# Variables affecting tooth survival and changes in probing depth: a long-term follow-up of periodontitis patients

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### Abstract

**Aim:** To retrospectively assess tooth-survival rate and its association with patient and oral variables in periodontal office patients, followed up to 18 years.

**Material and Methods:** Patients in a private periodontal office whose files included initial examination ($T_0$), reevaluation ($T_{Re}$) and ≥10 years after $T_0$ ($T_F$) chartings, and received periodontal therapy and supportive periodontal therapy (SPT) after $T_{Re}$ were included. General health, plaque scores (PI), probing depth (PPD), bleeding on probing (BOP) at six points/tooth, tooth extractions, and SPT visits were extracted from patient files at $T_0$, $T_{Re}$, and $T_F$. Descriptive statistics and Cox regression analysis were performed.

**Results:** Fifty patients (mean 26 ± 4 teeth/patient, 1301 teeth) fulfilled inclusion criteria. About 20 and 129 teeth respectively were extracted before/after $T_{Re}$, 96 of them for periodontal causes. PPD>7 mm at $T_{Re}$ (HR = 17.7, 95%CI 8.6, 36.6), age above 60 years (HR = 3.3, 95%CI 1.5, 7.2), multi-rooted teeth (HR = 1.9, 95%CI 1.2, 3.1) and SPT<3 times/year (HR = 1.8, 95%CI 1.1, 2.9), were the best prognostic factors for tooth loss during follow-up. ($p < 0.05$, Cox regression analysis). A continuous, statistically significant reduction was observed in mean PPD among teeth that survived follow-up [4.3 ± 1.8 mm, 3.5 ± 1.4 mm, 3.2 ± 1.3 mm, at $T_0$, $T_{Re}$, $T_F$, respectively. ($p < 0.001$, Repeated-measures test)].

**Conclusion:** Regular SPT was associated with low tooth-loss rates and continuous reductions in probing depth. PPD after initial therapy, age above 60, multi-rooted teeth and infrequent SPT were strong negative prognostic factors for long-term tooth survival among periodontal patients.

The ultimate goal of periodontal therapy is to preserve teeth by

resolving the inflammatory process and arrest disease progression. Therefore, tooth survival/tooth loss, and factors that are associated with it, are of great interest in longitudinal reports of periodontal therapy. Several long-term studies reporting tooth survival were published since the 1970's (Hirschfeld & Wasserman 1978, Becker et al. 1979, McFall 1982, Goldman et al. 1986, Papapa-

nou et al. 1989, Tonetti et al. 2000, Eickholz et al. 2008, Matuliene et al. 2010). These studies report tooth loss during periods ranging from 6 months to 53 years in patients from different geographical locations, which were treated in different settings, (such as university clinics, private periodontal specialist clinics), with various reimbursement systems (such as national insurance

programs, private insurance programs and pay per service).

Tooth survival has been associated with a multitude of factors. These include local periodontal and dental conditions, patient factors such as age, gender, systemic health, environmental factors such as socioeconomic status, (Ismail et al. 1990, Beck et al. 1997a, Machtei et al. 1999, Albandar & Rams 2002, Thomson et al. 2004, Burt 2005). Most of the recent studies report on tooth survival in patients from university clinics (Tonetti et al. 2000, Eickholz et al. 2008, Matuliene et al. 2010). However, quality of dental care and extent of data collection in private practice settings around the world are probably different from those that exist in academic institutions. Relatively few publications from private practices are available (Fardal et al. 2004, Chambrone & Chambrone 2006), which may provide the dental practitioner with field information that may aid in treatment planning.

Therefore, the aim of the present retrospective study was to evaluate long-term tooth survival and associated factors, in patients treated and maintained in a private periodontal practice. Secondary outcome variables included changes in probing depth, bleeding on probing and plaque score.

## Material and Methods

This study is a retrospective observational study.

The dental records of patients attending a private periodontal practice were screened. All patients were examined throughout the entire study period by the same periodontist (JH). An initial database of patients whose records included a periodontal initial examination ($T_0$), and a final examination at least 10 years later ($T_F$) was prepared. From this database, only patients whose records also included a reevaluation visit after cause-related therapy ($T_{Re}$) were included in the final database (Fig. 1). No other inclusion/exclusion criteria were used for patient selection. Patients were examined at $T_0$ clinically and radiographically, diagnosed and received a treatment plan that consisted of initial therapy, including oral

hygiene instructions and motivation, and scaling and root planing. Patients that were additionally diagnosed with caries, defective restorations and/or endodontic conditions were referred back to their referring dentist for dental treatment. Some teeth were extracted as part of the initial phase of therapy. The decision to extract was individually tailored according to patients' needs. Extractions were performed when teeth were deemed irrational to treat due to extensive loss of periodontal support, extensive carious lesions or fractures (e.g. vertical root fracture). Initial therapy was performed in 2–6 appointments as necessary. After completion of this phase patients were reevaluated ($T_{Re}$) and a treatment plan was proposed, which included repeated root planing and/or surgical therapy as necessary, followed by supportive periodontal therapy (SPT). Patients were then charted, re-examined and treatment planned approximately every 1–2 years. Two time periods were evaluated: Initial therapy period ($T_0 - T_{Re}$) and follow-up period ($T_{Re} - T_F$).

$T_0$ examinations included recordings of pocket probing depth (PPD) at six sites per tooth. Later, bleeding on probing (BOP) at six sites and one plaque score per tooth (PI) (Löe 1967) were added to yearly examinations. For the present study

the following data were collected from

1 **Baseline ($T_0$)**: Probing depth, age, gender, general health status, medications associated with gingival side effects – calcium channel blockers, phenytoin, cyclosporine (Pihlstrom et al. 1980, Lucas et al. 1985, Seymour & Jacobs 1992), Smoking status (smoker/non-smoker), Periodontal diagnosis (Armitage 1999).
2 **Reevaluation after initial therapy ($T_{Re}$)**: Probing depth, Number of extracted teeth during initial therapy and the cause of extraction [periodontal/non-periodontal (carious, endodontic, restorative, other causes)].
3 **Last recorded clinical charting and evaluation ($T_F$)**: Probing depth, BOP, PI, Number of extracted teeth between $T_{Re}$ and $T_F$ and the cause of extraction.

### Statistical analysis

Data were tabulated in a computerized database (Microsoft Office Excel Version 14.0, Microsoft Corporation, Redmond, WA, USA).

Statistical analysis was performed using SPSS (Statistics Products Solutions Services) 21.0 software for Windows (IBM North America, New York, NY, USA). Two-tailed $p$
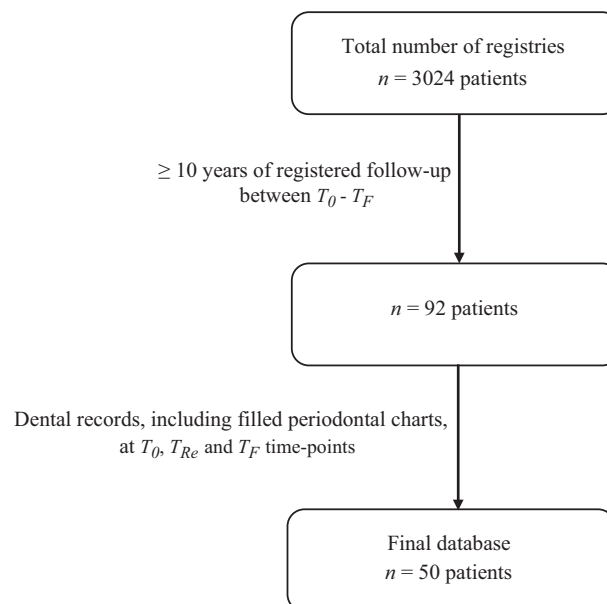


*Fig. 1.* Final database formation flowchart.

values of 0.05 or less were considered as statistically significant.

Data from $T_0$, $T_{Re}$, and $T_F$ and changes that occurred during initial therapy and follow-up were analysed.

Correlation between putative factors influencing tooth loss and further multivariate analysis model were assessed using Cox regression analysis:

- Bivariate Cox regression was used for the calculation of the Hazard risks (HR) with 95% confidence intervals (CI) and $p$ values.
- Multivariate Cox Regression analysis was performed to assess the relation between patients' characteristics and outcomes.

All variables with a $p$ value of 0.2 in bivariate analyses were selected as candidates for the multivariate analysis.

Comparison of PPD subgroup differences was calculated using chi-squared test.

Changes in mean PPD throughout the study were compared with repeated-measures test.

## Results

### Patient-related data

The initial database consisted of 3024 registries, which included all the patients that attended the periodontal practice, regardless of the number of their visits. Since the majority of patients returned to the referring dentists for maintenance therapy, only 92 patients, who were identified as having been diagnosed, treated, and maintained with a minimum of 10 years between their first and last recorded visit were initially identified. A total of 42 patients were excluded due to lack of sufficient data (mainly due to lack of $T_{Re}$ record), the final database included 50 patients. Male/female ratio was 38%/62% (19/31). Mean age at admittance was 46.6 ± 10.6 years (range 27–70). The mean follow-up period was 12.7 ± 2.1 years (range 8.3–18.3, median 12.3 years) (Table 1).

Nine patients (18%) were smokers, one patient reported taking calcium channel blockers and five patients (10%) took anticoagulant

medications. Six patients (12%) reported having cardiovascular diseases, no diabetes was reported.

All patients were diagnosed at $T_0$ with Chronic Periodontitis, (Armitage 1999).

### Tooth loss

At baseline ($T_0$) a total of 1301 teeth were present with a mean 26 ± 3.97 teeth/patient (range 14–32). Twenty teeth (1.5%) were extracted during the initial therapy. Out of 1281 teeth left, a total of 129 teeth (10%) were extracted during follow-up, of which 96 were extracted due to periodontal causes. This amount to 7.5% cumulative periodontal tooth loss rate during follow-up ($T_{Re}$ – $T_F$). Tooth loss rate per patient per year, due to periodontal causes, was 0.16. No tooth loss during follow-up was observed in fifteen patients (30%).

Patients were grouped according to data from $T_{Re}$ versus $T_F$ -

Well-maintained: lost 0–3 teeth; Downhill: lost 4–9 teeth; Extreme downhill: lost 10 or more teeth (Hirschfeld & Wasserman 1978).

Thirty-five patients were classified as 'well-maintained', 11 patients were classified as 'downhill' and only four patients as 'extreme downhill'.

Five teeth were excluded from survival rate calculations, due to lack of extraction date.

According to Fardal & Grytten (2014), tooth-years lost provides a more accurate way of measuring long-term tooth loss. Tooth years and tooth years lost were calculated from the numbers of years the teeth were present from initial examination

until they were lost (Fardal & Grytten 2014).

Mean maximum tooth years possible in the present study were 326 ± 78, (range 136–546); Actual tooth years – mean 284 ± 81, (range 93–464); Mean number of tooth loss years – 42 (12.9%).

### Periodontal variables

#### Probing depth

For a tooth level analysis the deepest probing depth for each tooth was chosen. The distribution of PPD groups at various time points ($T_0$, $T_{Re}$, $T_F$) and the changes in their proportions are presented in Table 2. Probing depths were further subdivided into shallow, moderate and deep PPD (1–3 mm, 4–6 mm and ≥7 mm, respectively). Among teeth that survived the follow-up period, 89.3% of teeth with deep PPD at $T_0$ became shallower at $T_F$. At the same time 93.9% of shallow pockets at $T_0$ remained shallow at $T_F$ ($p < 0.001$, Chi-squared test).

Mean PPD for the retained teeth became significantly shallower during the study period from 4.29 ± 1.8 at $T_0$, to 3.53 ± 1.4 at $T_{Re}$, to 3.2 ± 1.3 at $T_F$ ($p < 0.001$, repeated-measure test).

#### Plaque Index and Bleeding on Probing

Mean PI was calculated for each patient. Data were subdivided into three groups of low, moderate and high mean PI (<1; 1–1.5; >1.5, respectively). The majority of patients (88%) presented with a moderate Mean PI (Table 2). BOP rate was calculated for each patient. Forty-eight patients (96%) presented

*Table 1.* Patient-related data

| Characteristics | $n = 50$ |
|---|---|
| Mean follow-up ± SD (years) | 12.7 |
| Range of follow-up (years) | 8.3–18.3 |
| Male/Female percent (*n* patients) | 38% (19)/62% (31) |
| Mean Age ± SD (years) at $T_0$ | 46.6 ± 10.6 |
| Age range (years) | 27–70 |
| Smoking status at $T_0$ (Yes/No) | 18% (9)/82% (41) |
| SPT (times per years) | |
| ≥3 | 38% (19) |
| 2–3 | 26% (13) |
| 1–2 | 22% (11) |
| <1 | 14% (7) |

SD, standard deviation; SPT, supportive periodontal treatment.

*Table 2.* Teeth-related data

| | $T_{Re}$ $n = 1276$ teeth | $T_F$ $n = 1153$ teeth |
|---|---|---|
| Tooth type | | |
| Single-rooted | 72% (925) | |
| Multi-rooted | 28% (351) | |
| Probing depth (mm) | | |
| 1–3 | 63% (803) | 70% (897) |
| 4–6 | 29% (367) | 17% (222) |
| ≥7 | 8% (106) | 3% (34) |
| Plaque Index* | | |
| <1 | | 46% (588) |
| 1–1.5 | | 43% (544) |
| >1.5 | | 9% (116) |
| Bleeding on Probing | | |
| <11% | | 77% (986) |
| 11%–15% | | 21% (262) |
| >15% | | 2% (28) |

*Based on 1248 teeth, after exclusion of 28 teeth (one patient), due to missing data.

less than 15% BOP score (Table 2). PI and BOP were only available at $T_F$ examination.

### SPT-related data

Supportive periodontal therapy (SPT) rate was calculated by dividing the number of SPT appointments by follow-up time (the time between $T_{Re}$ and $T_F$). The majority of patients (32 out of 50) received two or more SPT per year and could be classified as periodontally compliant and well maintained (Table 1).

### Factors associated with tooth loss

Tooth loss association with various factors was examined (Table 3):

- Tooth type: Tooth loss was compared between multi-rooted (molars) and single-rooted (incisors, canines, pre-molars) teeth. A significant difference in favor of single rooted teeth (3.6% single rooted *versus* 17.9% multi-rooted) was found, with a Hazard risk of 5.6 (95%, CI 3.7–8.5), for multi-rooted tooth to be extracted ($p < 0.001$, Cox regression analysis).
- Patient characteristics: Of all patient-related data collected in the present study only age was found to be significantly correlated with tooth loss. The extraction rate, due to periodontal reasons among patients aged <40 years at admittance was 4.4%. This proportion increased

to 8.8% among patients aged 40–59 years, and to 13.9% in the age group of ≥60. The hazard risks were 2.2 (95%, CI 1.4–3.7) and 3.8 (95%, CI 1.8–8.0) respectively, with $p$ value <0.001 and 0.002 respectively (Cox regression analysis). No association was found between age groups and PPD, BOP and PI parameters. No association was found between smoking status at $T_0$ and extraction rate.

- Periodontal variables: Hazard risk (HR) for tooth extraction was evaluated in association with PPD. A direct correlation was found between PPD at $T_{Re}$ and the risk for tooth loss. About 11.7% of teeth with moderate pockets and 37.7% of teeth with deep pockets were extracted, their HR for extraction being HR = 5.3 (95%, CI 2.5–11.4) and HR = 14.6 (95%, CI 8.0–26.3), respectively ($p < 0.001$, Cox regression analysis). No significant correlations were found between mean BOP and mean PI at $T_F$ and tooth loss during follow-up.
- SPT frequency: With the exception of patients who attended SPT less than once a year, a trend of an inverse association between SPT rate and tooth loss rate was observed (Table 3).

### Proportional hazards model

Probing depth at $T_{Re}$ combined with low rate of SPT attendance and age

≥60 years at admittance were highly prognostic of tooth loss. (Cox regression analysis, see Table 4).

### Discussion

In the present study 7.5% of teeth were lost (due to periodontal reasons) during 8–18 years follow-up, which amounts to 0.16 teeth/patient/year. Previously, Becker et al. (1979) reported 7.7% tooth loss after 10 years among untreated periodontitis patients. Similarly, in another retrospective 22 years study (Hirschfeld & Wasserman 1978) of 600 periodontal treated patients, tooth loss was 7.1%, with a mean loss of 1.8 teeth per patient. More recently, several studies have re-visited this issue: Eickholz et al. (2008) reported loss of 0.15 teeth/patient/year in a university setting and Rieder et al. (2004) reported a loss of 0.11–0.18 teeth/patient/year among patients treated in a private practice. A mean tooth loss of 0.11 teeth/patient/year, reported by Martin et al. (2010) in a study which gathered data from nine different periodontists. However, lower rates of tooth loss were found by Chambrone & Chambrone (2006) who reported 1.8% tooth loss during a 10 year follow-up and by Fardal et al. (2004) reporting 1.5% cumulative tooth loss rate during 9–11 years of follow-up, also performed in private practice settings. Chambrone et al. (2010) in a systematic review of tooth loss (>5 years follow-up) reported ranges of between 1.5% and 9.8%.

Age at admittance to periodontal treatment was found to be strongly associated with tooth loss, especially among patients older than 60. With an adjusted HR = 3.3 (CI 1.54–7.15), these results were consistent with Fardal et al. (2004), who showed an adjusted OR of 4.02 (CI 1.35–11.35) for tooth loss among patient aged above 60 years old.

Multi-rooted teeth were at a higher risk (HR = 5.6, 95%, CI 3.7–8.5) to be extracted. This finding is supported by previously reported data by König et al. (2002) and others (Akhter et al. 2008, Tsami et al. 2009).

Mean PPD of teeth, excluding extracted teeth, exhibited a continuous reduction throughout the study (4.29 ± 1.83; 3.53 ± 1.44; 3.2 ± 1.3

*Table 3.* Tooth loss correlation to different factors – general results and due to periodontal disease

| Parameter | Extraction rate total | | | Extraction rate due to periodontal disease | | |
|---|---|---|---|---|---|---|
| | | HR (95%, CI) | *p*-value | | HR (95%, CI) | *p*-value |
| Age | | | | | | |
| <40 | 7% | | | 4.4% | | |
| 40–59 | 10.8% | 1.7 (1.2, 2.6) | 0.008 | 8.8% | 2.2 (1.4, 3.7) | 0.002 |
| 60+ | 15.2% | 2.8 (1.5, 5.3) | 0.002 | 13.9% | 3.8 (1.8, 8.0) | <0.001 |
| Smoking at $T_0$ | 13% | | 0.18 | 7.8% | | >0.2 |
| Tooth type | | | | | | |
| Single-rooted | 5% | | | 3.6% | | |
| Multi-rooted | 22.2% | 5 (3.4, 7.2) | <0.001 | 17.9% | 5.6 (3.7, 8.5) | <0.001 |
| Probing depth at $T_{Re}$ (mm) | | | | | | |
| 1–3 | 3% | | | 1.6% | | |
| 4–6 | 15.5% | 3.9 (2.1, 7.3) | <0.001 | 11.7% | 5.3 (2.5, 11.4) | <0.001 |
| 7+ | 40.6% | 9.2 (5.8, 14.5) | <0.001 | 37.7% | 14.6 (8.0, 26.3) | <0.001 |
| SPT (times per years) | | | | | | |
| ≥3 | 7.1% | | | 5.1% | | |
| 2–3 | 11% | 1.7 (1.0, 2.7) | 0.02 | 7.8% | | 0.07 |
| 1–2 | 10.8% | 1.6 (1.0, 2.6) | 0.05 | 9.8% | 2 (1.2, 3.4) | 0.01 |
| <1 | 12.9% | | 0.2 | 10.4% | | 0.14 |

HR, hazard risk; CI, confidence interval.

*Table 4.* Proportional hazards model – Predictors of tooth loss

| Parameter | Extractions total | | Extractions due to periodontal disease | |
|---|---|---|---|---|
| | HR (95%, CI) | *p*-value | HR (95%, CI) | *p*-value |
| Multi-rooted teeth | 2 (1.3, 3.0) | 0.002 | 1.9 (1.2, 3.1) | 0.01 |
| Probing depth at $T_{Re}$ (mm) | | | | |
| 4–6 | 3.4 (2.1, 5.5) | <0.001 | 5.7 (2.9, 10.9) | <0.001 |
| 7 + | 9.2 (5.3, 16.1) | <0.001 | 17.7 (8.6, 36.6) | <0.001 |
| SPT < 3 times per years | 1.7 (1.2, 2.6) | 0.008 | 1.8 (1.11, 2.8) | 0.02 |
| Age at $T_0$ | | | | |
| >60 | 2.5 (1.4, 4.8) | 0.008 | 3.3 (1.5, 7.2) | 0.002 |

for $T_0$, $T_{Re}$, $T_F$ respectively). This phenomenon was statistically significant ($p < 0.001$, repeated-measures test). 73.9% of moderate pockets and 89.3% out of deep pockets were improved during the follow-up period, whereas only 6.1% and 2.3% of shallow and moderate pockets, respectively, became deeper between $T_0$ and $T_F$. A similar trend was reported by König et al. (2002) who found that the average proportion of teeth with PPD>6 mm dropped from 21.8% to 2.7% and the percentage of teeth with PPD<4 mm increased from 17% to 64.4% after 8 years follow-up. In this report 60% of teeth with deep pockets at $T_{Re}$ were still present at $T_F$. This would be interpreted as a relatively high long-term survival rate of teeth, even when they present with deep initial PPD (Machtei & Hirsch 2007). Over time, periodontally maintained patients seem to have higher rates of shallow (≤3 mm) pockets and attachment level gain (Costa et al. 2012). A similar finding was seen in a study by Miyamoto et al. (2006) conducted in a private practice, who showed a reduction in the percentage of >3 mm periodontal pockets among highly compliant patients compared to erratic compliers.

Supportive periodontal therapy did not show significant correlation with tooth loss. Likewise, Chambrone & Chambrone 2006 and Fardal et al. 2004 failed to demonstrate such association. A possible explanation for this phenomenon is that in the present patient group the frequency of periodontal maintenance was individually tailored to each patient and thereby may have influenced tooth survival. It should be noted that these patients were highly compliant to their SPT regiment. Interestingly, five patients received less than 1 SPT/year, nevertheless they had no extractions during the observation period. This may be an incidental finding but may also be explained by the low prevalence (3%) of deep PPD among them, which compared to the rest of the patients who exhibited approximately 10% deep PPD. Based on retrospective studies, patients' adherence to SPT had a profound, long-term effect on periodontal stability. This was expressed as higher tooth survival rates (Checchi et al. 2002, Chambrone & Chambrone 2006, Matuliene et al. 2008, Tsami et al. 2009, Costa et al. 2012) and as improvement in surrogate outcomes such as probing pocket depth (PPD), attachment level (AL), bleeding on probing (BOP) and plaque (PI) indices measured at different time points (Renvert & Persson 2002, Carnevale et al. 2007a, Pretzl et al. 2008b).

In a study by Checchi et al. (2002) the risk for tooth loss among patients complying erratically with supportive periodontal therapy was 5.6 times greater than patients who complied with the recommended maintenance schedule. Greater risk for tooth extraction among patients with erratic compliance to supportive periodontal treatment was seen in a 10 years follow-up study in a Greek population published by Tsami et al. (2009). Tooth loss rate, as low as 1.5%, during a mean of 10 years follow-up, was found among patients who underwent comprehensive periodontal treatment, in a periodontal practice in Norway (Fardal et al. 2004).

In most tooth survival studies data were analyzed using the Kaplan–Meier method, which calculates the probability of survival in a given period of time. Its disadvantage is that only a few factors can be considered (dichotomous or categorical), and continuous variables cannot be handled without categorization. Moreover this method cannot be used to measure the impact of a continuous variable on the probability of an event, nor can it definitively quantify the risk of the event according to the value of a

variable. Cox regression analysis (or proportional hazards regression), which was used in the current study, allows additional covariates to be included, thus analysing and taking into account the combined effect of several risk factors on survival.

It is well established that tooth survival is influenced by a combination of different factors, which might have a synergistic effect. Thus Cox regression analysis seems to be a more appropriate tool for analysing risk factors associated with tooth survival.

One of the shortcomings of this study is the lack of PI and BOP at $T_0$ and $T_{Re}$. Although PI and BOP were available only at $T_F$, these indices provide some insight into patients' adherence to SPT and compliance to oral hygiene instructions. While the majority of patients (32 of 50) attended SPT at least twice a year, most of them appeared with moderate to low rates of BOP and PI at their last visit. Smoking was self reported as yes/no bases which might account for the lack of association between this variable and other periodontal variables.

Long-term data on tooth survival and changes in periodontal parameters require extensive documentation followed by statistical analysis, both of which are usually performed in academic settings. This may explain the relative scarcity of data from private periodontal practices. Yet, when available, these data are particularly valuable in extending our knowledge regarding the effect of periodontal therapy on progression of periodontal disease, especially in terms of tooth survival and changes in probing depth.

## Conclusions

Active periodontal therapy followed by regular SPT results in relatively low tooth loss rates and continuous reduction in probing depth.

Probing depth after the initial phase therapy and age at admittance were found as strong prognostic factors for long-term tooth survival among periodontally maintained patients.

## Acknowledgements

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## Clinical Relevance

*Scientific rational for the study*: Recent long-term data on tooth survival and on changes in periodontal parameters, in private periodontal practices, is relatively scarce. These data may be particularly valuable, regarding tooth preservation and treatment effectiveness.

*Principal findings*: Probing depth after initial periodontal therapy, age >60 at admittance, multi-rooted teeth and infrequent SPT were strongly associated with long-term tooth survival among periodontal patients. SPT > 3 times/year was associated with lower tooth loss and reductions in probing depth.

*Practical implications*: High long-term tooth-survival rates and continuous reduction in probing depth, associated with regular SPT, may encourage clinicians to preserve periodontally affected teeth.