. One explanation for this pattern may be that at maxillary molars two of the furcation entrances are located at proximal sites and, consequently, positioned in areas which usually show the highest frequency of plaque-associated lesions (Lang et al. 1973).

Probably caused by the root morphology FI (degree I, II) could be found in only 16 of a total of 70 third molars. FI of degree III was only seen in one upper third molar.

Treatment modalities for molars

The evaluation of different treatment modalities in the course of active periodontal therapy in relation to the degree of FI revealed that tunnel preparation was most frequently performed in molars with degree III and occasionally with degree II FIs. Root resection was primarily performed in molars with degrees II and III furcation defects, but also in four teeth without or with a degree I furcation defect; probably because of endodontic indications. The frequency of non-surgical therapy and flap surgery, respectively, decreased with increasing degrees of FI. However, 18 molars with through-and-through furcation defects were subjected exclusively to scaling and root planing or flap surgery, respectively. Twelve of these teeth were maxillary molars. A through-and-through furcation defect in mandibular molars with pronounced horizontal bone loss often can be opened up for inter-radicular cleaning by scaling and root planing alone; avoiding further surgical intervention.

However, tunnel preparations in upper molars demand advanced skills for proper inter-radicular cleaning post-surgically (Hamp et al. 1975, Helldén et al. 1989) and have only rarely been described in the literature (Topoll & Lange 1987, Helldén et al. 1989, Little et al. 1995, Rüdiger 2001). Anatomical and individual factors (minor root divergence, higher risk for caries, insufficient compliance) may have influenced the decision not to perform tunnel preparation or root resection in the above-mentioned molars with degree III FI.

GTR therapy was predominantly performed in molars with degree II FI. However, during 1992 and 1995 also a number of molars with a degree III FI were treated by GTR assuming that these defects could be closed by regeneration. The majority of defects remained through and through (Eickholz & Hausmann 1999), which is in close agreement with findings reported previously (Pontoriero & Lindhe 1995). On the other hand, only one of these molars got lost during the follow-up period of at least 5 years. GTR was also performed in four molars without furcation defects because of proximal infrabony defects.

Our findings revealed that only 20 molars were treated with root resection compared with 57 teeth in the GTR group. The main reason for this imbalance may be that in the observation period an increasing number of molars were treated with GTR to define methodically the clinical application for the GTR procedure (Eickholz & Hausmann 1999). However, summarizing the present findings it can be concluded that treatment modalities were mostly chosen and performed according the indications discussed in the literature (Newell 1998).

During active periodontal therapy 33 out of a total of 505 molars were extracted. Hamp et al. (1975) reported 114 extractions out of 284 molars (40.1%) during active periodontal therapy. Compared with the data of Hamp et al. (1975) in the present study only 6.5% of the molars were extracted during active periodontal therapy and overall 14.1% during the complete observation period. However, a direct comparison of the various studies evaluating tooth loss during periodontal therapy is difficult. If a high proportion

of the teeth with a questionable prognosis are extracted during active treatment then there are likely to be fewer teeth lost during subsequent maintenance (McGuire 1991) and vice versa.

Our analysis showed that the survival rate of molars (85.9%) was inferior compared with non-molar teeth (97.2%) which corresponds to the data in the literature (Hirschfeld & Wassermann 1978, Goldman et al. 1986).

As the reason for tooth extraction during the APT was not documented for all molars it could not be considered for this investigation. However, 13 extracted molars (APT) showed no FI (among them six third molars in the mandible). In this context it should be taken into consideration that besides FI also other factors including pronounced bony defects, endodontic complications, restorative, prosthetic, and prophylactic considerations (primarily in third molars) may influence the decision for tooth extraction.

Further 38 teeth were extracted in the course of the maintenance therapy. The main reasons for extraction were periodontal problems (31.6%), followed by endodontic and periodontal–endodontic lesions (21.5% in each case). Seventy-one percent of the 38 molars were lost within the first 5 years of SPT. Eight of these molars had undergone resective procedures during APT. Data in the literature regarding the long-term prognosis of teeth after resective therapy differ significantly. Langer et al. (1981) reviewed 100 patients 10 years after root resection. A significant finding was that 38% of these teeth failed during the observation period, the majority occurring between the fifth and seventh year. The authors concluded that the initial outcome of root resection therapy is favourable but not lasting, and that most instances of breakdown occur between 5 and 10 years (Langer et al. 1981). Endodontic problems and root fractures were the dominating causes for the failure in this study while recurrence/progression of periodontal disease accounted for comparatively few failures (10%). However, Blomlöf et al. (1997) reviewed the relative survival rates of resected molars and single-rooted root-filled teeth in 80 patients. They compared the two groups over a 10-year period and found a survival rate of 83% at 5 years and 68% at 10 years. Moreover, they concluded that the prognosis of root resection is not poorer than the prognosis of root-filled, single-rooted teeth with an equal susceptibility to periodontitis, if endodontic conditions and maintenance care are optimal. Carnevale et al. (1998) described a tooth loss of only 6% in 175 molars treated with root resection covering the same observation period. The attempt to maintain some teeth with questionable prognosis by root resection may explain the high failure rate of this treatment procedure in our analysis. But it should be noted, that the number of teeth treated with root resection in this evaluation is too small to allow a comparison with other studies. However, in the present study these teeth have the highest failure rate in the maintenance phase (40%).

Beneficial effect of periodontal therapy

Various clinical trials investigated the progression of periodontal disease and tooth loss in untreated patients (Becker et al. 1979, Löe et al. 1986, Harris 2003). Harris (2003) studied 30 patients with untreated periodontitis over a mean period of 2.1 years. The rate of tooth loss in relation to the observation period was 0.32 teeth/patient/year, 3% of all teeth and 5% of the molars present at the time of initial diagnosis were lost. The percentage of extracted non-molar and molar teeth (2.8% and 14.1%, respectively) in our study is clearly higher for molars, but our observation period is four times longer compared with the study of Harris. In the present investigation a total of 108 non-molar or molar teeth were extracted during APT and SPT. The tooth mortality, based on all individuals and the follow-up of 107 months added up to 0.17 teeth/patient/year. The mean loss of molars per patient during the SPT was 0.06 teeth/year which matches with the annual tooth mortality in the SPT described by other authors (Checchi et al. 2002: 0.07 teeth/year; König et al. 2002: 0.07 teeth/year). Löe et al. (1986) evaluated the progression of periodontal disease in a group of 490 male labourers at tea plantations in Sri Lanka who had never been exposed to dental care. At the age of 46 years an average of 21.8 teeth were present (excluding third molars). Unfortunately, the authors did not further specify between molars and non-molar teeth. Patients considered for our study had a mean age of 46 years and exhibited an average of 24.7 teeth (excluding third molars) at the beginning of periodontal therapy. After the observation period the number of teeth decreased to 23.5 per patient which represents still a clearly better result compared with the numbers reported in untreated patients.

In contrast to the observations in untreated patients we could demonstrate that periodontal therapy results in a beneficial effect for the prognosis of teeth particularly for molars which is in accordance with data in the literature (Ross & Thompson 1980, Checchi et al. 2002).

Survival rates of molars in relation to FI

As 16 of the total 19 extracted third molars displayed no FI the decision for extraction of these teeth was basically not related to FI but substantiated by other factors like degree of periodontal destruction, occlusal contact, and strategic value. Hence, the survival rates of molars in relation to the degree of FI were calculated excluding third molars. Molars with an FI of degree III at the start of active therapy had a significant inferior survival rate compared with the other molars. In particular the upper molars showed a noticeable inferior prognosis compared with lower molars. Molars with FI of degrees I and II had a comparable prognosis to teeth without FI after active periodontal therapy.

McGuire & Nunn (1996) evaluated retrospectively the influence of different clinical parameters on the survival prognosis of teeth, including FI assessed after completion of active periodontal therapy. They described that teeth with degrees II and III FI had a statistically significant inferior survival rate over the averaged follow-up of 9.97 years (with a maximum of 16 years). In accordance with the current study no significant differences regarding survival rate could be observed between teeth without FI and degrees I and II FI during the first 5 years of SPT. After 5 years the survival curve of teeth with degrees II FI separated from the FI 0 and FI I curves and molar survival of degree II FI became statistically significantly worse than that of degrees 0 and I FI (McGuire & Nunn 1996). In contrast to the study of McGuire and Nunn we did not find a deterioration of the survival rate of molars with degree II FI after 5 years compared with FI degree 0 and I. This observation may be due to difference in furcation assessment in both studies. Whereas McGuire and Nunn categorized molars according to the FI assessment at the beginning of the SPT

we measured FI at the beginning of the APT or if possible intra-surgically. Thus, a gain of attachment in the furcation area achieved by periodontal therapy might be responsible for the good prognosis of molars with degree II FI observed in this study.

Almost half of all extracted molars were lost in a group of only 11 patients (15.5% of all patients). But the number of extracted non-molar teeth in this group was clearly smaller (16.2% of the totally extracted non-molar teeth). However, overall periodontal therapy seemed to be less successful in this patient group indicating a patient dependent influence. Hirschfeld & Wassermann (1978) and McFall (1982) in their analysis took into consideration that patients respond differently to periodontal treatment. Besides the kind of periodontitis (chronic or aggressive periodontitis), systemic (e.g. diabetes mellitus) and individual factors (smoking, stress) have an impact on the treatment outcome. However, these criteria have only been considered for the small group of 'down hill' patients in this study. Patients in this group had a slightly higher median PCR (22.6%) compared with all patients (21.3%). The group included comparatively more active smokers, former smokers, and patients with aggressive periodontitis.

Prognostic factors

Most patients contributed more than one molar to the sample investigated in this study. Thus, a multi-level event-time regression analysis using a patient-specific γ distribution for shared frailty was used to account for within-subject dependencies. This analysis revealed further patient and tooth-specific factors deteriorating the prognosis of molars. Degree III FI influenced the retention time of molars most negatively. This observation reflects the results in the literature that molars with FI are lost more frequently than other teeth (Hirschfeld & Wassermann 1978, McFall 1982, Goldman et al. 1986, Wang et al. 1994). Moreover, depending on the extent of baseline bone loss less molar survival may be expected. However, this is an observation that may be made for teeth in general (Papapanou & Wennström 1991, Svärdstrom et al. 2000, Kaltschmitt et al. 2005). Smoking as measured by packyears as well as older age emerged as negative impact on the retention time of molars in agreement with other studies (König et al. 2002, Fardal et al. 2004). This observation confirms the unfavourable impact of smoking on periodontal stability.

Conclusions

Within the limitations of the present study we may draw the following conclusions: (i) overall periodontal therapy results in a good prognosis of molars for at least 5 years. (ii) Degree III FI leads to a significant deterioration of prognosis particularly in maxillary molars. (iii) Beyond FI smoking, baseline bone loss, and number of molars left influence the survival of molars.

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References

Al-Shammari, K. F., Kazor, C. E. & Wang, H. L. (2001) Molar root anatomy and management of furcation defects. *Journal of Clinical Periodontology* **28**, 730–740.

Armitage, G. C. (1999) Development of a classification system for periodontal diseases and conditions. *Annals of Periodontology* **4**, 1–6.

Becker, W., Berg, L. & Becker, B. E. (1979) Untreated periodontal disease. A longitudinal study. *Journal of Periodontology* **50**, 234–244.

Blomlöf, L., Jansson, L., Appelgreen, R., Ehnevid, H. & Lindskog, S. (1997) Prognosis and mortality of root-resected molars. *International Journal of Periodontics and Restorative Dentistry* **17**, 190–201.

Carnevale, G., Pontoriero, R. & Di Febo, G. (1998) Long-term effects of root-resective therapy in furcation-involved molars. *Journal of Clinical Periodontology* **25**, 209–214.

Cattabriga, M., Pedrazzoli, V. & Wilson, T. G. (2000) The conservative approach in the treatment of furcation lesions. *Periodontology 2000* **22**, 133–153.

Checchi, L., Montevecchi, M., Gatto, M. R. A. & Trombelli, L. (2002) Retrospective study of tooth loss in 92 treated periodontal patients. *Journal of Clinical Periodontology* **29**, 651–656.

DeSanctis, M. & Murphy, K. G. (2000) The role of resective periodontal surgery in the treatment of furcation defects. *Periodontology 2000* **22**, 154–168.

Eickholz, P. (1995) Reproducibility and validity of furcation measurements as related to class of furcation invasion. *Journal of Periodontology* **66**, 984–989.

Eickholz, P. & Hausmann, E. (1999) Evidence for healing of class II and class III furcations 24 months afther guided tissue regeneration therapy: digital subtraction and clinical measurements. *Journal of Periodontology* **70**, 1490–1500.

Eickholz, P. & Kim, T. S. (1998) Reproducibility and validity of the assessment of clinical furcation parameters as related to different probes. *Journal of Periodontology* **69**, 328–336.

Eickholz, P., Kim, T. S., Holle, R. & Hausmann, E. (2001) Long-term results of guided tissue regeneration therapy with non-resorbable and bioabsorbable barriers. I. Class II furcations. *Journal of Periodontology* **72**, 35–42.

Eickholz, P. & Staehle, H. J. (1994) The reliability of furcation measurements. *Journal of Clinical Periodontology* **21**, 611–614.

Fardal, Ø., Johannessen, A. C. & Linden, G. J. (2004) Tooth loss during maintenance following periodontal treatment in a periodontal practice in Norway. *Journal of Clinical Periodontology* **31**, 550–555.

Fleischer, H. C., Mellonig, J. T., Brayer, W. K., Gray, J. L. & Barnett, J. D. (1989) Scaling and root planing efficacy in multirooted teeth. *Journal of Periodontology* **60**, 402–409.

Goldman, M. J., Ross, I. F. & Goteiner, D. (1986) Effect of periodontal therapy on patients maintained for 15 years or longer. A retrospective study. *Journal of Periodontology* **57**, 347–353.

Hamp, S.-E., Nyman, S. & Lindhe, J. (1975) Periodontal treatment of multirooted teeth. Results after 5 years. *Journal of Clinical Periodontology* **2**, 126–135.

Harris, R. J. (2003) Untreated periodontal disease: a follow-up on 30 cases. *Journal of Periodontology* **74**, 672–678.

Helldén, L. B., Elliot, A., Steffensen, B. & Steffensen, J. E. M. (1989) The prognosis of tunnel preparation in treatment of class III furcations. A follow-up study. *Journal of Periodontology* **60**, 182–187.

Henderson, R. & Oman, P. (1999) Effect of frailty on marginal regression estimates in survival analysis. *Journal of the Royal Statistical Society* **B61**, 367–379.

Hirschfeld, L. & Wasserman, B. (1978) A long-term survey of tooth loss in 600 treated periodontal patients. *Journal of Periodontology* **49**, 225–237.

Jepsen, S., Heinz, B., Jepsen, K., Arjomand, M., Hoffmann, T., Richter, S., Reich, E., Sculean, A., Gonzales, J. R., Bodecker, R. H. & Meyle, J. (2004) A randomized clinical trial comparing enamel matrix derivates and membrane treatment of buccal class II furcation involvement in mandibular molars. Part I: study design and results for primary outcomes. *Journal of Peridontology* **75**, 1150–1160.

Kalkwarf, K. L., Kaldahl, W. B. & Patil, K. D. (1988) Evaluation of furcation region response to periodontal therapy. *Journal of Periodontology* **59**, 794–804.

Kaltschmitt, J., Pretzl, B. & Eickholz, P. (2005) Langzeitergebnisse 10 Jahre nach parodontaler

Therapie. 2. Zahnbezogene Faktoren. *Deutsche Zahnärztliche Zeitschrift* **60**, 211–214.

König, J., Plagmann, H. C., Rühling, A. & Kocher, T. (2002) Tooth loss and pocket probing depths in compliant periodontally treated patients: a retrospective analysis. *Journal of Clinical Periodontology* **29**, 1092–1100.

Lang, N. P., Cumming, B. & Löe, H. (1973) Toothbrushing frequency as it relates to plaque development and gingival health. *Journal of Periodontology* **44**, 396–405.

Langer, B., Stein, S. D. & Wagenberg, B. (1981) An evaluation of root resections. A ten-year study. *Journal of Periodontology* **52**, 719–722.

Little, L. A., Beck, F. M., Bagci, B. & Horton, J. E. (1995) Lack of furcal bone loss following the tunneling procedure. *Journal of Clinical Periodontology* **22**, 637–641.

Löe, H., Anerud, A., Boysen, H. & Morrison, E. (1986) Natural history of periodontal disease in man. Rapid, moderate and no loss of attachment in Sri Lankan laborers 14 to 46 years of age. *Journal of Clinical Periodontology* **13**, 431–445.

Loos, B., Nylund, K., Claffey, N. & Egelberg, J. (1989) Clinical effects of root debridement in molar and non-molar teeth. A 2-year follow-up. *Journal of Clinical Periodontology* **16**, 498–504.

McClain, P. K. & Schallhorn, R. G. (2000) Focus on furcation defects – guided tissue regeneration in combination with bone grafting. *Periodontology 2000* **22**, 190–212.

McFall, W. T. (1982) Tooth loss in 100 treated patients with periodontal disease. A long-term study. *Journal of Periodontology* **53**, 539–549.

McGuire, M. K. (1991) Prognosis versus actual outcome: a long term survey of 100 treated periodontal patients under maintenance care. *Journal of Periodontology* **62**, 51–58.

McGuire, M. K. & Nunn, M. E. (1996) Prognosis versus actual outcome. III. The effectiveness of clinical parameters in developing an accurate prognosis. *Journal of Periodontology* **67**, 666–674.

Newell, D. H. (1998) The diagnosis and treatment of molar furcation invasions. *The Dental Clinics of North America* **42**, 301–337.

Nordland, P., Garrett, S., Kriger, R., Vanooteghem, R., Hutchens, L. H. & Egelberg, J. (1987) The effect of plaque control and root debridement in molar teeth. *Journal of Clinical Periodontology* **14**, 231–236.

O'Leary, T. J., Drake, R. B. & Naylor, J. E (1972) The plaque control record. *Journal of Periodontology* **43**, 38–39.

Papapanou, P. N. & Wennström, J. L. (1991) The angular bony defect as indicator of further alveolar bone loss. *Journal of Clinical Periodontology* **18**, 317–322.

Pontoriero, R., Lindhe, J., Nyman, S., Karring, T., Rosenberg, E. & Sanavi, F. (1989) Guided tissue regeneration in the treatment of furcation defects in mandibular molars. A clinical study of degree III involvement. *Journal of Clinical Periodontology* **16**, 170–174.

Pontoriero, P. & Lindhe, J. (1995) Guided tissue regeneration in the treatment of degree III furcation defects in maxillary molars. *Journal of Clinical Periodontology* **22**, 810–812.

Ross, I. F. & Thompson, R. H. (1980) Furcation involvement in maxillary and mandibular molars. *Journal of Clinical Periodontology* **51**, 450–454.

Rüdiger, S. G. (2001) Mandibulary and maxillary furcation tunnel preparations – literature review and case report. *Journal of Clinical Periodontology* **28**, 1–8.

Sanz, M. & Giovandoli, J. L. (2000) Focus on furcation defects: guided tissue regeneration. *Periodontology 2000* **22**, 169–189.

Schei, O., Waerhaug, J., Lovdal, A. & Arno, A. (1959) Alveolar bone loss as related to oral hygiene and age. *Journal of Periodontology* **30**, 7–16.

Svärdström, G. & Wennström, J. L. (1996) Prevalence of furcation involvements in patients referred for periodontal treatment. *Journal of Clinical Periodontology* **23**, 1093–1099.

Svärdström, G. & Wennström J, . L. (2000) Periodontal treatment decisions for molars: an analysis of influencing factors and long-term outcome. *Journal of Periodontology* **71**, 579–585.

Topoll, H. H. & Lange, D. E. (1987) Die Tunnelierung mehrwurzeliger Zähne Ergebnisse 8 Jahre post operationem. *Deutsche Zahnärztliche Zeitschrift* **42**, 445–449.

Wang, H. L., Burgett, F. G., Shyr, Y. & Ramfjord, S. (1994) The influence of molar furcation involvement and mobility on future clinical periodontal attachment loss. *Journal of Periodontology* **65**, 25–29.

Zappa, U., Grosso, L., Simona, C., Graf, H. & Case, D. (1993) Clinical furcation diagnosis and interradicular bone defects. *Journal of Periodontology* **64**, 219–227.

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Clinical Relevance

Scientific rationale for this study: Furcation involved molars are reported to respond less favourably to periodontal therapy and are at greater risk for tooth loss compared with molars without FI or single-rooted teeth. This study aims to evaluate our own patient pool and to identify prognostic factors for molar survival.

Principal findings: Baseline degree III FI leads to a significant deterioration of prognosis particularly in maxillary molars. Beyond FI smoking, baseline bone loss, tooth type, and number of molars left are predictors for molar survival.

Practical implication: Overall periodontal therapy results in a good prognosis for molars.