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A 30-year retrospective cohort outcome study of periodontal treatment of stages III and IV patients in a private practice

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Abstract

Aim: Tooth loss studies show that periodontal treatment is effective. However, it is not known whether these results can be projected into a lifetime of treatment. The aim of the study was to study all patients with stages III/IV of periodontitis over 30 years in a private practice.

Materials and Methods: All patients referred between 1986 and 1990 were monitored for 30 years for tooth loss and prognostic factors. All dropouts were accounted for.

Results: In all, 386 patients were followed, of whom 283 patients dropped out, leaving 103 patients (67 females and 36 males, average age 40.1 years) monitored over 30 years. Tooth loss was stable until 16 years, when the population was divided into groups of low ($n = 65$), moderate ($n = 18$) and high ($n = 20$) tooth loss, losing 1.05 (SD 1.27), 4.83 (SD 0.96) and 11.90 (SD 4.25) teeth, respectively. The strongest prognostic factors were first-degree relatives with periodontitis, periodontal treatment before the age of 35 years, diabetes and patients with teeth with initial hopeless prognosis.

Conclusion: The majority of patients with stages III and IV periodontitis could be successfully treated with conventional periodontal treatment over a period of 30 years. The findings suggest that retrospective studies with shorter observation times cannot automatically be projected onto the outcome of a lifetime of periodontal treatment.

KEYWORDS

advanced periodontitis, periodontal treatment, prognostic factors, retrospective study, tooth loss

Clinical Relevance

Scientific rationale for study: Little is known about the lifelong treatment of patients with stages III and IV periodontitis.

Principal findings: The majority of patients treated over 30 years were stable, but a minority lost many teeth after 15–20 years.

Practical implications: Treatment may not succeed in preventing tooth loss in a minority of patients. The prognostic factors and features described should be helpful for early detection in an attempt to avoid major treatment complication. It is important to monitor all patients through their lifetime for changes in their periodontal conditions.

1 | INTRODUCTION

The ultimate goal of periodontal treatment is to keep the patients' teeth for life. It has been reported that the average age for patients referred for periodontal treatment is approximately 46 years (Fardal et al., 2004). The average lifespan in Western countries is just over 80 years, so a lifetime of treatment comprises at least 30 years.

A review of tooth loss studies by Chambrone et al. (2010) showed that the proportion of patients who lose teeth is low over many years of follow-up and that a number of variables are associated with tooth loss, especially age, smoking and initial tooth prognosis. However, the certainty of the evidence is limited by the study design and the lack of prospective data. The standard of the methodology was a major issue in the review, with only 8 out of 527 eligible papers reaching medium methodological quality. Patient selection, inclusion criteria, inadequate reporting on dropouts and considering too few prognostic factors have been problematic and added to the heterogeneity of the studies (Fardal et al., 2022). In addition, it is not clear whether the outcomes and prognostic factors reported can be projected into a lifetime of periodontal treatment.

A number of quality assurance studies from the same periodontal practice setting have reported on the outcomes, cost of periodontal and implant therapy as well as patients' behaviour, habits and inputs. Data from these studies have also been verified against the National Health big data (Fardal et al., 2022). The studies showed that patients referred for periodontal treatment were apprehensive about their pending treatment even if the treatment caused low levels of discomfort. The patients had a high compliance with maintenance therapy and tooth loss over 10 years was low, except for a minority of patients who showed high tooth loss and implant complications. Periodontal treatment was more cost effective than prosthetic tooth replacements, and it was more costly to maintain implants than teeth. In addition to the prognostic factors identified in the systematic review, male gender, using calcium channel blockers and first-degree family members with a history of periodontal disease were also reported in these studies (Chambrone et al., 2010; Fardal, 2006; Fardal et al., 2003; Fardal et al., 2012; Fardal et al., 2013; Fardal et al., 2016; Fardal et al., 2022; Fardal & Grytten, 2013, 2014; Fardal & Linden, 2005, 2008, 2010; Fardal & Lygre, 2015; Fardal & McCulloch, 2011; Fardal, Skau, & Grytten, 2020).

Screening all the patients for inclusion from the start of this practice, documenting the dropouts and focusing on the patients who received treatments for more than 30 years would provide unique information about the nature, outcomes and prognostic factors of a lifetime of periodontal and implant treatments in patients with stages III and IV periodontitis.

The aim therefore was to study the patients from the start of the practice to investigate tooth loss with the duration of the maintenance treatment. The hypothesis is that it is possible to monitor patients over a 30-year period in a private practice, even though the number of dropouts will be substantial. Furthermore, it is possible to maintain most of the patients' teeth over a long period, but the proportion of patients losing teeth will increase with time.

2 | MATERIALS AND METHODS

2.1 | Study population

All the patients included in the present study were from a specialist practice in periodontics located in the south-western part of Norway. The specialist practice was established part-time in the late 1986 and gradually built up to full-time practice over a 3 to 4-year period. The practice receives referrals from general dental practitioners, community dentists and physicians in Norwegian rural communities with a total population of 25,000–30,000. The area has approximately 25 dentists split evenly between private practice and the community dental service. The primary investigator (ØF) is a specialist certified by the Norwegian Department of Health and Care Services and is the only periodontal specialist in the area. The next nearest specialist is located more than 1 h away by car or public transport.

There are 71 periodontists in Norway. They perform nearly 70% of the surgical periodontal therapy for the entire population. This suggests that general dentists ($n = 2833$) refer the most advanced cases to the periodontists (Fardal, Skau, Rongen, et al., 2020). The present study was therefore performed on stages III and IV periodontitis patients, as it was unlikely that the specialist practice would reflect a true patient population by including stages I and II.

All patients with an initial diagnosis of the equivalent of periodontitis stages III and IV during the period between 1986 and 1990 were studied (Papapanou et al., 2018). The following parameters were used to establish stages I–IV: interproximal radiographic bone loss at worst site (mesial or distal), stage I < 15%, stage II 15%–33% and stage III/IV > 33%. In addition, to adjust the diagnosis for complexity, pocket depth ≥6 mm, presence of degree II or III furcation involvement and the presence of ≥3-mm-deep intrabony defect were used. The worst parameter/site was used to determine the stage.

The diagnosis was supplemented by Grades A, B and C based on the ratio between the percentage of radiographic bone loss and patient age (Grade A <0.25; Grade B 0.25–1.0; Grade C >1.0).

The extent of disease was determined by the number of teeth showing clinical attachment loss divided by the total number of teeth (generalized >30%; localized <30%).

2.2 | Study design/variables

The following were recorded at the initial examination: ethnic background (North Europeans or others); oral, periodontal and X-ray examinations to establish the equivalent of the present periodontitis stages (III and IV) and grades (A,B and C); age at initial examination; number of observation-years; age at final examination; number of teeth at the initial examination; gender; close relatives with periodontitis (parents, children, siblings) (Fardal, Skau, & Grytten, 2020); previous periodontal treatment (age); medical history; initial smoking (≥10 cigarettes); and symptoms—bleeding on brushing, sensitivity, gingival discomfort/pain,

loose teeth, halitosis, bad taste and food impaction. Smoking was assessed only at the initial examination because of the difficulties in assessing the effects of patients increasing, decreasing, stopping or possibly starting smoking again during the observation period.

Following the initial examination, a diagnosis and a treatment plan was made. The initial treatment plan consisted of active periodontal treatment (APT) including control of individual biofilm and risk factors (step 1) as well as non-surgical (step 2) or, if required, surgical (step 3) treatment.

At the assessment stage after the initial treatment, the following were recorded: case diagnosis and the prognosis of individual teeth (uncertain, poor or hopeless). Individual tooth prognosis was determined according to Fardal et al. (2004) as follows:

- Uncertain prognosis: Residual pocket depths 4–6 mm; proximal bone loss of one-third to two-thirds of normal bone height; inflammation of the tissues with bleeding on probing; furcation involvement not exceeding grade II.
- Poor prognosis: Residual pocket depths ≥7 mm; proximal bone loss of more than two-thirds of normal bone height; inflammation of the tissues with bleeding on probing; furcation involvement at least class II if present; horizontal mobility of up to 1 mm.
- Hopeless prognosis: Pocket depths ≥9 mm; inflammation of the tissues with bleeding on probing; horizontal mobility of ≥1 mm with apical depressibility; furcation involvement III if present.

The furcation classification was according to Hamp et al. (1975).

The diagnosis, the treatments performed and the individual tooth prognosis were communicated to the referring dentist with a plan for a shared maintenance therapy, usually 2–4 times a year. The maintenance therapy was performed as previously described by Fardal et al. (2004). Briefly, during each maintenance visit, scaling, root planing and polishing of teeth were routinely performed according to the needs of each patient. Individual radiographs were taken as needed with a full-mouth periapical series after 7–8 years. Minor occlusal adjustments were performed as necessary. The interval between recall visits was shortened or lengthened as appropriate according to the stability of the periodontal condition. During the maintenance period, sites with increasing probing depth were treated with repeated scaling and root planing. Subsequently, if there were clinical signs of residual subgingival calculus or persistent inflammation, surgical intervention was performed.

During the maintenance treatment, the following were recorded: the number of re-treatments, systemic antibiotics (types and numbers of courses), compliance (complete: compliant with the prescribed maintenance programme; erratic: patients not compliant regarding the frequencies of maintenance visits or leaving and returning for re-treatment/maintenance treatment), construction of dental bridges, removable dentures, placement of implants, peri-implantitis, loss of implants and average level of oral hygiene (good, moderate and poor). Oral hygiene was assessed by the clinician at each maintenance visit based on the distribution and abundance of plaque (Fardal et al., 2004): The presence or absence of bleeding was determined after running a probe along the wall of the pocket/crevice. The oral health status was determined as follows: good will equate to little or no generalized plaque and no gingival inflammation; moderate will equate to the generalized presence of minor amounts of plaque (not covering more than one third of the buccal/lingual surfaces from the gingival margin) with bleeding on probing, or isolated areas of abundant plaque (covering more than one third of the buccal/lingual surfaces) with bleeding on probing; poor will equate to generalized abundant plaque (covering more than one third of the buccal/lingual tooth surfaces) with bleeding on probing. The scores were recorded at every maintenance visit and the overall oral health status was the majority score.

Tooth loss was recorded longitudinally from the initial examination until the end of the study. Tooth loss was specified as total tooth loss and tooth loss due to periodontal diseases.

The dropouts were recorded with lengths of observation and reasons for the discontinuation. The patients who were monitored for 30 years underwent a population association assessment with the dropout population. The following variables were used: age, gender, initial number of teeth, smoking and the number of years in maintenance.

2.3 | Specific focus on the patients who were maintained for at least 30 years

- Tooth loss: The patients were divided into groups of low (0–3 teeth), moderate (4–6 teeth) and high (≥7 teeth) tooth loss. The average tooth loss due to periodontal reasons for each of these groups was recorded.
- Tooth loss distribution: This was identified according to tooth type and patient categories (low, moderate and high).
- Tooth loss with time: Tooth loss was identified for each of the 30 years of maintenance treatment.
- Change in population profile: The proportions of low, moderate and high tooth loss patients were recorded for each of the 30 years of observation.
- The prognostic factors were examined at (i) the initial examination/initial therapy stage and (ii) during the maintenance treatment. In total, 45 possible prognostic factors were considered (see Tables 4 and 5).
- Predicting tooth loss in the high-loss group: All teeth with uncertain, poor and hopeless prognosis were followed to assess how these teeth coincided with the teeth that eventually were lost. All teeth with initial mobility were also assessed against the teeth that were lost.

The practice philosophy was in general not to remove teeth with uncertain or poor prognosis at the initial therapy but to keep them for as long as possible.

The study was part of a quality control measure to assess and confirm the long-term effects of conventional periodontal therapy for this private practice.

2.3.1 | Ethical approval

The present quality assurance and evaluation project was exempted from approval by the Norwegian Regional Committees for Medical and Health Research Ethics (REC) by the following general statement: 'Quality control/audit is a required part of the health service and is defined as projects, examinations and evaluations with the intension to reveal if the diagnosis and conventional treatment produce the intended results. The quality control/audit must be based on systematic documentation' (Regional Committees for Medical and Health Research Ethics, 2012).

3 | RESULTS

3.1 | Study population

Four-hundred and twenty-five patients were referred to the practice between 1986 and the end of 1990. Of these, 39 patients did not have the diagnosis of stage III or IV or were referred for other reasons, so 386 patients (219 females [56.7%] and 167 males [43.3%]) were included in the study. The average age was 46.2 years (standard deviation 10.9; range 20–87 years). The total number of teeth studied were 8955, that is, on average 23.2 per patient (standard deviation 5.1; range 3–32). One-hundred and seventeen (30.3%) patients were smokers (≥10 cigarettes/day). The average follow-up time was 16.3 years (standard deviation 10.5; range 1–34). Altogether, 103 patients completed ≥30 years of treatment.

3.2 | Dropouts

The reasons for dropping out were as follows: deceased (94 patients), medical problems/institutionalized (55 patients), leaving the area (23 patients), referring dentist taking over the maintenance treatment (65 patients) and unknown reason (46 patients). The average number of observation-years for the dropouts was 11.1 years and for the patients who completed 30 years or more of observations 30.6 years (Table 1). A diagram showing the number of patients versus the number of observation-years is given in Figure 1.

Population assessment between the patients with 30 years or more of observation and the dropouts showed that the proportion of men was higher among the dropouts, as was the mean initial age. The highest proportion of smokers was found among the patients with 30 years or more of observation. This group had also the highest number of initial teeth present (Table 1).

3.3 | Specific focus on the patients who completed 30 years of more of observation

3.3.1 | Tooth loss

The average tooth loss due to periodontal reasons was as follows:

- low-loss patients (0–3 teeth) 1.05 (number of patients = 65)
- moderate-loss patients (4–6 teeth) 4.83 (number of patients = 18)
- high-loss patients (≥7 teeth) 11.9 (number of patients = 20).

This population consisted of only low-loss patients (0–3) up to 10 years. Although 7% of the teeth were lost at 10 years, these were distributed between the patients, but no individual patient lost enough teeth to move from the low-loss group to medium- or high-loss group at this time point. More than 80% of all patients were low-loss patients until 16 years into the study (Figure 2).

3.3.2 | Tooth loss distribution according to tooth type

The low-loss group showed mainly tooth loss in the molar regions, while the high-loss group showed a more even pattern of tooth loss for all types of teeth (Table 2).

3.3.3 | Tooth loss over time

44.5% of the tooth loss occurred in the high-loss group of patients between 16 and 20 years of observation and a further 26.1%

TABLE 1 Population assessments between patients who completed less than 30 years of observation and patients who completed 30 years or more of observation

	Patients with less than 30 years of observation ($n = 283$)			Patients with 30 years or more of observation ($n = 103$)			
Variables	Proportion/mean	Standard deviation	Range	Proportion/mean	Standard deviation	Range	*p*-value
Male	0.46			0.35			.067
Smoker	0.31			0.34			.50
Initial age	48.7	11.0	20–67	40.1	7.5	22–57	<.001
Initial number of teeth	22.2	5.3	3–32	25.9	3.5	5–32	<.001
Number of observation-years	11.1	7.0	1–31	30.6	0.9	30–34	<.001

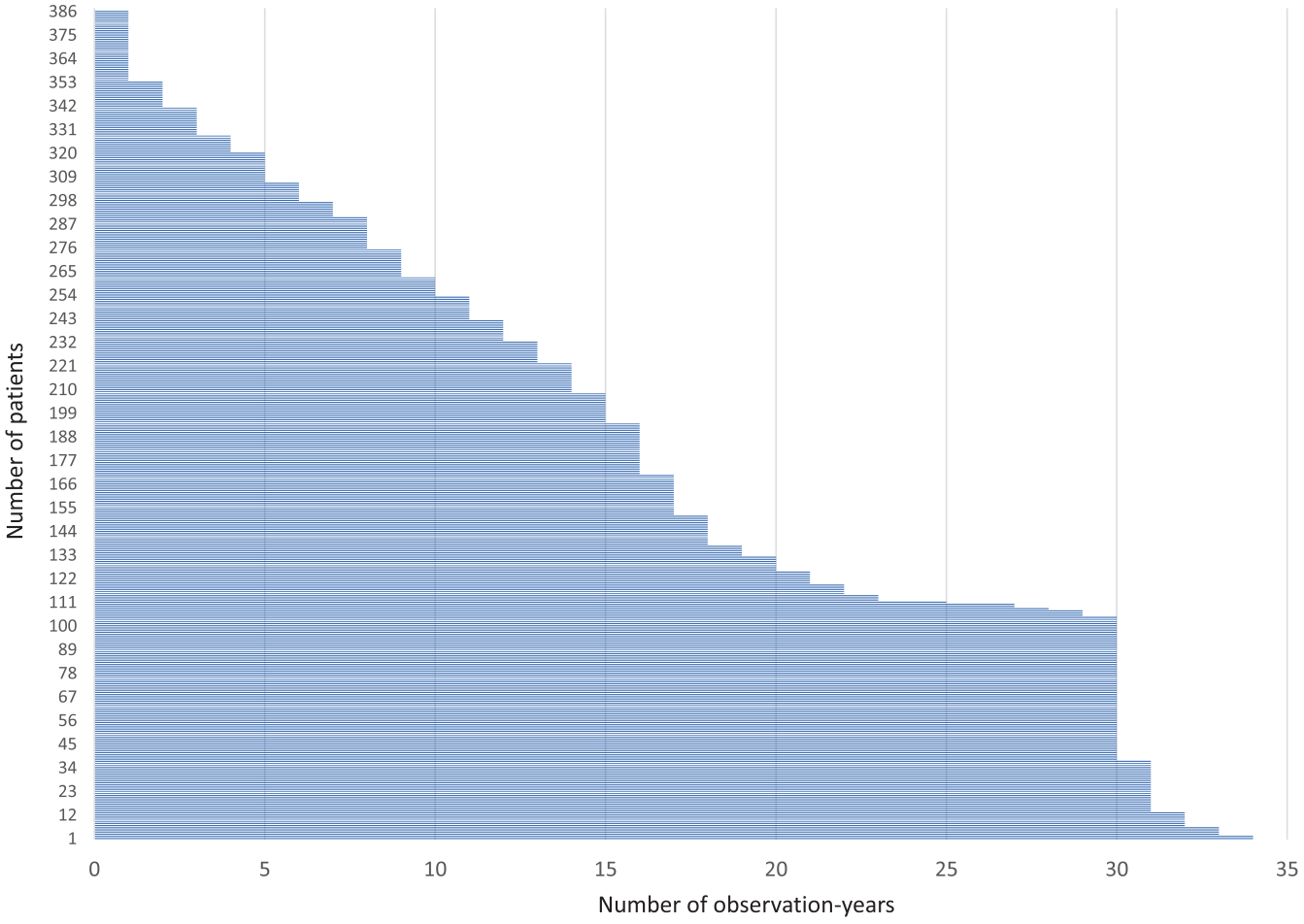

FIGURE 1 Number of patients according to observation-years.

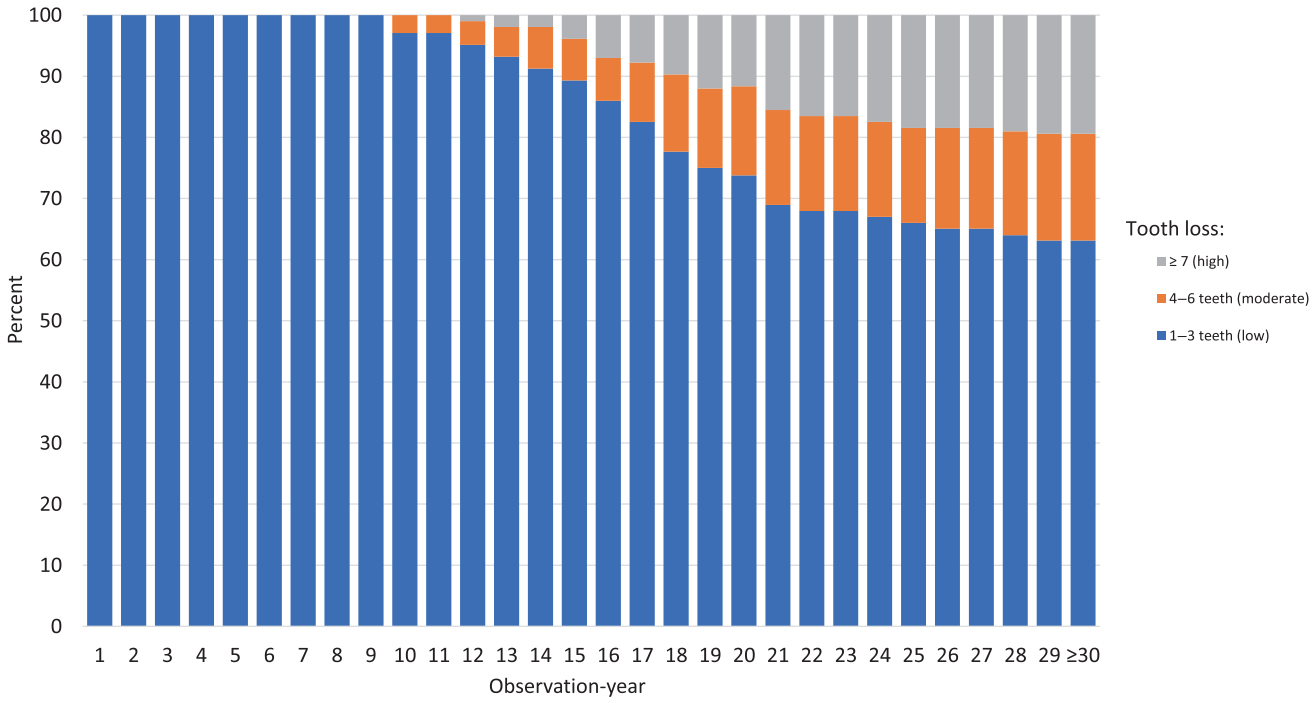

FIGURE 2 The distribution of low, moderate and high tooth loss group of patients versus observation-years. Patients who completed 30 years or more of observation ($n = 103$) in percentage. Changes in patient population.

TABLE 2 Number of teeth lost in the upper and lower jaw.

Number of teeth lost														
Upper jaw														
Tooth loss														
1–3 (low)	10	7	3	3	1	1	1	1	0	1	7	2	4	9
4–6 (moderate)	9	5	2	4	0	0	0	0	1	0	10	4	4	7
≥7 (high)	13	14	12	12	6	10	10	8	10	7	15	10	13	11
Type of tooth lost	7	6	5	4	3	2	1	1	2	3	4	5	6	7
Lower jaw														
Tooth loss														
1–3 (low)	6	4	1	0	0	1	0	0	0	0	0	1	0	5
4–6 (moderate)	7	5	1	1	1	1	3	4	1	1	0	2	7	7
≥7 (high)	14	8	4	1	0	6	8	9	9	0	3	7	8	10

Note: Number of patients according to tooth loss: 1–3 teeth (low) $n = 65$; 4–6 teeth (moderate) $n = 18$; ≥7 teeth (high) $n = 20$. Patients who completed 30 years or more of observation ($n = 103$).

TABLE 3 Distribution of tooth loss according to the number of observation-years.

	Number of observation-years							
	0–10 years		11–20 years		21–30 years		Total	
Tooth loss	Number of teeth lost	Percent	Number of teeth lost	Percent	Number of teeth lost	Percent	Number of teeth lost	Mean tooth loss
≥7 teeth (high)	17	7.1	159	66.8	62	26.1	238	11.90
1–3 teeth (low)	9	13.2	28	41.2	31	45.6	68	1.05

Note: Number of patients according to tooth loss: 1–3 teeth (low) $n = 65$; ≥7 teeth (high) $n = 20$. Patients who completed 30 years or more of observation ($n = 103$).

between 21 and 30 years. For the low-loss group, 45.6% of the tooth loss took place between 21 and 30 years (Table 3)

3.3.4 | Identifying prognostic factors

All tooth loss groups had the same operator over 30 years, the same ethnic background and severity stages III or IV and grades A, B and C. There were only small differences in age at initial examination, number of observation-years and average number of teeth present at the initial examination (Table 4). The proportion of men was lowest in the group with low tooth loss, while there was a more even gender distribution in the other two groups. Seventy percent of the patients in the high tooth loss group had close relatives with periodontitis, making this an important prognostic factor. Another important factor was starting periodontal treatment before the age of 35 years, as was stage III or stage IV at the initial exam. For most of the other prognostic factors identified at initial examination/initial therapy, there were only small differences, with the exception of diabetes 1 and 2, initial smoking and the number of teeth with poor prognosis (Table 4).

Table 5 shows prognostic factors identified during treatment. All patients received non-surgical and surgical therapy. There was no difference in the number of re-treatments, but the use of antibiotics was higher among patients in the high tooth loss group. Antibiotics were used in acute exacerbations of periodontal disease. The types used were in general a reflection of the historical recommendations, beginning early in the study with tetracyclin, rovamycin, doxycillin and metranidazole and up to the more recent combination of amoxicillin and metranidazole.

Receiving prosthetic tooth replacements was most common in the highest tooth loss group, as was peri-implantitis. The average tooth loss per patient per year was almost 0.4 for patients in the highest group compared to 0.16 and 0.03 for the other two groups, respectively. For the other prognostic factors identified during treatment, there were only small differences (Table 5).

3.3.5 | Other reasons for tooth loss

Other reasons for tooth loss were caries ($n = 22$), root fractures ($n = 9$) and endodontic complications ($n = 11$).

4 | DISCUSSION

This is the first retrospective cohort study of periodontal therapy to include all patients at the starting point in a private practice and

TABLE 4 Prognostic factors for low-, moderate- and high-loss group of patients.

Prognostic factors	Tooth loss			
	1–3 (low) ($n = 65$)	4–6 (moderate) ($n = 18$)	≥7 (high) ($n = 20$)	*p*-value
Same operator over 30 years	Yes	Yes	Yes	
Same ethnic background	Yes	Yes	Yes	
Same stages III and IV	Yes	Yes	Yes	
Background characteristics				
Age at initial exam (in years)	39.68	42.00	39.45	.899
Number of observation-years	30.48	30.33	31.00	.037
Age at final exam (in years)	69.97	72.33	69.95	.991
Average number of teeth present at initial exam	26.77	23.28	25.60	.086
Male	0.28	0.50	0.45	.201
Relatives with periodontitis	0.28	0.39	0.70	.005
Treatment of periodontitis started before age 35	0.16	0.28	0.40	.020
Stage III	0.37	0.33	0.15	.134
Stage IV	0.63	0.67	0.85	.054
Grade A	0.08		0.10	.744
Grade B	0.88		0.75	0.171
Grade C	0.05		0.15	0.155
Medical history				
Cardiovascular	0.26	0.44	0.30	.736
Diabetes (1 and 2)	0.02	0.33	0.20	.002
Calcium channel blocker	0.09	0.11	0.15	.466
Smoking initial	0.29	0.39	0.45	.308
Periodontal status				
Teeth with poor prognosis	0.02	0.05	0.08	.152
Patients with teeth with poor prognosis	0.15	0.39	0.35	.047
Teeth with hopeless prognosis	0.002	0.01	0.01	.002
Patients with teeth with hopeless prognosis	0.05	0.11	0.20	.027
Tooth mobility	0.02	0.04	0.06	.438
Teeth with gingival retractions	0.004	0.002	0.000	.778
Patients' symptoms				
Bleeding on brushing	0.63	0.67	0.50	.322
Sensitivity	0.20	0.11	0.15	.619
Gingival discomfort/pain	0.14	0.11	0.20	.499
Loose teeth	0.14	0.06	0.20	.499
Halitosis	0.09	0.06	0.00	.549
Bad taste	0.08	0.11	0.15	.617
Food impaction	0.02	0.00	0.05	.818

Note: Prognostic factors were identified at initial examination/initial therapy. Patients who completed 30 years or more of observation ($n = 103$). Proportions/means.

covering 30–34 years. It shows that it is not possible to follow all patients because of the inclusion criteria and a substantial dropout. The patients followed were initially diagnosed with stages III and IV periodontitis. The results show that it is possible to keep tooth loss at a minimum for over 15 years. Most teeth with initial poor prognosis were maintained for this length of time. This was also reported by Graetz et al. (2011) and Rahim-Wöstefeld et al. (2020). However, after 16–20 years, a number of teeth were lost and the patient population became polarized into low, moderate and high tooth loss groups. Most patients were remarkably stable (0.03 tooth/patient/year), which is the same as reported from the same setting over 10 years of treatment (Fardal et al., 2004). A minority experienced moderate tooth loss

TABLE 5 Prognostic factors for low-, moderate- and high-loss group of patients. Prognostic factors were identified during treatment.

Prognostic factors	Tooth loss 1–3 (low) ($n = 65$)	4–6 (moderate) ($n = 18$)	≥7 (high) ($n = 20$)	*p*-value
Treatment				
Same initial therapy	Yes	Yes	Yes	
Same surgical therapy	Yes	Yes	Yes	
Number of re-treatments	1.83	1.39	1.90	.826
Number of courses of antibiotics	1.69	2.00	4.14	.009
Mucogingival treatment	0.01	0.06	0.00	.763
Systemic antibiotics	0.40	0.33	0.70	.046
Compliance	0.88	0.83	0.70	.067
Prosthetics				
Bridges	0.24	0.44	0.60	.015
Dentures	0.00	0.17	0.50	.001
Implants	0.09	0.17	0.30	.019
Peri-implantitis	0.03	0.00	0.50	.002
Implant failure	0.14	0.00	0.08	.442
Hygiene				
Good	0.37	0.33	0.20	.242
Moderate	0.60	0.61	0.70	.422
Poor	0.03	0.06	0.10	.711
Outcome				
Tooth loss	1.48	5.61	11.9	<.001
Tooth loss due to periodontitis	1.05	4.83	11.9	<.001
Tooth loss per patient per year	0.03	0.16	0.38	

Note: Patients who completed 30 years or more of observation ($n = 103$). Proportions/means.

(0.16 tooth/patient/year), which is the same tooth loss as in the 10-year study when this was projected to 30 years (Fardal et al., 2004). The most concerning finding of this study was the minority of patients (19%) who lost nearly half of their teeth (0.38 tooth/patient/year) over 30 years. The pattern of tooth loss for this group was very different from that of the moderate and low groups. While the latter groups lost mainly premolars and molars, the high-loss group lost nearly the same number of all types of teeth. This may suggest that if tooth loss is not limited to tooth-related factors, it may be that systemic factors (genetics and systemic disease) play an important role.

The present study used a slightly different classification from the one used by Hirschfeld and Wasserman (1978). We used a loss of 7 teeth or more to define the high tooth loss group as opposed to the loss of 12 teeth or more for the extreme downhill group. This was done to better link tooth loss with tooth replacements. We feel that by starting at 7 or more teeth lost, major tooth replacements would be considered, and we therefore did not use the 12 teeth or more category. However, when the patients in the present study were re-classified according to the Hirschfeld and Wasserman classification, the tooth loss and pattern of tooth loss were very similar as in their study as well as in the study by McFall Jr. (1982).

The success of treating molars with furcation involvements has previously been reported by Svärdström and Wennström (2000) and Salvi et al. (2014). The latter study reported that furcation involvements 2 and 3, lack of maintenance and smoking were risk factors for molar loss.

Tooth loss other than from periodontitis was most often due to caries, endodontic complications and root fractures. This is similar to the findings of Axelsson et al. (2004), except that they reported that root fracture was the most common cause of tooth loss.

The fact that these patients did not lose many teeth until 16–20 years into the treatment can make long-term treatment planning unpredictable. It is thus important to identify these patients as early as possible to avoid treatment complications and added costs to the patients. It has, however, been shown that it is difficult to predict increased risk of tooth loss for patients with aggressive periodontitis (Meyer-Bäumer et al., 2012).

In the present study, a total of 45 possible prognostic factors were examined both initially and during treatment in an attempt to

find predictive factors that could be useful in identifying the high-loss patients. For most factors, there were no or only small differences between the tooth-loss groups. There were, however, some strong indicators: Diabetes 1 and 2 and having teeth with an initial poor prognosis. In addition, the combination of having first-degree relatives with a history of periodontitis and receiving periodontal treatment before the age of 35 occurred only in the high tooth loss group. The diabetic connection has been well documented (Preshaw et al., 2012), as well as a having a high susceptibility to periodontitis at baseline (Rosling et al., 2001). In addition, a strong genetic influence has previously been reported from the present setting (Fardal, Skau, & Grytten, 2020). It is, however, important to keep in mind that some patients would have developed systemic diseases such as diabetes during the observation period and this would have influenced the outcome.

The prognostic factors identified during treatment were not predictive, as the events had already taken place. They only describe features that were different between the low- and high-loss groups. The most marked differences were receiving removable dentures and a high level of peri-implantitis. Related to this, it has been shown that being an abutment tooth is a risk factor for tooth loss (Müller & Schimmel, 2010; Pretzl et al., 2008). A high level of peri-implantitis has also been reported by Schou et al. (2006), Fardal and Linden (2008) and Fardal et al. (2013). No higher failure rate of implants for the high-loss group was observed. This is in contrast to a systematic review by Monje et al. (2014). In the present setting, the maintenance treatment may have had a protective effect on the diseased implants.

All types of prosthetic replacements were significantly higher in the high-loss group. An interesting clinical observation was that the patients who received stabilizing bridges lost virtually no more teeth in the areas covered by these. The success of stabilizing bridges in periodontally affected patients has also previously been reported from the present practice setting (Fardal & Linden, 2010) and also by Nyman and Lindhe (1979) and Graetz et al. (2013).

Interestingly, the number of re-treatments, compliance or oral hygiene levels were not different between the high and low tooth loss patients.

It would be highly desirable to identify the individual high-loss patient as early as possible. Ideally, this should be possible at the initial therapy, 15–20 years before the major tooth loss. The other important challenge would be to predict exactly which teeth are going to be lost. This is why we followed all teeth with uncertain, poor and hopeless initial prognosis over 30 years to assess how well the initial prognosis coincided with the teeth that were eventually lost. The majority of teeth that were later lost did not have sufficient initial periodontal changes to receive other than good initial prognosis. The problem of predicting individual tooth loss has previously been described (Fardal et al., 2016; McGuire, 1991; Petsos et al., 2020). In addition, by increasing the period, one is making a prognosis for, the more likely it is to fail since conditions, patients and knowledge change with time.

Staging and grading at baseline were not significant in predicting tooth loss over 30 years; however, as this classification is dynamic and will pick up periodontal changes ahead of tooth loss, it should be a very valuable prognostic factor when used over time.

From a clinical standpoint, it is important to continuously monitor all patients to identify changes which may suggest that previously stable periodontal conditions are no longer stable.

There are a number of limitations associated with this study.

1. The involvement of only one clinician is a strength of the study design. However, it also means that the results are dependent on one clinician's skills and competence. It is possible that other single or multiple clinicians could have obtained different results. For example, a much lower tooth loss has been reported in a study of over 25 years (Bäumer et al., 2020). However, this was a study with different inclusion criteria, and no data were provided for the rest of the patient population. In addition, the present study's philosophy of not removing questionable teeth at the initial stage is an important variable to be considered when comparing the results with those of other studies.
2. Even though the patients were observed for more than 30 years, some of these patients will survive for several more years. It may not be correct to present these results as a 'lifetime of treatment' for all the patients.
3. The 30-year 'survival' population may not be representative for all the patients treated. Although due care was taken to document the dropouts and compare the two populations, there were some differences such as initial age and initial number of teeth. It seems, however, to be in the nature of the study that some patients had to start treatment at a younger age to complete the 30 years of treatment. The fact that the older patients had fewer teeth could also be a result of the age differences. Gender and the proportion of smokers were not significantly different. While the parameters reported do not identify major differences compared with the 30-year group, there might be important systematic differences such as better/worse treatment response, which might bias the results. In addition, the number of patients who were followed up for exactly 30 years constitutes the largest group, whereas other follow-up periods form equally sized smaller groups. This may also bias the results.
4. As the numbers are not high, it is likely that individual prognostic factors exert only small effects. With the high heterogeneity of treatment responses, identifying signal from noise will always be difficult from this type of study. Therefore, it is important to acknowledge the distinct possibility that lack of a statistical effect does not rule out the possible impact of the prognostic factors.
5. Social class and educational status were not included. The Norwegian society have relatively small differences in social class. The educational system is based on completion up to university level for all citizens. Compared with other countries, it is thus difficult to use social class and educational level in Norway as determinants for long-term tooth loss.

6. Only data on smoking status at the initial examination were analysed. Smoking status was collected at every visit during the maintenance treatment. However, during the 30 year period, some patients could have decreased, increased, stopped, started smoking again and used cigarette replacements with or without nicotine. Analysing the effects of these changes on tooth loss for each patient over such a long period was beyond the scope of this study.

5 | CONCLUSION

Most patients with stages III and IV periodontitis can be treated successfully with conventional periodontal treatment over a period of 30 years. The patients were remarkably stable during the first 10–15 years of observation. However, after this time the patient population profile changed and revealed a minority of patients who lost many teeth. It is still not clear why in a group of patients who had virtually the same initial features and received the same treatments, some will lose many teeth.

The present findings suggest that the results of retrospective studies of shorter than 30 years may not automatically be projected to the outcomes of a lifetime of periodontal treatment.

AUTHOR CONTRIBUTIONS

Øystein Fardal made substantial contributions to the conception, design of the work, acquisition, analysis and interpretation of data, as well as drafting the paper and revising it critically for important intellectual content. Irene Skau and Jostein Grytten made substantial contributions to interpretation of the data for the work and revising the manuscript critically for important intellectual content. All authors gave final approval of the version to be published. They all agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings will be available by contacting the first author Prof. Øystein Fardal.

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