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ORIGINAL ARTICLE

Probing pocket depth reduction after non-surgical periodontal therapy: Tooth-related factors

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Abstract

Background: To investigate tooth-related factors that influence the reduction of probing pocket depths (PPD) after non-surgical periodontal therapy (NST).

Methods: Seven hundred forty-six patients with a total of 16,825 teeth were included and retrospectively analyzed. PPD reduction after NST was correlated with the tooth-related factors; tooth type, number of roots, furcation involvement, vitality, mobility, and type of restoration; using logistic multilevel regression for statistical analysis.

Results: NST was able to reduce probing depth overall stratified probing depths (1.20 ± 1.51 mm, $p \leq 0.001$). The reduction was significantly higher at teeth with higher probing depths at baseline. At pockets with PPD ≥ 6 mm, PPD remains high after NST. Tooth type, number of roots, furcation involvement, vitality, mobility, and type of restoration are significantly and independently associated with the rate of pocket closure.

Conclusions: The tooth-related factors: tooth type, number of roots, furcation involvement, vitality, mobility, and type of restoration had a significant and clinically relevant influence on phase I and II therapy. Considering these factors in advance may enhance the prediction of sites not responding adequately and the potential need for additional treatment, such as re-instrumentation or periodontal surgery, to ultimately achieve the therapy end points.

KEYWORDS
multilevel analysis, periodontal debridement, periodontitis

1 | INTRODUCTION

Periodontitis is a chronic multifactorial inflammatory disease associated with dysbiotic biofilms that leads to the destruction of the tooth-supporting apparatus, which may eventually result in tooth loss. Consequently, the ultimate goal of periodontal therapy is the long-term retention of natural teeth.[1] In patients receiving periodontal therapy however, tooth loss is quite rare,[2] which is why surrogate end points such as probing pocket depth (PPD) reduction or pocket closure (PC) are often used in daily practice to predict disease progression and the risk of tooth loss.[3–6] Hence, especially probing depths of periodontal pockets and their reduction resemble critical clinical parameters,

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indicating the necessity, complexity, and success of phase I and II therapy.

Non-surgical therapy (NST) as an initial cause-related therapy is effective in reducing the majority of pockets and should be performed regardless of the stage or grade in advance to additional therapies[4,7–11] to achieve the end points of phase I and II therapy as defined by the current EFP guidelines published in 2020 by Sanz et al.[12] However, NST is technique-sensitive, and clinicians may not be able to debride the entire affected surface of the root.[13–15] According to a recent systematic review by Suvan et al., the mean reduction of initially moderate pockets (4–6 mm) is 1.5 mm, whereas in deep pockets (≥7 mm) a mean reduction of 2.6 mm can be expected.[8] Consequently, inflamed pockets often persist despite thorough subgingival instrumentation.[16] In fact, only one-third of cases show complete disease resolution, while in approximately 70% of cases, residual pockets with a need for further treatment remain.[17] Matuliene et al. further showed that persisting pockets with inflammatory symptoms after initial therapy may predict further progression and tooth loss, eventually.[17]

It has been noticed that success of therapy shows considerable individual differences among both patients, and teeth. There have been identified numerous factors responsible for these differences on the subject and the tooth level.[2,18–21] Besides a few well-known factors at the patient level, several tooth-related factors such as periodontal bone loss,[22,23] furcation involvement (FI),[21,24–28] use as abutment tooth,[21,28,29] tooth type,[25,29–31] tooth mobility,[22,28,32] and tooth vitality[32] were identified to contribute to the risk of tooth loss.

To evaluate the impact of these factors on the prognosis of short-term treatment outcomes and the potential needs for additional therapy after NST, however, clearly, tooth loss is not a reliable parameter. In this context, Tomasi et al. were able to conduct multilevel analyses on some of these factors in a relatively small cohort with regards to PPD reduction and PC as outcome variables and showed a significant influence on primary treatment results for the tooth-related factors: plaque at site level and tooth type.[3] In comparison, D'Aiuto et al. investigated patient, tooth, and site-related factors in 94 patients with regards to PPD reduction followed by NST.[19] In their cohort, tooth mobility had a significant proportional effect as well the type of tooth showed a significant impact on PPD reduction.

Due to partially contradicting and lacking evidence in the literature, the aims of this retrospective study were to assess whether previously identified tooth-related risk factors for tooth loss also have an impact on PPD reduction and PC in a large cohort (1), and if these results could be used to identify predictors for additional therapy, such as periodontal surgery or re-instrumentation after cause-related therapy (2).

2 | MATERIALS AND METHODS

This retrospective clinical trial was approved by the Ethics Committee of the Medical Faculty of the Ludwigs-Maximilians-University, Munich (No. 22-0669) and conducted in accordance with good clinical practice and the principles of the Declaration of Helsinki.

2.1 | Study population

The study included 759 patients, who received phase I and II therapy treatment for the first time upon diagnosis or retreatment according to the diagnosis of recurrent disease following to previous periodontal treatment, between February 2011 and March 2016 in the undergraduate course at the Department of Conservative Dentistry and Periodontology, University Hospital, LMU Munich. The final analysis includes 746 patients with a total of 16,825 teeth. All patients met the following inclusion criteria: 1) aged ≥18 years; 2) diagnosis of periodontitis according to the current classification[33]; 3) a periodontal chart with documentation of PPD and bleeding on probing (BOP) at six sites/tooth, tooth mobility, FI, before and after phase I and II therapy and plaque index before phase I and II therapy; 4) a periodontal chart with documentation of PPDs and BOP at six sites/tooth at reevaluation; and 5) dental examination chart containing the type of restoration and tooth vitality at baseline. The exclusion criteria were: 1) pregnancy at baseline or during the observation period; 2) withdrawal of the consent between the NST and the re-evaluation; 3) previous periodontal treatment <2 years before enrollment into the study, and 4) receiving SPT.

2.2 | Clinical parameters

Periodontal examination has been conducted before active periodontal treatment (baseline, T0) and after an appropriate healing period (re-evaluation T1). Periodontal charts containing at least PPD and BOP and PI at six sites per tooth were included.[34] PPD were measured to the nearest millimeter using a PCP-12 periodontal probe with a trained probing force of ≈ 0.2–0.3 N as proposed by Gabathuler and Hassell.[35] BOP was assigned ≈ 30 s after probing according to van der Weijden et al.[36] Mobility was assessed as described by Miller, assigning each tooth to one of four classes reflecting tooth mobility.[37] FI was measured with a 2N-Nabers probe and graded according to Hamp et al.[38]

PC defined per site, as stated by the current classification, as a PPD of 4 mm in absence of BOP or ≤3 mm.[39] Vitality was tested using a foam pellet sprayed with Endo Ice (1,1,1,2-tetrafluoroethane) and applied on the buccal side of the tooth.[40]

2.3 | Periodontal treatment

Before NST, patients were given detailed information on the etiology, pathogenesis, risk factors, and treatment of periodontitis and were subjected to oral hygiene instructions and professional mechanical plaque removal. Subgingival debridement was performed under local anesthesia at all teeth with PPD > 3 mm using sonic devices in combination with different Gracey curettes (SG5/6, SG7/8, SG 13/14, SG15/16), without limits in time or numbers of visits.[19]

2.4 | Statistical analysis

Data are expressed as mean ± standard deviation (SD) and categorical variables are presented as frequencies (with percentage) unless stated otherwise. The normality of data was tested using Shapiro-Wilk test. Teeth were categorized into three groups (CAT1 = 1–3 mm, CAT2 = 4–5 mm, and CAT3 = > 6 mm) at baseline and re-evaluation using their deepest PPD. Differences between the different tooth-related factors were compared using an analysis of variance (ANOVA) for continuous variables, the Mann-Whitney *U* test or the Kruskal-Wallis test for ordinal and skewed variables, and the Chi-square test for categorial variables. Post hoc pairwise analysis for Kruskal-Wallis test was done using Dunn-Bonferroni Test. For the comparison of PD reduction between different groups, analysis of covariance (ANCOVA) was included in the group as the main factor and the baseline PPD as a covariate to adjust for significant baseline difference. Multivariable logistic regression was used to model PC and potential tooth-related risk factors. Results are shown as odds ratios per 1-unit change with corresponding 95% CIs. The two-sided significance level was set at $\alpha = 0.05$ for all tests. All analyses were performed using the SPSS statistic software.

3 | RESULTS

3.1 | Patient characteristics

Seven hundred fifty-nine patients received phase I and II therapy between February 2011 and March 2016. The final analysis included 746 patients, respectively, 16,825 teeth, who fulfilled the inclusion criteria as mentioned above. Patients' mean age was 57 ± 14 the male-to-female ratio was 53/47 %, 17% were smokers, and 9% had been diagnosed with diabetes mellitus (Table 1). During NST, 109 (15%) of the patients received systemic antibiotics (Table 1).

Out of the 16,825 teeth, 7909 were incisors, 4626 were premolars, and 4290 were molars. The single-rooted to multirooted ratio was 68%/32%, and 16% of the multirooted teeth had FI ≥ 2. Also, 16% presented with a degree of mobility ≥ 1, 52% with restorations (i.e., filling or crown), and 85% tested positive for vitality. At 43% of the teeth showed plaque and 41% of all teeth showed BOP on >2 sites (Table 1).

TABLE 1 Baseline characteristics.

Variable	*n* (%)
Patient	746 (100)
Age, y	57 ± 14
Male	393 (53)
Smokers	127 (17)
Diabetes	70 (9)
Number of teeth	23 ± 6
Systemic antibiotics	109 (15)
Teeth	16,825 (100)
Category at baseline	
PPD 1–3 mm	8516 (50)
PPD 4–5 mm	5328 (32)
PPD ≥6 mm	2981 (18)
Category at re-evaluation	
PPD 1–3 mm	10,727 (64)
PPD 4–5 mm	4302 (26)
PPD ≥6 mm	1796 (11)
Type	
Incisor	7909 (47)
Premolar	4626 (28)
Molar	4290 (26)
Single-rooted	11,445 (68)
Furcation involvement ≥2, multirooted	811 (16)
Mobility	2686 (16)
PI +	7256 (43)
BOP +	6913 (41)
Restoration	
None	8109 (48)
Filling	4711 (28)
Crown	4005 (24)
Vitality +	14,324 (85)

Data are presented in frequencies with %.

Abbreviations: BOP, bleeding on probing; PI, plaque index; PPD, probing pocket depth.

TABLE 2 Site-specific probing depth changes for periodontal pockets.

Factor	PPD BASE	PPD REV	PPD RED
All	5.02 ± 1.32	3.82 ± 1.55	1.20 ± 1.51
Incisor	4.95 ± 1.32	3.57 ± 1.50	1.41 ± 1.52[a]
Premolar	4.90 ± 1.22	3.71 ± 1.48	1.25 ± 1.40[a]
Molar	5.13 ± 1.35	4.07 ± 1.59	1.00 ± 1.55[a]
p	**<0.001**[†‡]	**<0.001**[†‡§]	**<0.001**[a,†‡§]
Single-rooted	4.91 ± 1.27	3.58 ± 1.47	1.37 ± 1.46[a]
Multirooted	5.12 ± 1.36	4.05 ± 1.59	1.02 ± 1.55[a]
p	**<0.001**	**<0.001**	**<0.001**[a]
FI 0/1	5.00 ± 1.31	3.80 ± 1.54	1.21 ± 1.50[a]
FI 2/3	5.45 ± 1.52	4.34 ± 1.76	0.91 ± 1.74[a]
p	**<0.001**	**<0.001**	**<0.001**[a]
Mobility	5.43 ± 1.59	4.03 ± 1.79	1.20 ± 1.78[a]
No mobility	4.87 ± 1.17	3.74 ± 1.45	1.20 ± 1.40[a]
p	**<0.001**	**<0.001**	0.768[a]
No restoration	4.97 ± 1.30	3.61 ± 1.46	1.39 ± 1.51[a]
Filling	5.03 ± 1.31	3.93 ± 1.59	1.09 ± 1.48[a]
Crown	5.06 ± 1.34	3.96 ± 1.59	1.07 ± 1.53[a]
p	**<0.001**[†]	**<0.001**[†‡]	**<0.001**[a,†‡§]
BOP -	4.87 ± 1.27	3.84 ± 1.52	1.01 ± 1.39[a]
BOP +	5.04 ± 1.32	3.81 ± 1.55	1.21 ± 1.53[a]
p	**<0.001**	0.447	**<0.001**[a]
PI -	5.05 ± 1.36	3.72 ± 1.54	1.33 ± 1.54
PI +	5.01 ± 1.30	3.85 ± 1.55	1.16 ± 1.50
p	0.075	**<0.001**	**<0.001**
Vitality +	5.02 ± 1.32	3.81 ± 1.55	1.21 ± 1.51
Vitality -	4.98 ± 1.29	3.85 ± 1.54	1.13 ± 1.49
p	0.084	0.168	**0.004**

Data are presented as mean ± standard deviation.

Abbreviations: BASE, baseline; BOP, bleeding on probing; FI, furcation; PI, plaque index; PPD, probing pocket depth; RED, reduction; REV, re-evaluation.

Bold indicates statistically significant values ($p < 0.05$).

[a]Adjusted for baseline probing depth.

†1 vs. 3 < 0.05; ‡ 1 vs. 2 < 0.05; § 2 vs. 3 < 0.05.

3.2 | Periodontal characteristics at baseline

The mean PPD at baseline was 5.02 ± 1.32 mm and differed significantly among the groups. The following factors were associated with increased PPD at baseline: tooth type (molars), number of roots (multirooted), FI (FI 2/3), restoration (filling or crown), mobility, and BOP (Table 2).

Based on their deepest PPD, all teeth were classified into three different categories (CAT1 = 1–3 mm; CAT2 = 4–5 mm; CAT3 = ≥6 mm). At baseline, 8516 teeth were in CAT1 (50 %), 5328 in CAT2 (32 %), and 2981 in CAT3 (18%) (Figure 1 and see Table S1 in online *Journal of Periodontology*). Incisors, single-rooted teeth, multirooted teeth with FI 0/1, teeth with no degree of mobility, without restoration, and PI and BOP negative were significantly more likely to be in CAT1 initially. Whereas molars, multirooted teeth with FI 2/3, teeth with a degree of mobility, restored teeth, and BOP-positive ones were more frequently distributed in CAT2 and CAT3 (Figure 1 and see Table S1 in online *Journal of Periodontology*).

3.3 | Periodontal characteristics at re-evaluation

3.3.1 | Average PPD reduction

The re-evaluation after 6 months revealed that NST led to a mean PPD reduction of 1.20 ± 1.51 mm (Table 2), however, differed significantly among the groups. Significantly reduced PPDs were associated with the factors: tooth type (premolars and molars), number of roots (multirooted), FI (FI 2/3), restoration (filling or crown), PI (positive), and BOP (Table 2). The factors of vitality and mobility showed no influence on PPD reduction.

Considering only initially moderate pockets of 4-5 mm (CAT2) NST led to a mean PPD reduction of 0.91 ± 1.16 mm, while in initially deep pockets of ≥6 mm (CAT3), a mean reduction of 1.95 ± 1.99 mm was observed (see Tables S2.1 and S2.2 in online *Journal of Periodontology*). Regarding factors associated with less PPD reduction teeth in CAT2 showed the same results as stated for all categories (see Table S3.1 in online *Journal of Periodontology*). In initially deep pockets, however, besides vitality and mobility, also FI and BOP showed no influence on PPD reduction (see Table S3.2 in online *Journal of Periodontology*).

3.3.2 | Categorical PPD reduction

Categorical reduction, measured by the reduction of the deepest pocket, confirms these findings. Across all teeth, there was a significant improvement in pocket categories (see Tables S2.1-2.2 in online *Journal of Periodontology*). Forty-eight percent of teeth changed from CAT2 to CAT1 and 54% from CAT3 to CAT2 and CAT1, $p = 0.001$). At re-evaluation, the factors: tooth type (molars), number of roots (multirooted), FI (FI 2/3), mobility, restoration (filling or crown), vitality (negative), and BOP were associated with residual deep pockets (CAT3). Plaque (positive or negative), however, showed no significant difference in categorical allocation at re-evaluation.

After stratification for the baseline category, it is noticeable that multirooted teeth with FI 2/3 from CAT2 and PI-positive from CAT2 and CAT3 improved less frequently. Teeth from CAT2 and CAT3, with BOP at baseline at

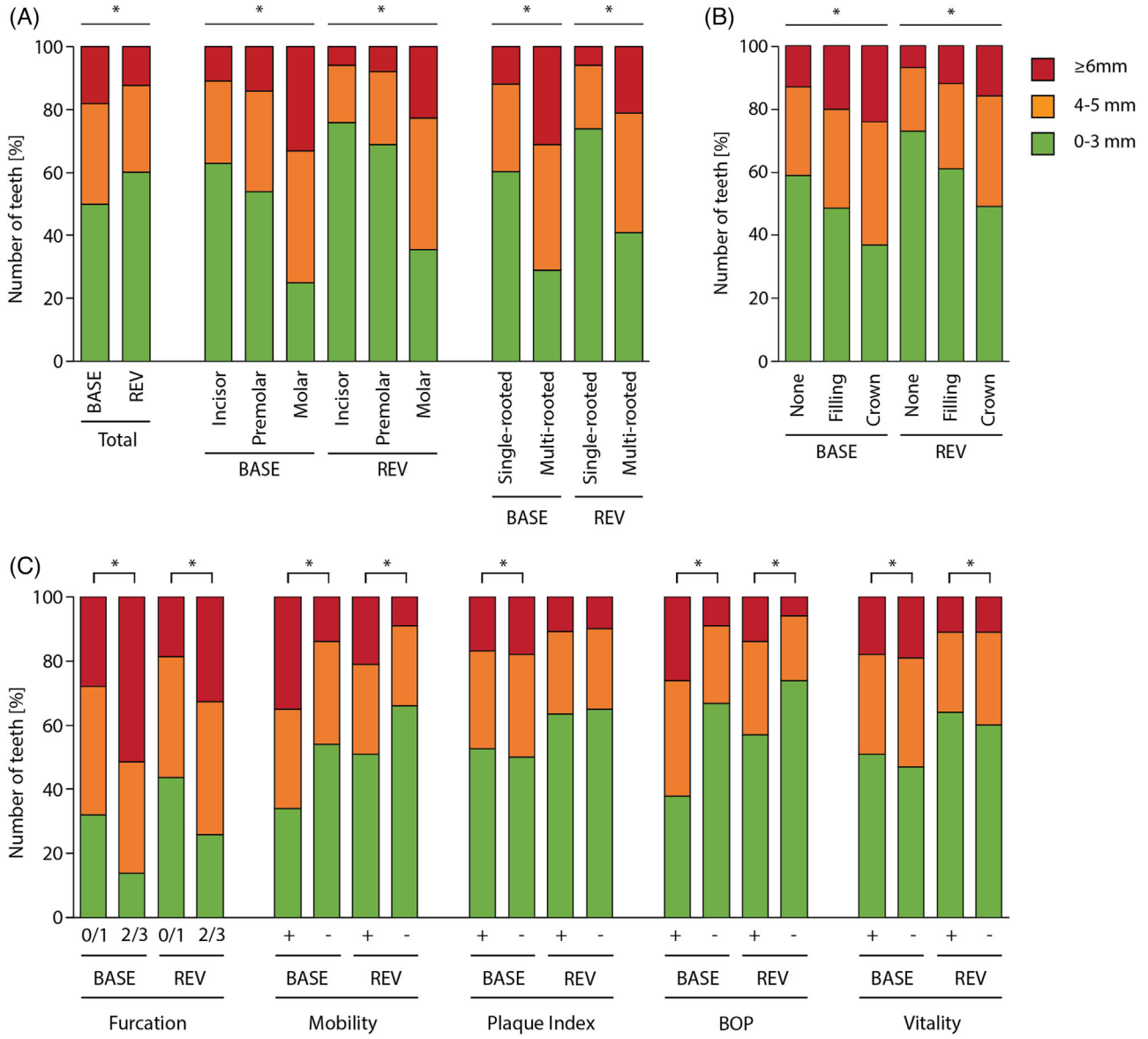

FIGURE 1 Relative probing pocket depth in categories through phase I and II therapy recorded at baseline (BASE) and re-evaluation (REV). Tooth-related factors are differentiated into the groups anatomy (A), restoration (B), and tooth marker (C). BOP (bleeding on probing) CAT1 = 1–3 mm (green), CAT2 = 4–5 mm (orange), and CAT3 ≥ 6 mm (red); n = 16.825, * indicates statistically significant values ($p < 0.05$).

multiple sites, or tested negative for vitality, did not differ in the distribution at re-evaluation (Figure 1 and see Tables S3.1-3.3 in online *Journal of Periodontology*).

3.3.3 | Pocket closure

Besides mean PPD reduction and categorical changes, the rate of PC defined as a PPD ≤3 or 4 mm without BOP was observed.

The mean PC rate was 49%. Initially, moderate pockets (CAT2) were significantly more likely to achieve closure than deep pockets (CAT3). In detail, 62 % of initial 4–5 mm pockets were closed after NST, whereas only 26% of pockets ≥6 mm reached PC ($p \leq 0.001$). The factors, initially deep PPD (CAT3); tooth type (molars and premolars); number of roots (multirooted); FI (FI 2/3); restoration (filling or crown); BOP; and PI (negative) were significantly associated with less PC than their respective control. Mobility and vitality on the other hand showed no significant influence on PC (Figure 2, Table 3, and see Tables S4.1-4.2 in online *Journal of Periodontology*). In fact, multivariable logistic regression confirmed the aforementioned factors, revealing higher chances for PC for initially moderate pockets (odds ratio [OR], 4.1), single-rooted (OR, 1.9), and non-restored teeth (OR, 1.4), no degree of mobility (OR, 1.2), degree 0 or 1 FI in multirooted teeth (OR, 1.3), as well as PI (OR, 1.3). The factors vitality, BOP, and type of

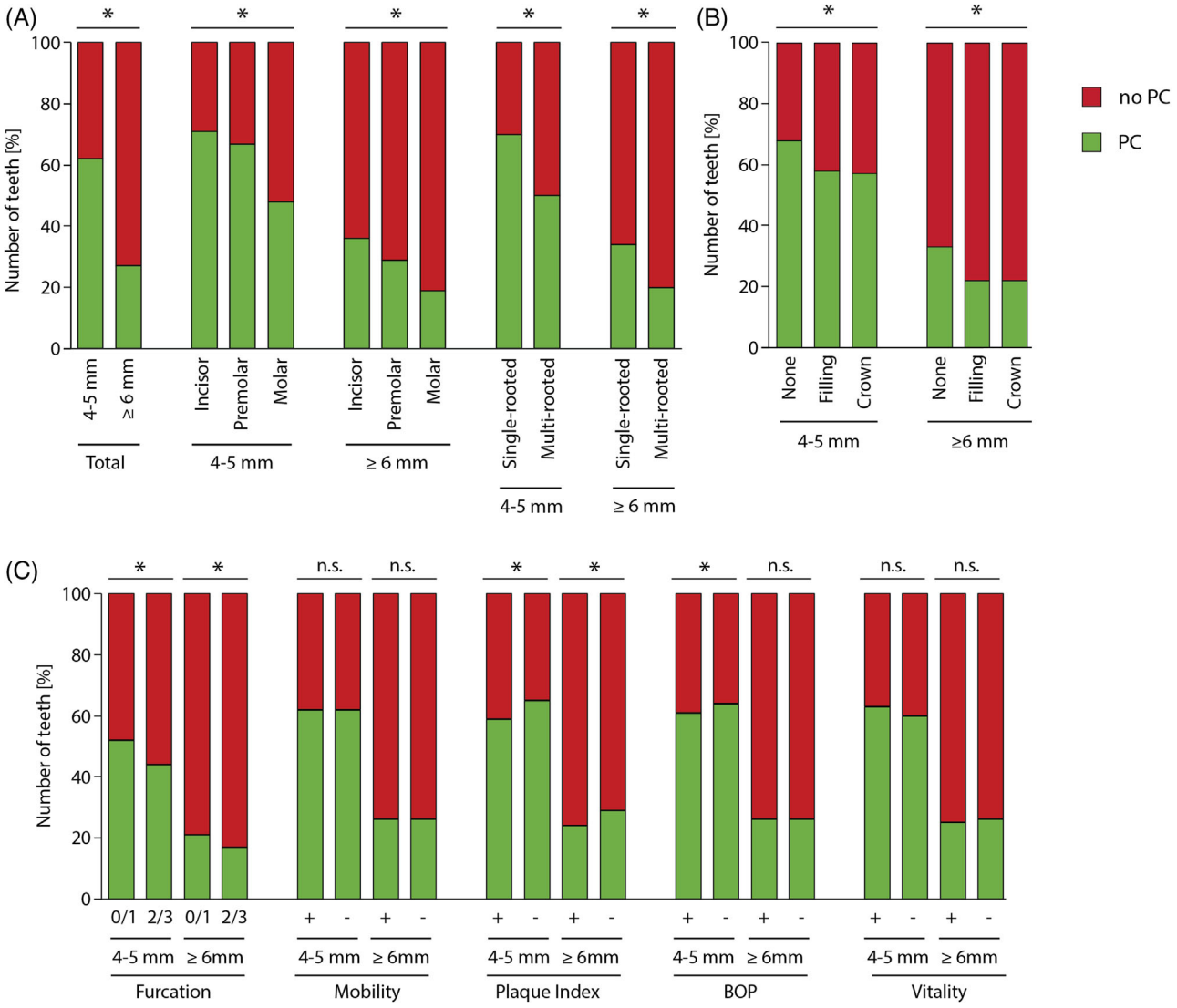

FIGURE 2 Periodontal pocket closure (PC) through phase I and II therapy. PC is defined as probing depth < 4 or 4 mm without bleeding on probing (BOP) at re-evaluation. Tooth-related factors are differentiated into the groups anatomy (A), restoration (B), and periodontal marker (C); $n = 8309$. * Statistically significant values ($p < 0.05$).

restoration (filling/crown) showed no significant correlation to PC (Table 4).

4 | DISCUSSION

The results of this retrospective trial showed significant and clinically relevant influence of several tooth-related factors on the outcome of NST in a large population comprising over 16,000 teeth.

Since probing depths of periodontal pockets at baseline and their reduction are critical clinical parameters determining the necessity, complexity, and the prognosis for successful treatment we used the surrogate parameters mean PPD reduction and the rate of PC to assess the outcome of NST. Especially PPD reduction is frequently used to predict disease progression and the risk of tooth loss in the literature,[3–6,41] while the rate of PC is of high clinical significance regarding the end points of therapy.[4]

Furthermore, PPD were categorized into moderate pockets of 4–5 mm (CAT2) and deep pockets ≥6 mm (CAT3) at baseline and re-evaluation as described by D'Aiuto et al.[19] This stratification is of clinical relevance considering the recommendations of the current treatment guidelines on additional treatment modalities following cause-related therapy.[12] While non-surgical re-instrumentation is indicated for residual moderate pockets 4–5 mm at re-evaluation a surgical approach is recommended for deep pockets ≥6 mm.[12,42] Yet, clinically, it seems reasonable to consider the efficacy of NST and potential limiting factors in the context of further treatment invasiveness.

TABLE 3 Pocket closure trough different groups.

Factor	Pocket closure	No pocket closure
All	4094 (49)	4215 (51)
PPD 4–5 mm	3313 (62)	2015 (40)
PPD ≥6 mm	781 (26)	2200 (74)
p	**<0.001**	
Incisor	1776 (60)	1178 (40)
Premolar	1184 (55)	950 (45)
Molar	1134 (35)	2087 (65)
p	**<0.001**	
Single-rooted	2685 (60)	1811 (40)
Multirooted	1409 (37)	2404 (63)
p	**<0.001**	
FI 0/1	3899 (51)	3710 (49)
FI 2/3	195 (28)	505 (72)
p	**<0.001**	
Mobility	770 (43)	1012 (57)
Immobility	3324 (51)	3203 (49)
p	**<0.001**	
No restoration	1911 (57)	1440 (43)
Filling	1093 (45)	1345 (55)
Crown	1090 (43)	1430 (57)
p	**<0.001**	
Vitality +	3468 (50)	3528 (50)
Vitality −	616 (48)	679 (52)
p	0.185	
BOP −	1256 (54)	1078 (46)
BOP +	2803 (48)	3100 (53)
p	**<0.001**	
PI −	2373 (52)	2204 (48)
PI +	1596 (46)	1833 (54)
p	**<0.001**	

Data are presented as frequencies.

Abbreviations: BOP, bleeding on probing; FI, furcation involvement; PI, plaque index.

Bold indicates statistically significant values ($p < 0.05$).

TABLE 4 Modulators of pocket closure at teeth with periodontal pockets.

Modulator	ß-coefficient (95% CI)	*p*
PPD at baseline (PPD 4–5 mm)	4.114 (3.703–4.571)	**<0.001**
Number of roots (single-rooted)	1.947 (1.746–2.171)	**<0.001**
Restoration type (none)	1.411 (1.243–1.602)	**<0.001**
Restoration type (filling)	1.100 (0.968–1.250)	0.143
FI (01)	1.297 (1.068–1.574)	**0.009**
Degree of mobility (none)	1.196 (1.059–1.351)	**0.004**
Vitality (positive)	1.040 (0.908–1.190)	0.575
BOP (negative)	1.079 (0.970–1.200)	0.160
PI (negative)	1.301 (1.177–1.437)	**<0.001**

Abbreviations: BOP, bleeding on probing; FI, furcation involvement; PI, plaque index; PPD, probing pocket depth.

Bold indicates statistically significant values ($p < 0.05$).

In the present cohort, NST significantly improved the clinical parameters, and a sufficient reduction of periodontal pockets was achieved. However, the mean PPD reductions of 1.20 mm for all PPD (Table 2), 0.91 mm for initially moderate pockets (4–5 mm), and 1.95 mm for initially deep pockets (≥6 mm) are slightly lower than described in the literature as reviewed by Suvan et al.[8]

Regarding the rate of PC after NST there is only limited evidence available so far. In their recent systematic review, Citterio et al. were not able to include any study directly reporting on PC following NST.[4] However, they were able to estimate a PC rate of ≈ 60% based on indirect calculations of data included in the analysis. Again, a slightly lower PC rate of almost 50% was found in the present population after NST. Regarding moderate pockets, the PC rate reached 62%, while initially deep pockets showed only poor closure rate of 27%. It must be mentioned, however, that we defined PC by PPD of ≤3 or 4 mm in the absence of BOP as described by Sanz et al.,[12] while Citterio et al. were only able to retrieve data from PPD thresholds to define PC.[4] Therefore, PC rates might not be accurately comparable with each other.

Considering site and tooth-related factors influencing the efficacy of NST, the studies by Tomasi et al. and Jiao et al. showed a significant correlation between baseline PPD and treatment outcome which is confirmed by the current data.[3,41] As expected previously deep pockets responded more favorably to NST in terms of PPD reduction, albeit moderate pockets were four times more likely to close. Intriguingly, higher baseline PPD but significantly decreased PPD reduction were found at molars, multirooted teeth, those with FI 2/3, and restored teeth. The factors tooth mobility and BOP, however, showed higher PPD at baseline but no inverse correlation to PPD reduction.

Regarding relevant factors associated with reduced efficacy of NST Tomasi et al. further identified the tooth type and plaque at site level.[3] These results are in line with data as made by D'Aiuto et al. reporting significantly higher PPD reduction for incisors than for premolars and molars but also for teeth with increased mobility.[19]

In terms of PPD reduction, the current results strongly confirm the factor tooth type showing a mean reduction of 1.42 ± 1.52 mm for incisors compared with 1.25 ± 1.40 mm at premolars and 1.00 ± 1.55 mm at molars (Table 2) and corresponding PC rates of 60%, 55%, and

35% (Table 3), respectively. Further analysis revealed that in general multirooted teeth including first upper premolars responded less favorably to NST than single-rooted teeth (1.02 ± 1.55 vs. 1.37 ± 1.46 mm [Table 2]). Since PC rates of 60% in single-rooted teeth and 37% in multirooted teeth are almost identical to those of incisors and molars, it might be assumed that the number of roots (single-rooted/multirooted) is more important in predicting therapy outcome than the type and/or intraoral location of tooth.

The importance of FI on tooth survival has been extensively reported.[21,24–28,43] Nibali et al. suggest a two-fold increased risk for molars with a stage 2 FI and even threefold higher risk for loss of molars with a stage 3 FI as compared with molars without any furcation defect or stage 1 FI.[43] Consistently, the results of the present study show significantly poorer PPD reduction at multirooted teeth with stage 2 or 3 FI compared with degree 1 and those without FI [1.21 ± 1.50 vs. 0.91 ± 1.74 mm (Table 2)] along with significantly lower rates of PC (28% vs. 51% [Table 3]) and more residual pockets after NST. Regarding the results of Matuliene et al., FI significantly impairs tooth survival most likely due to deeper residual pockets following NST, leading to persisting attachment loss.[17] These results confirm that due to well-known difficulties in the access and cleanability of the furcation area that is frequently further complicated by anatomical variations FI represents one of the greatest challenges in periodontal therapy causing persistence and recurrence of infection.[44–46]

Increased tooth mobility has been previously shown to be associated with initially higher PPD.[19] Regarding PPD reduction, however, no significant difference was evident herein when values were adjusted for baseline depth. In contrast, when mobility is considered a singular parameter and not adjusted for baseline PPD, non-mobile teeth show higher rates of PC than mobile ones, concluding that mobility is a factor negatively influencing therapy outcomes. This confirms the argumentation of D'Aiuto et al. assuming that the phenomenon of mobile teeth responding better to NST is rather due to initially deeper PPD than mobility actually being a factor favoring the efficacy of NST.[19]

The function as abutment tooth has been described as further critical factor in predicting tooth loss in different multilevel analyses setting a greater impact on tooth survival than the initial bone loss.[21,29,47] Comparably, regarding the efficacy of NST of restored teeth showed significantly deeper PPD at baseline, less PPD reduction and lower rates of PC than non-restored teeth, regardless of the type of restoration considered (filling/crown). Interestingly, the stratification for initially deep PPD (CAT3) showed no significant differences in PPD comparing restored to non-restored teeth. However, significant, and clinically relevant differences were identified in PPD reduction for initially deep sites (2.24 ± 2.01 mm for non-restored teeth vs. 1.76 ± 1.92/1.82 ± 2.00 mm for restored [filling/crown] [see Tables S2.1-2.2 in online *Journal of Periodontology*]), concluding that restored teeth respond less favorably to NST and are at a higher risk for further attachment loss.

Likewise, the presence of plaque negatively affected PPD reduction (1.33 ± 1.54 vs. 1.16 ± 1.50 mm [Table 2]) and PC with an OR of 1.3. These results are in accordance with Tomasi et al. and clearly highlight the importance of the first step of therapy enabling the patient to achieve sufficient self-performed plaque control as proposed by Sanz et al.[12]

Identifying these tooth-related factors in advance of therapy could be of help not only for clinicians estimating the efficacy of their NST but for patients that can be informed more precisely about the expected outcomes of cause-related therapy, the potential need for additional therapies and the different treatment modalities comprised in the third step of therapy.[12] In line with the present results several previous studies found an association between the baseline pocket depth, tooth mobility at baseline, or number of roots and the reduction of pocket depth after anti-infective therapy.[3,19,41] Accurate prognosis of the individual course of disease comprises an integral part of successful treatment.[48] Despite many efforts to improve prognostic models only poor quality of prognosis has yet been achieved.[49–51] Particularly the prognosis of severely affected teeth is still rather difficult reaching an accuracy of only 40%.[48] Since tooth survival is strongly linked to the success of periodontal treatment efforts the tooth-related factors as found herein to be predictive for the treatment success might help to improve the prognostic accuracy

The following limitations of this study need to be addressed. All data were collected in the context of a monocentric retrospective analysis. The quality of randomized controlled clinical trials (RCTs) is of course higher and more precise in answering specific questions. But RCTs can only address narrow questions and have strict inclusion criteria. In the present cohort, NST was carried out in an undergraduate program under the supervision of experienced periodontists while in most of the studies included in the systematic review of Suvan et al. dental hygienists or periodontists have performed the therapy. Although this must be considered as a limitation regarding the comparability of the data, in the context of varying levels of experience and skill in general dentists or hygienists the therapy outcomes in the study cohort are satisfactory.[52] Therefore, our setting includes a much more heterogeneous data sample and offers a more realistic picture of daily dental practice.[41,53] For the factor number of roots, a

simplified categorization (multirooted and single-rooted) was assumed. The division into one to three roots would feign higher accuracy, but other anatomical features such as three-rooted premolars or two- and four-rooted upper molars would be suppressed.

Due to the quantity of data, it was focused on tooth-related factors, several patient-related factors that maybe influence treatment outcomes were for the sake of simplicity not included in this study. Regarding the patient-related factor age, it must be mentioned that the mean age of the study cohort was relatively high (57 ± 14 years, Table 1) and therefore, is not representative for the general population. On the other hand, it must be emphasized that periodontitis predominantly affects the elderly.[54] Thus, the clinical relevance of the results can be interpreted as high.

5 | CONCLUSIONS

The tooth-related factors tooth type, number of roots, FI, restoration, and presence of plaque were associated with significantly higher baseline PPD, less PPD reduction, higher chances for residual pockets, and decreased likelihood for PC. Considering these factors in advance to NST may enhance the prediction of sites not responding adequately and the potential need for further treatment, such as reinstrumentation or periodontal surgery, to ultimately achieve the therapy end points.

AUTHOR CONTRIBUTIONS

Nils Werner, Caspar Victor Bumm, and Matthias Folwaczny contributed to the study design and conception, to data analysis and interpretation, and to the writing and revision of this manuscript. Christina Ern contributed to the study design and conception, to data acquisition, and to the writing and revision of this manuscript. Katrin Heck and Elias Walter contributed to data acquisition, analysis, and interpretation and to the writing and revision of this manuscript. Caspar Victor Bumm and Matthias Folwaczny contributed equally to this work. All authors reviewed and approved the final manuscript and agreed to be accountable for all aspects of work ensuring integrity and accuracy.

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CONFLICT OF INTEREST STATEMENT

All authors report no conflicts of interest.

ETHICS STATEMENT

This retrospective study was approved by the Ethics Committee of the Medical Faculty of the Ludwigs-Maximilians-University, Munich (22-0669).

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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