

## ORIGINAL ARTICLE

# Factors influencing outcomes of surgical therapy of peri-implantitis: A secondary analysis of 1-year results from a randomized clinical study

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## Abstract

**Aim:** To identify predictors of treatment outcomes following surgical therapy of peri-implantitis.

**Materials and Methods:** We performed a secondary analysis of data from a randomized controlled trial (RCT) comparing access flap with or without bone replacement graft. Outcomes at 12 months were probing pocket depth (PPD), bleeding on probing (BOP), soft-tissue recession (REC) and marginal bone level (MBL) change. Multilevel regression analyses were used to identify predictors. We also built an explanatory model for residual signs of inflammation.

**Results:** Baseline PPD was the most relevant predictor, showing positive associations with final PPD, REC and MBL gain, and negative association with probability of pocket closure. Smokers presented higher residual PPD. Absence of keratinized mucosa at baseline increased the probability of BOP but was otherwise not indicative of outcomes. Plaque at 6 weeks was detrimental in terms of residual PPD and BOP. Treatment allocation had an effect on REC. Final BOP was explained by residual PPD  $\geq 6$  mm and plaque at more than two sites.

**Conclusions:** Baseline PPD was the most relevant predictor of the outcomes of surgical therapy of peri-implantitis. Pocket closure should be a primary goal of treatment. Bone replacement grafts may be indicated in aesthetically demanding cases to reduce soft-tissue recession. The importance of smoking cessation and patient-performed plaque control is also underlined.

## KEYWORDS

bone graft, dental implant, peri-implantitis, reconstructive therapy, surgical therapy

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### Clinical Relevance

*Scientific rationale for study:* Given the large variability of outcomes following surgical therapy of peri-implantitis, not attributable to surgical modality, the identification of critical predictors is pertinent.

*Principal findings:* Baseline probing pocket depth was the most relevant predictor of 12-month outcomes. Smoking and the presence of plaque during follow-up were detrimental.

*Practical implications:* Probing pocket depth is relevant in predicting and evaluating outcomes of surgical therapy of peri-implantitis. Smoking cessation and an effective oral hygiene should be targets of both pre- and post-surgical care.

## 1 | INTRODUCTION

In the management of angular bony defects associated with periodontitis (Nibali et al., 2020), it is well understood that patient- (e.g., smoking), clinician- (e.g., training) and site-related (e.g., defect morphology) aspects all are critical indicators of outcomes (Lang, 2000; Tonetti et al., 1993, 1995, 1998). This allows for personalized and site-specific treatment planning. Corresponding data for peri-implantitis-associated bony defects, however, are limited (de Waal et al., 2016; Koldslund et al., 2018; Ravidà et al., 2020; Rocuzzo et al., 2016).

Surgical therapy of peri-implantitis is effective in reducing peri-implant probing and clinical signs of inflammation (Karlsson et al., 2023). Although generally effective, current evidence also suggests that no specific surgical approach is superior in terms of clinical outcomes one year after treatment (Donos et al., 2023). The considerable variability in outcomes described across most clinical trials highlights the importance of identifying parameters—other than the surgical approach—that affect treatment results.

The clinical practice guidelines on the management of peri-implantitis presented by the European Federation of Periodontology (Herrera et al., 2023) have emphasized probing pocket depth (PPD) and bleeding on probing (BOP) as the primary clinical outcomes to be evaluated. In a recently completed randomized controlled trial (RCT) comparing surgical therapy of peri-implantitis with or without the use of a bone substitute (Derks et al., 2022), no differences for either variable were observed between treatment groups. Again, a significant variability in outcomes across patients, which could not be explained by treatment allocation, was noted. Identification of relevant predictors of treatment outcomes in this respect may, ultimately, help in optimizing treatment choices and patient selection. Thus, a secondary analysis of potential indicators, using the dataset referred to above, is justified.

The aim of the present study was to identify predictors of treatment outcomes following surgical therapy of peri-implantitis with or without the use of a bone replacement graft.

## 2 | MATERIALS AND METHODS

Data from a previously published multi-centre, parallel-group randomized controlled study (Derks et al., 2022) were re-evaluated

in the present analysis. The trial was performed at six centres located in Sweden, Italy, Spain and Germany. Ethical approval was obtained (Gothenburg: 1192-16; Bilbao: 06/2017; Málaga: 27/09/2017; Perugia: 3173/18; Trento: 21390; Munich: 17028), and the protocol was registered at clinicaltrials.gov (NCT03077061).

### 2.1 | Study sample and intervention

Briefly, a total of 138 patients were enrolled. Participants presenting with a diagnosis of advanced peri-implantitis (peri-implant PPD of  $\geq 7$  mm, BOP and/or suppuration on probing [SOP] and radiographically confirmed bone loss of  $\geq 3$  mm) at one or more implants with a minimum function time of 1 year were included. Medical history and details pertaining to the implant-supported restorative therapy were collected through anamnesis and patient records. Following a baseline examination and non-surgical therapy, the surgical procedure was scheduled. Three days before surgery, a 10-day regimen of systemic antibiotics was initiated. Upon flap elevation, exposed implant surfaces were decontaminated by titanium curettes and a rotating titanium brush under irrigation with saline. Patients were then randomly allocated to either access flap alone (control) or access flap combined with application of a bone replacement graft (test; Bio-Oss Collagen, Geistlich, Lucerne, Switzerland). Surgeries were performed between July 2017 and February 2021.

### 2.2 | Measurements

The following clinical parameters were considered at baseline and at 6 and 12 months after surgery: plaque (PL), PPD, BOP/SOP (all at four sites per implant), soft-tissue level and width of keratinized mucosa (KM; at buccal aspects). PL was also recorded at the 6-week follow-up. Marginal bone levels (MBLs) were measured at baseline and 12 months after surgery at mesial and distal aspects (ImageJ 2.0.0-rc-69/1.52n; National Institutes of Health, Bethesda, MD). During surgery, the dimensions of the peri-implant bony defect were recorded in terms of width, depth and configuration (contained, partially open or open). For PPD, MBL, defect depth and width, the deepest/worst

**TABLE 1** Patient, implant and surgical parameters.

	Test		Control		Total	
Patients						
Gender						
Female	41	63.1%	44	68.8%	85	65.9%
Male	24	36.9%	20	31.2%	44	34.1%
Smoker						
No	50	76.9%	43	67.2%	93	72.1%
Yes	15	23.1%	21	32.8%	36	27.9%
Diabetes						
No	63	96.9%	61	95.3%	124	96.1%
Yes	2	3.1%	3	4.7%	5	3.9%
Age at surgery (years)	61.9	(11.4)	59.7	(11.5)	60.8	(11.5)
Implants						
Location						
Anterior	13	18.8%	10	14.9%	23	16.9%
Posterior	56	81.2%	57	85.1%	113	83.1%
Jaw						
Maxilla	34	49.3%	28	41.8%	62	45.6%
Mandible	35	50.7%	39	58.2%	74	54.4%
Implant surface						
Osseospeed	32	46.4%	24	35.8%	56	41.2%
SLA/SLActive	14	20.3%	16	23.9%	30	22.1%
TiUnite	9	13.0%	12	17.9%	21	15.4%
Other	14	20.3%	15	22.4%	29	21.3%
Prosthesis retention						
Cemented	29	42.0%	27	40.3%	56	41.2%
Conometric	1	1.4%	4	6.0%	5	3.7%
Screw-retained	39	56.5%	36	53.7%	75	55.1%
Prosthesis						
Not removed	21	30.4%	19	28.4%	40	29.4%
Removed	48	69.6%	48	71.6%	96	70.6%
Presence of KM at baseline						
No	14	20.3%	14	20.9%	28	20.6%
Yes (≥0.5 mm)	55	79.7%	53	79.1%	108	79.4%
Defect configuration <sup>a</sup>						
Open at buccal and lingual aspect	26	37.7%	25	37.3%	51	37.5%
Open at either buccal or lingual aspect	30	43.5%	21	31.3%	51	37.5%
Contained	13	18.8%	21	31.3%	34	25.0%
Buccal bone wall <sup>b</sup>						
Intact	35	50.7%	30	44.8%	65	47.8%
Partially missing	18	26.1%	12	17.9%	30	22.1%
Missing	16	23.2%	25	37.3%	41	30.1%
Neighbouring						
Nothing	9	13.0%	12	17.9%	21	15.4%
Implant-nothing or Implant-Implant	12	17.4%	17	25.4%	29	21.3%
Tooth-Implant or Tooth-nothing	27	39.1%	16	23.9%	43	31.6%
Tooth-Tooth	21	30.4%	22	32.8%	43	31.6%

**TABLE 1** (Continued)

	Test		Control		Total	
Plaque at baseline						
No	54	78.3%	55	82.1%	109	80.1%
Yes	15	21.7%	12	17.9%	27	19.9%
Plaque at 6 weeks						
No	56	81.2%	56	83.6%	112	82.4%
Yes	13	18.8%	11	16.4%	24	17.6%
Implant years	10.1	(5.0)	9.9	(5.8)	10.0	(5.4)
PPD at baseline (mm)	8.7	(1.6)	8.5	(1.6)	8.6	(1.6)
MBL at baseline (mm)	5.9	(1.8)	6.1	(1.7)	6.0	(1.8)
Defect depth (mm; to crest)	5.9	(1.9)	6.0	(2.1)	6.0	(2.0)
Defect width (mm)	3.1	(1.0)	3.0	(0.7)	3.0	(0.9)
Buccal KM (mm)	2.2	(1.8)	2.2	(1.7)	2.2	(1.7)

Abbreviations: KM, keratinized mucosa; MBL, marginal bone level; PPD, probing pocket depth.

<sup>a</sup>Defect configuration: 'open' is defined as an implant exposure >2 mm (distance from implant shoulder to bottom of defect minus distance from crest to bottom of defect).

<sup>b</sup>Buccal bone wall: 'partially missing' is defined as buccal implant exposure >2 and ≤4 mm; 'missing' is defined as buccal implant exposure >4 mm.

**TABLE 2** Outcomes at 12 months (by potential predictor).

	PPD (mm)	Change in PPD (mm)	Recession (mm)	MBL gain (mm)	Pocket closure (PPD ≤ 5 mm)		Bleeding on probing (≤1 site)		Composite outcome <sup>a</sup>	
					No	Yes	No	Yes	No	Yes
Group										
Test	4.9 (1.8)	3.8 (2.0)	0.7 (1.0)	1.2 (1.4)	23 33.3%	46 66.7%	36 52.2%	33 47.8%	38 55.1%	31 44.9%
Control	4.6 (1.8)	3.9 (1.9)	1.2 (1.4)	1.1 (1.0)	17 25.4%	50 74.6%	37 55.2%	30 44.8%	35 52.2%	32 47.8%
Gender										
Female	4.9 (1.8)	3.6 (1.9)	1.1 (1.3)	1.2 (1.1)	29 32.2%	61 67.8%	47 52.2%	43 47.8%	50 55.6%	40 44.4%
Male	4.6 (1.7)	4.3 (2.0)	0.7 (1.1)	1.1 (1.4)	11 23.9%	35 76.1%	26 56.5%	20 43.5%	23 50.0%	23 50.0%
Current smoker										
No	4.6 (1.8)	4.1 (1.9)	1.0 (1.3)	1.3 (1.2)	25 25.8%	72 74.2%	54 55.7%	43 44.3%	48 49.5%	49 50.5%
Yes	5.2 (1.7)	3.3 (2.1)	0.8 (1.0)	0.9 (1.2)	15 38.5%	24 61.5%	19 48.7%	20 51.3%	25 64.1%	14 35.9%
Jaw										
Maxilla	4.7 (1.7)	4.1 (1.8)	1.3 (1.2)	1.2 (1.0)	17 27.4%	45 72.6%	41 66.1%	21 33.9%	29 46.8%	33 53.2%
Mandible	4.8 (1.8)	3.6 (2.1)	0.7 (1.2)	1.1 (1.4)	23 31.1%	51 68.9%	32 43.2%	42 56.8%	44 59.5%	30 40.5%
Presence of KM										
No	5.4 (1.6)	3.5 (1.8)	0.7 (0.9)	1.2 (1.3)	12 42.9%	16 57.1%	8 28.6%	20 71.4%	20 71.4%	8 28.6%
Yes	4.6 (1.8)	3.9 (2.0)	1.0 (1.3)	1.1 (1.2)	28 25.9%	80 74.1%	65 60.2%	43 39.8%	53 49.1%	55 50.9%

(Continues)

TABLE 2 (Continued)

	PPD (mm)	Change in PPD (mm)	Recession (mm)	MBL gain (mm)	Pocket closure (PPD ≤ 5 mm)		Bleeding on probing (≤1 site)		Composite outcome <sup>a</sup>	
					No	Yes	No	Yes	No	Yes
Implant surface										
Osseospeed	4.2	4.1	0.8	1.1	12	44	35	21	26	30
	(1.7)	(2.1)	(1.0)	(1.3)	21.4%	78.6%	62.5%	37.5%	46.4%	53.6%
SLA/SLActive	5.1	3.9	0.9	1.0	11	19	16	14	16	14
	(1.3)	(1.8)	(1.4)	(0.9)	36.7%	63.3%	53.3%	46.7%	53.3%	46.7%
TiUnite	4.7	3.5	0.9	1.4	5	16	8	13	13	8
	(1.8)	(1.7)	(0.9)	(1.6)	23.8%	76.2%	38.1%	61.9%	61.9%	38.1%
Other	5.4	3.7	1.3	1.3	12	17	14	15	18	11
	(2.2)	(2.1)	(1.5)	(1.1)	41.4%	58.6%	48.3%	51.7%	62.1%	37.9%
Prosthesis retention										
Cemented	4.7	4.0	1.2	0.8	15	41	35	21	25	31
	(2.0)	(1.8)	(1.4)	(0.9)	26.8%	73.2%	62.5%	37.5%	44.6%	55.4%
Conometric	5.8	2.4	0.4	0.9	3	2	4	1	3	2
	(1.3)	(2.1)	(0.9)	(0.8)	60.0%	40.0%	80.0%	20.0%	60.0%	40.0%
Screw-retained	4.8	3.9	0.8	1.4	22	53	34	41	45	30
	(1.6)	(2.1)	(1.0)	(1.4)	29.3%	70.7%	45.3%	54.7%	60.0%	40.0%
Prosthesis at surgery										
Not removed	4.8	3.8	1.1	1.0	10	30	22	18	20	20
	(1.8)	(1.8)	(1.4)	(1.2)	25.0%	75.0%	55.0%	45.0%	50.0%	50.0%
Removed	4.8	3.9	0.9	1.2	30	66	51	45	53	43
	(1.8)	(2.0)	(1.2)	(1.3)	31.2%	68.8%	53.1%	46.9%	55.2%	44.8%
Defect configuration										
Open at buccal and lingual aspect	5.2	4.1	1.2	1.1	20	31	29	22	27	24
	(2.0)	(2.5)	(1.5)	(1.3)	39.2%	60.8%	56.9%	43.1%	52.9%	47.1%
Open at either buccal or lingual aspect	4.7	3.5	0.7	1.2	13	38	24	27	29	22
	(1.5)	(1.7)	(1.0)	(1.2)	25.5%	74.5%	47.1%	52.9%	56.9%	43.1%
Contained	4.2	4.0	1.0	1.1	7	27	20	14	17	17
	(1.7)	(1.5)	(1.0)	(1.3)	20.6%	79.4%	58.8%	41.2%	50.0%	50.0%
Plaque at 6 weeks										
≤1 site	4.5	4.0	0.9	1.2	28	84	65	47	55	57
	(1.7)	(2.0)	(1.0)	(1.1)	25.0%	75.0%	58.0%	42.0%	49.1%	50.9%
≥2 sites	5.8	3.0	1.1	0.8	12	12	8	16	18	6
	(1.9)	(1.8)	(2.0)	(1.7)	50.0%	50.0%	33.3%	66.7%	75.0%	25.0%
Total	4.8	3.8	1.0	1.1	40	96	73	63	73	63
	(1.8)	(2.0)	(1.2)	(1.2)	29.4%	70.6%	53.7%	46.3%	53.7%	46.3%

Note: Outcomes are presented as mean (standard deviation) or count and percentage.

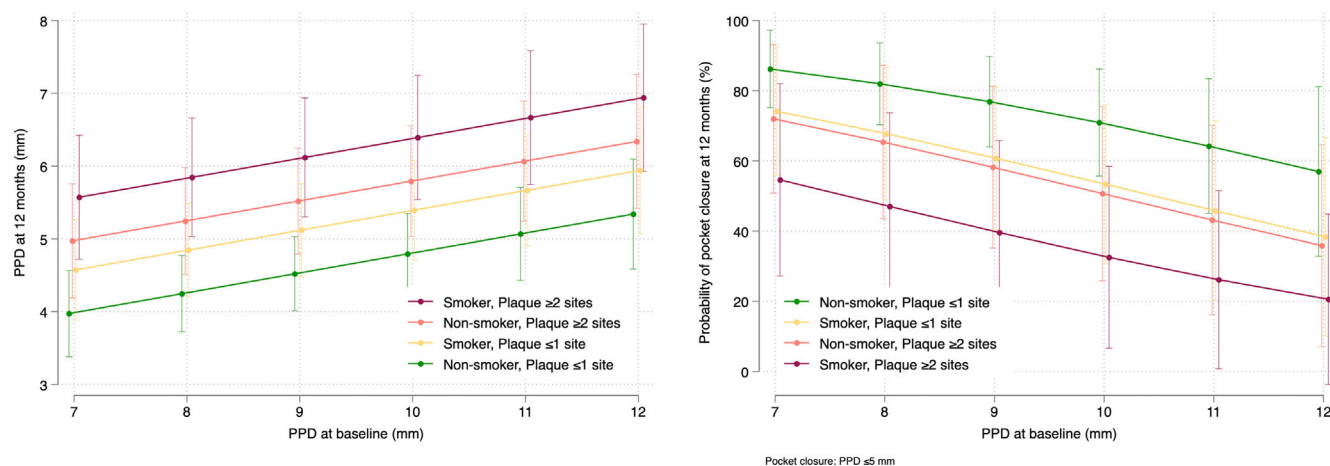
Abbreviations: KM, keratinized mucosa; MBL, marginal bone level; PPD, probing pocket depth.

<sup>a</sup>Composite outcome defined as PPD ≤5 mm and bleeding on probing ≤1 site.

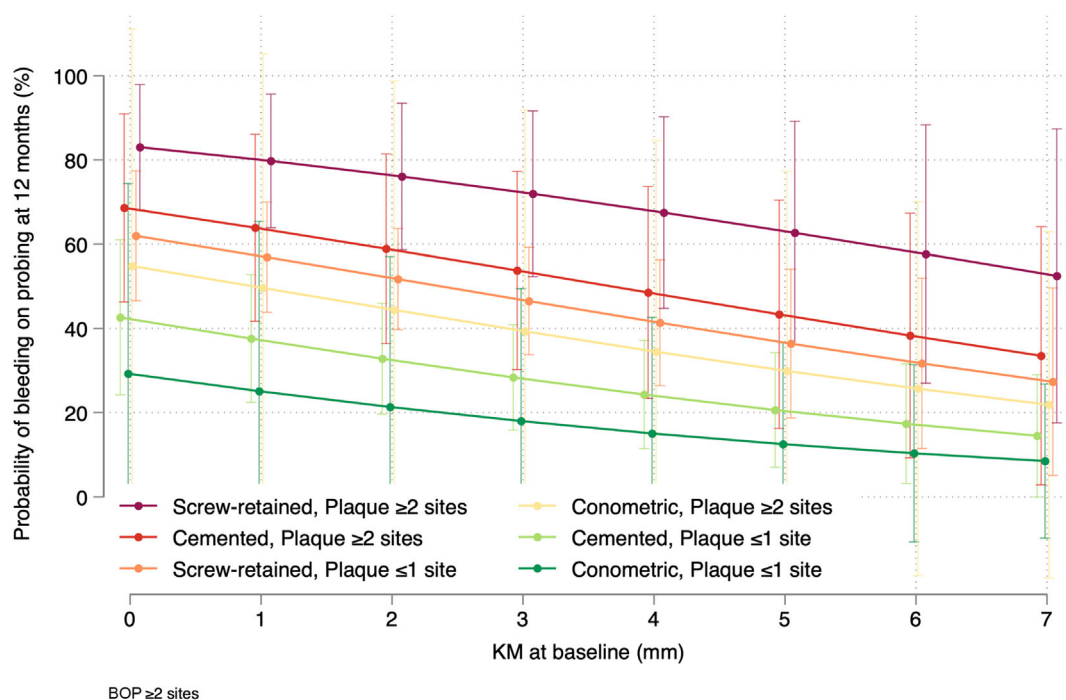
value (in mm) was representative of each implant. BOP and PL were scored dichotomously (yes/no). All clinical assessments were performed with a metal periodontal probe by the responsible calibrated clinician. Radiographic evaluations were performed by a trained examiner (YI).

## 2.3 | Data analysis

Implants present at the 12-month examination were considered for the present per-protocol analysis. One implant showing a pronounced increase in PPD (from 7 mm at baseline to 13 mm at 12 months;



**FIGURE 1** Predicted probing pocket depth (PPD) (left) and predicted probability of pocket closure (right) at 12 months by baseline PPD. The models also included smoking and plaque at 6 weeks (only significant for PPD), as well as baseline keratinized mucosa and treatment group (none of them statistically significant). The corresponding multilevel models are illustrated in Tables A2 and A3.



**FIGURE 2** Predicted probability of bleeding on probing (BOP) at 12 months by baseline keratinized mucosa (KM). The model also included plaque at 6 weeks, prosthesis retention, defect depth, implant surface and group (the latter three were not statistically significant). The corresponding multilevel model is illustrated in Table A4b.

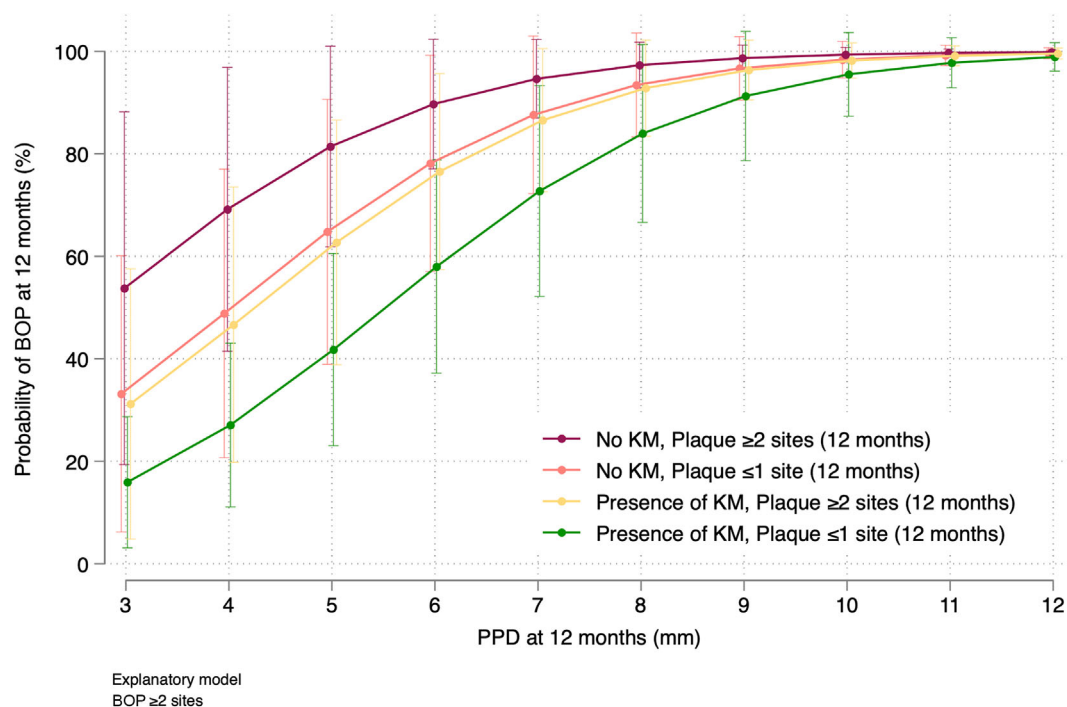
Figure A1) was excluded from all analyses. Thus, data from 129 patients (136 implants) were included. The study population is described in Table 1, which also presents an overview of independent parameters considered in the risk analyses.

We used linear or logistic multilevel regression models at two levels (mixed effects regression allowing for random intercepts; lower level: implant; higher level: clinical centre) to estimate the following outcomes at 12 months (implant level): final PPD, pocket closure (PPD ≤ 5 mm), BOP (BOP ≥ 2 sites), recession (change in buccal soft-

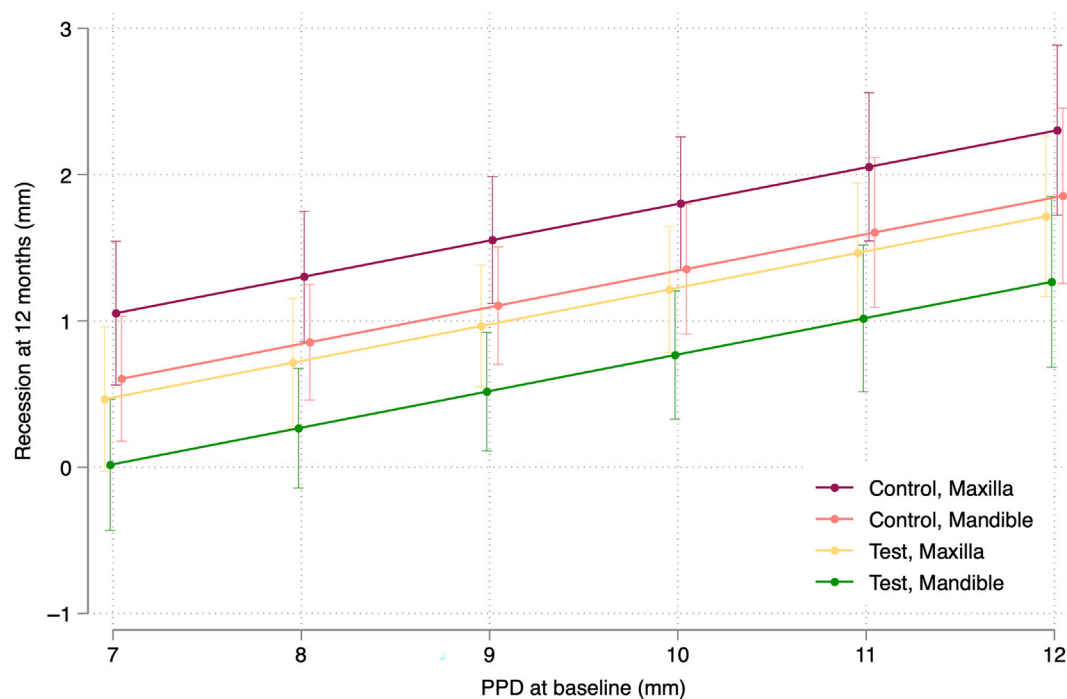
tissue level; REC) and MBL gain (modelling of factors associated with the composite outcome as per the original publication are presented in the Appendix, see Table A8). As the original RCT was designed to compare two treatment modalities, all models were adjusted for group allocation (test/control). The final model was built following a structured approach based on clinical relevance, significant associations of single predictors and model fit.

Because of the collinearity between baseline PPD, MBL and defect depth (Table A1), only one of these factors was considered at a





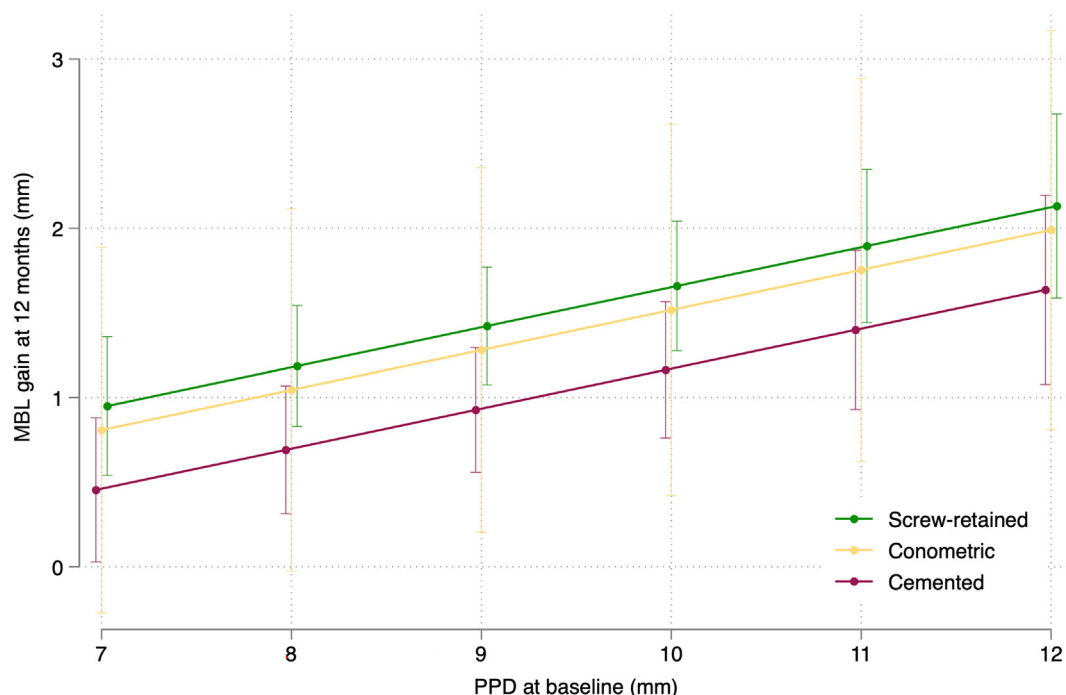
**FIGURE 3** Predicted probability of final bleeding on probing (BOP) by probing pocket depth at 12 months. The model also included plaque and keratinized mucosa (KM) at 12 months. The corresponding multilevel model is illustrated in Table A5b. PPD, probing pocket depth.



**FIGURE 4** Predicted recession at 12 months by baseline probing pocket depth (PPD). The model also included the group, jaw and baseline keratinized mucosa (the latter was not statistically significant). The corresponding multilevel model is illustrated in Table A6.

time. A final selection was based on model fit. Normality of the distributions of residuals was confirmed through Q-Q plots (Figures A2–A4).

In addition to the predictive modelling above, an explanatory model was built for the final BOP considering parameters also obtained at 12 months (PPD, KM, PL).



**FIGURE 5** Predicted marginal bone level (MBL) gain at 12 months by baseline probing pocket depth (PPD). The model also included prosthesis retention, smoking and group (the latter two were not statistically significant). The corresponding multilevel model is illustrated in Table A7.

KM was included in the models both as a continuous variable and dichotomized (presence vs. absence; alternative categorization  $\leq 2$  mm vs.  $> 2$  mm presented in the Appendix, see Table A9).

All analyses were performed using Stata (Stata SE version 17.0, StataCorp LLC, College Station, TX). Outcomes were reported as adjusted regression coefficients and odds ratios (ORs) with 95% confidence intervals (95% CIs). Most patients ( $n = 122$ ) contributed with one implant only. Therefore, the unit of analysis was the implant.

### 3 | RESULTS

Outcomes at 12 months are presented in Table 2.

#### 3.1 | Probing pocket depth

Mean PPD at 12 months was  $4.8 \pm 1.8$  mm (SD), and reduction relative to baseline amounted to  $3.8 \pm 2.0$  mm. Baseline PPD (coefficient: 0.27, 95% CI 0.10–0.45), smoking (0.60, 95% CI 0.03–1.17) and PL at 6 weeks (1.00, 95% CI 0.30–1.70) were significant predictors of final PPD. Neither treatment group ( $-0.33$ , 95% CI  $-0.84$  to  $0.19$ ) nor KM was significant (0.61, 95% CI  $-0.05$  to  $1.27$ ; Figure 1, Table A2).

Pocket closure was achieved at 96 implants (70.6%). PPD at baseline was the only factor with a statistically significant impact on the probability of pocket closure in the final model (OR 0.71, 95% CI 0.54–0.93; Figure 1, Table A3).

#### 3.2 | Bleeding on probing

Sixty-three out of 136 implants (46.3%) presented with BOP (at two or more sites) at 12 months. Absence of KM at baseline (OR 5.18, 95% CI 1.55–17.23), PL at 6 weeks (3.47, 95% CI 1.14–10.56) and screw-retained prosthesis (reference: cemented; 2.93, 95% CI 1.06–8.08) had a significant impact on the probability of BOP at 12 months (Figure 2, Table A4a); while treatment group did not (0.80, 95% CI 0.36–1.76).

According to the explanatory model focusing on the 12-month time point, final BOP was explained to a high degree by the simultaneous presence of PPD  $\geq 6$  mm (OR 6.04, 95% CI 2.23–16.37) and plaque ( $\geq 2$  sites; OR 3.73, 95% CI 1.23–11.2). The relationship between final BOP and KM at 12 months was not statistically significant (OR 2.75, 95% CI 0.94–8.06; Figure 3, Table A5a).

#### 3.3 | Soft-tissue recession

Mean buccal recession at 12 months was  $1.0 \pm 1.2$  mm. Treatment without bone substitute (coefficient: 0.59, 95% CI 0.22–0.95), baseline PPD (0.25, 95% CI 0.13–0.37) and maxillary location (0.45, 95% CI 0.06–0.83) were relevant predictors (Figure 4, Table A6).

#### 3.4 | MBL gain

Mean MBL gain at 12 months was  $1.1 \pm 1.2$  mm. Baseline PPD (coefficient: 0.24, 95% CI 0.11–0.36) and screw-retained prosthesis



(0.50, 95% CI 0.09–0.90) had a significant effect on MBL gain. Treatment group was not relevant (0.09, 95% CI –0.30 to 0.47; Figure 5, Table A7).

## 4 | DISCUSSION

The present study describes a secondary analysis of 1-year data from an RCT on surgical therapy of peri-implantitis aiming at reconstruction of peri-implant tissues. Regression analyses were used to identify baseline parameters relevant in the prediction of final outcomes. We also built an explanatory model for residual signs of soft-tissue inflammation. Our findings suggest that PPD at baseline is the most relevant predictor of treatment outcomes, showing a strong positive association with final PPD, soft-tissue recession and bone level gain. A negative association with probability of pocket closure (PPD  $\leq$  5 mm) at 12 months was observed. Implant sites in smokers presented with higher residual PPD. Absence of KM at baseline increased the probability of BOP at 12 months but was otherwise not indicative of outcomes. The presence of plaque at 6 weeks post surgery was detrimental in terms of residual PPD and BOP. Defect configuration and treatment modality (bone replacement graft vs. open flap debridement) had only a minor effect on treatment outcomes. The 12-month findings explaining final BOP were residual PPD  $\geq$  6 mm and plaque at two or more sites.

The fact that PPD at baseline is a strong predictor of treatment outcomes of surgical therapy of peri-implantitis is in general agreement with prospectively collected data by other groups. Thus, at 6 months following surgery, Koldslund et al. (2018) reported a significantly lower likelihood of favourable outcomes at sites with an initial PPD  $\geq$  8 mm. Similar to our approach, de Waal et al. (2016) re-analyzed data generated in an RCT setting. The authors observed pocketing at baseline to be significantly associated with treatment failure in an initial binary evaluation but not in an adjusted analysis. In this context, it is relevant to note that we found baseline PPD, MBL and surgically assessed depth of the bony defect to be strongly correlated with each other. Hence, all three variables probably describe the same concept, namely severity of the disease. In the study by de Waal et al. (2016), RBL at baseline was a relevant predictor. We chose to highlight PPD, rather than a radiographic or intra-surgical measure, because of its overall clinical relevance and superior model fit.

Our data also suggested that smokers had, on average, 0.6 mm more residual PPD than non-smokers. We further observed that the presence of plaque during follow-up was detrimental. Both findings are in agreement with the data presented by Koldslund et al. (2018) and also fit well with the concept that outcomes of periodontal treatment are strongly affected by smoking habits (Chang et al., 2021; Labriola et al., 2005) and patient-performed plaque control (Tomasi et al., 2007). One baseline factor with only limited effect on 12-month results was the height of KM. Although we observed a higher likelihood of residual BOP at sites lacking KM at baseline, there was no association with other outcomes including the final PPD, MBL change or REC. It should be highlighted that the inclusion of plaque in the

statistical models resulted in non-significance of KM as a predictor. This confirms a potential confounding effect of KM on plaque levels (Souza et al., 2016). In a retrospective case series, Ravidà et al. (2020) also failed to demonstrate differences in outcomes in cases with abundant ( $>2$  mm) or limited ( $\leq 2$  mm) height of KM.

Neither the treatment modality nor the defect configuration had a critical effect on the present treatment results. The latter observation is in line with the data presented by Rocuzzo et al. (2016). At 12 months after reconstructive therapy, the authors could not observe differences in outcomes across five defect categories. This stands in contrast with data reported by Schwarz et al. (2010), who noted less favourable outcomes at implants with dehiscence-type bony defects. Reasons for the conflicting results may be related to the surgical techniques and/or choice of the reconstructive approach. For example, in the present study, clinicians were not limited to a specific flap design, which might have influenced treatment outcomes. It is also important to point out that we applied a more simplified defect categorization when compared with other authors (Monje et al., 2019; Schwarz et al., 2007).

In the present case, the use of bone graft was beneficial in terms of reducing soft-tissue recession (Derks et al., 2022). This fact, taken together with the finding that recession was generally more pronounced in the upper jaw, makes the anterior maxilla a target area for this therapeutic approach.

Residual BOP at 12 months was strongly related to the residual PPD, which has been previously described for both implant and tooth sites (Farina et al., 2017). While the relatively short follow-up of the present study (1 year) prevented us from evaluating disease progression, previous studies have identified both residual BOP and PPD as strong predictors for progression and/or recurrence at implants (Carcuac et al., 2020; Karlsson et al., 2019). Thus, the present data underline the importance of reducing peri-implant pocketing and are therefore in line with recently published treatment recommendations (Herrera et al., 2023). To be consistent with the clinical guidelines, we used 5 mm as a threshold for PPD and allowed for one site with BOP to define positive treatment outcomes. This stands in slight contrast to the earlier publication on this subject (Derks et al., 2022).

Some limitations need to be considered when interpreting the present findings. The study was originally designed to answer a research question different from the one evaluated in this secondary analysis. Matters of statistical power were not addressed. Some parameters (e.g., KM) were assessed to the nearest 0.5 mm, a level of detail not easily assessed in a clinical setting.

In conclusion, the present data indicate that PPD at baseline is the most relevant predictor of outcomes of surgical therapy of peri-implantitis with or without the use of a bone replacement graft. Pocket closure (PPD  $\leq$  5 mm) should be one of the primary goals of treatment. Because of the beneficial effect in terms of soft-tissue recession, the use of a bone replacement graft may be particularly relevant in aesthetically demanding cases. The data also underline the importance of smoking cessation and patient-performed plaque control.

## AUTHOR CONTRIBUTIONS

Jan Derks and Tord Berglundh contributed to study conception and design. All authors contributed to data collection. Erik Regidor, Yuki Ichioka and Carlotta Dionigi acted as study monitors and were responsible for data management. Yuki Ichioka, Anna Trullenque-Eriksson and Cristiano Tomasi contributed to data analysis and interpretation. Yuki Ichioka, Anna Trullenque-Eriksson, Alberto Ortiz-Vigón, Adrián Guerrero, Mauro Donati, Eriberto Bressan, Paolo Ghensi, Dennis Schaller, Cristiano Tomasi, Karolina Karlsson, Ingemar Abrahamsson, Carlotta Dionigi, Erik Regidor, Tord Berglundh and Jan Derks contributed to drafting and revision of the manuscript.

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## CONFLICT OF INTEREST STATEMENT

Dr. Jan Derks reports speakers' honoraria from Osteology Foundation, Dentsply Sirona Implants, Straumann Group, and received research grants from Dentsply Sirona Implants, Eklund Foundation and Electro Medical Systems. Dr. Alberto Ortiz-Vigón reports speakers' honoraria from Straumann Group and Arrow Development research, Klockner as well as non-financial and other support from Arrow Development research and Thinking Perio research. Dr. Guerrero reports honoraria from Inibsa and Dentsply Sirona Implants. Dr. Mauro Donati reports speakers honoraria from Dentsply Sirona Implants and has received research grants from Dentsply Sirona Implants. Dr. Eriberto Bressan reports speakers' honoraria from Dentsply Sirona Implants and Sweden & Martina. Dr. Paolo Ghensi reports speakers' honoraria from Geistlich Pharma AG and BioHorizons Camlog. Dr. Dennis Schaller reports speakers' honoraria from Zimmer Biomet. Dr. Tomasi reports speakers' honoraria from Dentsply Sirona Implants, Straumann Group, Geistlich Pharma AG and Sweden & Martina. Dr. Karolina Karlsson reports speakers' honoraria from Dentsply Sirona Implants. Dr. Ingemar Abrahamsson has received research grants from Dentsply Sirona Implants. Dr. Tord Berglundh reports honoraria from Dentsply Sirona Implants and speakers' honoraria from Osteology Foundation and has received research grants from Dentsply Sirona Implants and Geistlich Pharma AG.

## DATA AVAILABILITY STATEMENT

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

## ETHICS STATEMENT

The study protocol was approved by the responsible authorities in Sweden, Spain, Italy and Germany (Gothenburg: 1192-16; Bilbao: 06/2017; Málaga: 27/09/2017; Perugia: 3173/18; Trento: 21390;

Munich: 17028). All participants were informed about the study protocol and informed consent was obtained.

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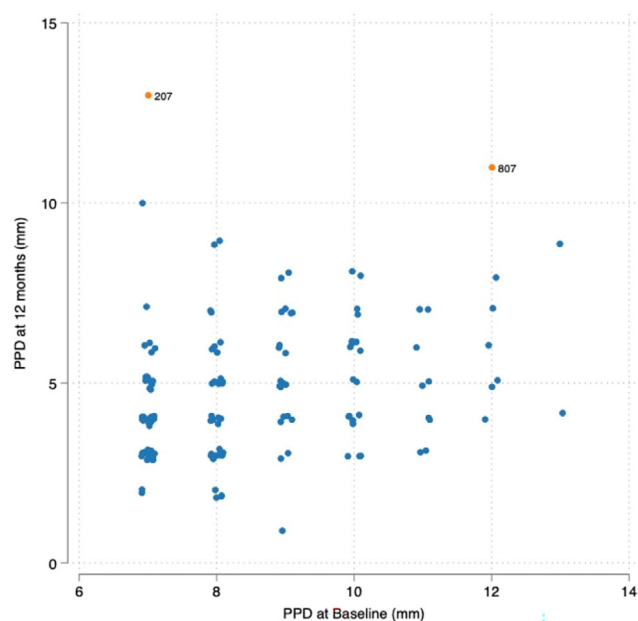
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# APPENDIX



**FIGURE A1** Illustration of outliers. Scatterplot illustrating outliers in terms of probing pocket depth (PPD) at 12 months. One implant (ID 207) was removed from all analyses.

**TABLE A1** Correlations between baseline probing pocket depth (PPD), marginal bone level (MBL) and defect depth ( $n = 136$ ).

	PPD	MBL	Defect_Depth
PPD	1.0000		
MBL	0.4344*	1.0000	
Defect_Depth	0.4769*	0.5095*	1.0000

\* $p < .05$ ; pairwise correlation with Bonferroni correction.

Mixed-effects ML regression  
Group variable: center

Number of obs. = 136

Number of groups = 6

Obs per group

min = 4

avg = 22.7

max = 47

Log likelihood = -252.14541

Wald  $\chi^2(5) = 27.50$

Prob >  $\chi^2 = .0000$

PPD3	Coefficient	SE	z	p >  z	[95% conf. interval]	
group						
Test	0 (base)					
Control	−0.3254468	0.2634398	−1.24	.217	−0.8417794	0.1908858
PPD1	0.2733845	0.0880423	3.11	.002	0.1008247	0.4459442
smoker						
No	0 (base)					
Yes	0.6003113	0.2906687	2.07	.039	0.030611	1.170012
Plaque6w						
No	0 (base)					
Yes	0.9982937	0.3555333	2.81	.005	0.3014612	1.695126
KM1_cat						
No	0.609448	0.3388169	1.80	.072	−0.054621	1.273517
Yes	0 (base)					
_cons	2.095318	0.8332281	2.51	.012	0.4622206	3.728415
Random-effects parameters		Estimate	SE	[95% conf. interval]		
center: Identity						
var(_cons)		0.1890293	0.1795769	0.0293692 1.216652		
var(Residual)		2.288047	0.2831548	1.795252 2.916114		

Note: LR test versus linear model:  $\text{chibar}^2(01) = 4.62$ . Prob  $\geq \text{chibar}^2 = .0158$ .

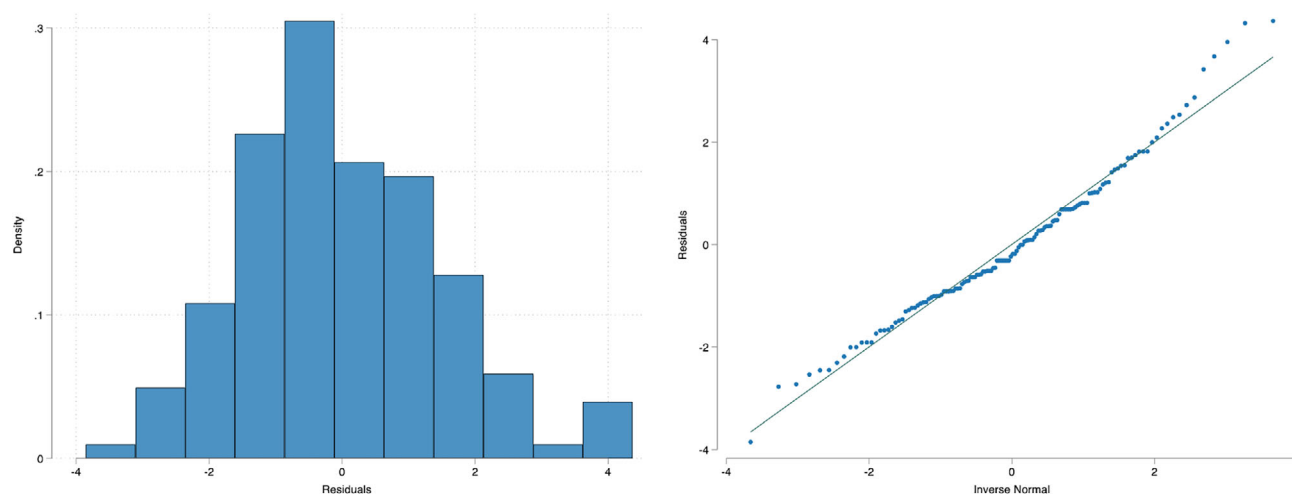


FIGURE A2 Distribution of residuals for probing pocket depth at 12 months.

TABLE A2 Multiple model for probing pocket depth (PPD) at 12 months (multilevel).

**TABLE A3** Multiple model for pocket closure at 12 months (multilevel).

Mixed-effects logistic regression				Number of obs = 136		
Group variable: center				Number of groups = 6		
				Obs per group		
				min = 4		
				avg = 22.7		
				max = 47		
Integration method: mvaghermite				Integration pts. = 7		
Log likelihood = -69.664495				Wald chi² (5) = 13.30		
				Prob > chi² = .0207		
PPDbelow6	Odds ratio	SE	z	p >  z	[95% conf. interval]	
group						
Test	1 (base)					
Control	1.847824	0.819618	1.38	.166	0.7746453	4.407763
PPD1	0.7104579	0.0980038	-2.48	.013	0.5421503	0.9310156
Plaque6w						
No	1 (base)					
Yes	0.3795582	0.198923	-1.85	.065	0.135885	1.060194
smoker						
No	1 (base)					
Yes	0.42786	0.200299	-1.81	.070	0.1709303	1.070987
KM1_cat						
No	0.4892039	0.2541505	-1.38	.169	0.1767156	1.354269
Yes	1 (base)					
_cons	70.88113	94.64424	3.19	.001	5.175607	970.7335
center						
var(_cons)	0.3863815	0.3829791			0.0553746	2.696016

Note: Estimates are transformed only in the first equation to odds ratios. \_cons estimates baseline odds (conditional on zero random effects). LR test versus logistic model:  $\chi^2(01) = 4.21$ ; Prob  $\geq \chi^2 = .0201$ .



**TABLE A4** Multiple model for bleeding on probing  $\geq 2$  sites at 12 months (multilevel).

(a) Baseline KM as categorical						
Mixed-effects logistic regression Group variable: center				Number of obs = 136		
				Number of groups = 6		
				Obs per group		
Integration method: mvaghermite				min = 4		
				avg = 22.7		
				max = 47		
Log likelihood = −79.501691				Integration pts. = 7		
				Wald chi <sup>2</sup> (9) = 18.22		
				Prob > chi <sup>2</sup> = .0327		
BoP1y	Odds ratio	SE	z	p >  z	[95% conf. interval]	
group						
Test	1 (base)					
Control	0.7948588	0.3218648	−0.57	.571	0.3594266	1.757801
KM1_cat						
No	5.17661	3.176992	2.68	.007	1.554696	17.23635
Yes	1 (base)					
Plaque6w						
No	1 (base)					
Yes	3.466488	1.970832	2.19	.029	1.137493	10.56405
Depth_Crest	1.211318	0.1384074	1.68	.093	0.9682743	1.515368
retention						
Cemented	1 (base)					
Conometric	0.2926822	0.3818725	−0.94	.346	0.0226884	3.77562
Screw-retained	2.929569	1.516435	2.08	.038	1.062174	8.08001
surface						
Osseospeed	1 (base)					
SLA/SLActive	2.194369	2.090086	0.83	.409	0.3392813	14.19252
TiUnite	3.162486	1.914541	1.90	.057	0.9654252	10.35949
Other	2.795294	1.733234	1.66	.097	0.829156	9.423642
_cons	0.0633033	0.0582207	−3.00	.003	0.0104368	0.3839592
center						
var(_cons)	0.4973689	0.7497742			0.0259125	9.546602
(b) Baseline KM as continuous						
Mixed-effects logistic regression Group variable: center				Number of obs = 136		
				Number of groups = 6		
				Obs per group		
Integration method: mvaghermite				min = 4		
				avg = 22.7		
				max = 47		
Log likelihood = −81.540401				Integration pts. = 7		
				Wald chi <sup>2</sup> (9) = 19.30		
				Prob > chi <sup>2</sup> = .0227		
BoP1y	Odds ratio	SE	z	p >  z	[95% conf. interval]	
group						
Test	1 (base)					
Control	0.8480896	0.3260947	−0.43	.668	0.3991632	1.80191
KM1	0.7974228	0.0911164	−1.98	.048	0.6374224	0.9975852

TABLE A4 (Continued)

(b) Baseline KM as continuous						
Mixed-effects logistic regression Group variable: center				Number of obs = 136		
				Number of groups = 6		
				Obs per group		
				min = 4		
				avg = 22.7		
				max = 47		
Integration method: mvaghermite				Integration pts. = 7		
Log likelihood = -81.540401				Wald chi²(9) = 19.30		
				Prob > chi² = .0227		
BoP1y	Odds ratio	SE	z	p >  z	[95% conf. interval]	
Plaque6w						
No	1 (base)					
Yes	3.204776	1.665854	2.24	.025	1.157017	8.876779
Depth_Crest	1.225539	0.1299858	1.92	.055	0.9955092	1.508722
retention						
Cemented	1 (base)					
Conometric	0.5313276	0.6298446	-0.53	.594	0.0520396	5.424889
Screw-retained	2.339156	0.9785416	2.03	.042	1.030327	5.310595
surface						
Osseospeed	1 (base)					
SLA/SLActive	1.233378	0.6594506	0.39	.695	0.4324976	3.517292
TiUnite	2.591528	1.48795	1.66	.097	0.8410669	7.985118
Other	2.281512	1.246147	1.51	.131	0.7821719	6.654927
_cons	0.1618865	0.1281857	-2.30	.021	0.0342932	0.7642106
center						
var(_cons)	2.53e-32	6.71e-16				

Note: Estimates are transformed only in the first equation to odds ratios. \_cons estimates baseline odds (conditional on zero random effects). LR test versus logistic model:  $\chi^2(01) = 1.06$ . Prob  $\geq \chi^2 = .1513$ .

**TABLE A5** Explanatory model for bleeding on probing  $\geq 2$  sites at 12 months (multilevel).

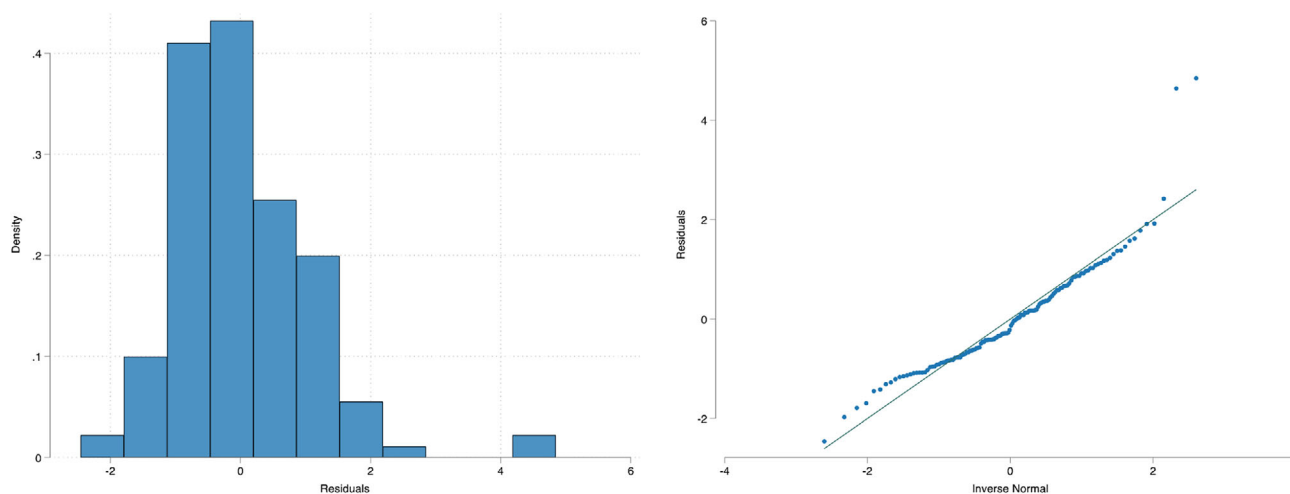
(a) PPD as categorical						
Mixed-effects logistic regression Group variable: center				Number of obs = 136		
				Number of groups = 6		
				Obs per group		
Integration method: mvaghermite				min = 4		
				avg = 22.7		
				max = 47		
Log likelihood = −79.032969				Integration pts. = 7		
				Wald chi²(3) = 18.78		
				Prob > chi² = .0003		
BoP1y	Odds ratio	SE	z	p >  z	[95% conf. interval]	
PPDover5						
0	1 (base)					
1	6.037809	3.072344	3.53	.000	2.227126	16.36869
KM3_cat						
No	2.750459	1.509422	1.84	.065	0.9381563	8.063716
Yes	1 (base)					
Plaque3_simpl						
No	1 (base)					
Yes	3.729494	2.107038	2.33	.020	1.232394	11.28626
_cons	0.3102812	0.1261524	−2.88	.004	0.1398553	0.6883861
center						
var(_cons)	0.3708213	0.5347054			0.0219672	6.259705
(b) PPD as continuous						
Mixed-effects logistic regression Group variable: center				Number of obs = 136		
				Number of groups = 6		
				Obs per group		
Integration method: mvaghermite				min = 4		
				avg = 22.7		
				max = 47		
Log likelihood = −73.937243				Integration pts. = 7		
				Wald chi²(3) = 22.06		
				Prob > chi² = .0001		
BoP1y	Odds ratio	SE	z	p >  z	[95% conf. interval]	
PPD3	2.089113	0.3782802	4.07	.000	1.464984	2.97914
KM3_cat						
No	2.88218	1.676594	1.82	.069	0.9216554	9.013091
Yes	1 (base)					
Plaque3_simpl						
No	1 (base)					
Yes	2.608586	1.491667	1.68	.094	0.8504777	8.00106
_cons	0.0172939	0.0163973	−4.28	.000	0.0026966	0.1109085
center						
var(_cons)	0.5731964	0.7122535			0.0501881	6.546451

Note: (a): Estimates are transformed only in the first equation to odds ratios. \_cons estimates baseline odds (conditional on zero random effects). LR test versus logistic model:  $\chi^2(1) = 2.06$ . Prob  $\geq \chi^2 = 0.0758$ . (b): Estimates are transformed only in the first equation to odds ratios. \_cons estimates baseline odds (conditional on zero random effects). LR test versus logistic model:  $\chi^2(1) = 3.57$ . Prob  $\geq \chi^2 = 0.0295$ .

**TABLE A6** Multiple model for recession at 12 months (multilevel).

Mixed-effects ML regression				Number of obs = 136		
Group variable: center				Number of groups = 6		
				Obs per group		
				min = 4		
				avg = 22.7		
				max = 47		
Log likelihood = -205.61759				Wald chi²(4) = 32.75		
				Prob > chi² = .0000		
REC_Change3	Coefficient	SE	z	p >  z	[95% conf. interval]	
group						
Test	0 (base)					
Control	0.5882158	0.1863481	3.16	.002	0.2229802	0.9534514
PPD1	0.2501616	0.0632651	3.95	.000	0.1261642	0.3741589
jaw						
Maxilla	0.4484485	0.19638	2.28	.022	0.0635509	0.8333461
Mandible	0 (base)					
KM1_cat						
No	-0.1878841	0.2473043	-0.76	.447	-0.6725916	0.2968234
Yes	0 (base)					
_cons	-1.696275	0.5806499	-2.92	.003	-2.834328	-0.5582222
Random-effects parameters		Estimate	SE	[95% conf. interval]		
center: Identity						
var(_cons)		0.0869758	0.0937478	0.0105177		0.7192424
var(Residual)		1.157005	0.1437609	0.9069246		1.476044

Note: LR test versus linear model:  $\text{chibar}^2(01) = 3.05$ . Prob  $\geq \text{chibar}^2 = 0.0404$ .



**FIGURE A3** Distribution of residuals for recession at 12 months.

Mixed-effects ML regression  
Group variable: center

Number of obs = 136  
Number of groups = 6  
Obs per group

min = 4  
avg = 22.7  
max = 47

Wald  $\chi^2(5) = 21.76$   
Prob >  $\chi^2 = .0006$

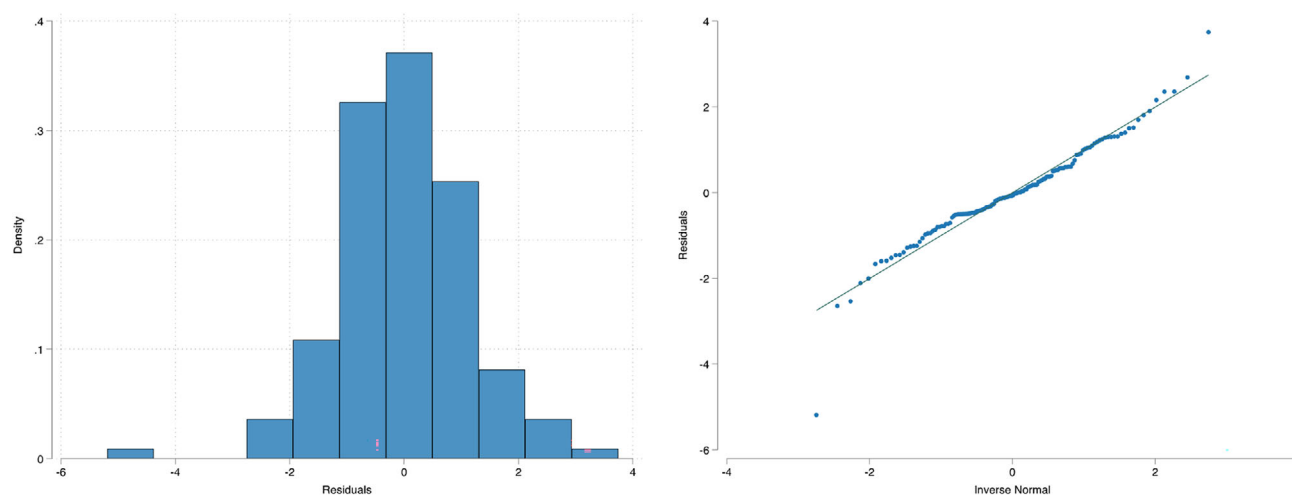
Log likelihood = -211.82129

MBL_Change_3	Coefficient	SE	z	p >  z	[95% conf. interval]	
group						
Control	0.0865616	0.1976574	0.44	.661	−0.3008397	0.4739629
PPD1	0.2363481	0.0651476	3.63	.000	0.1086613	0.364035
retention						
Conometric	0.3539243	0.5581822	0.63	.526	−0.7400927	1.447941
Screw-retained	0.4954674	0.2057561	2.41	.016	0.0921928	0.8987421
smoker						
Yes	−0.3133843	0.2185351	−1.43	.152	−0.7417052	0.1149367
cons	−1.152991	0.6160776	−1.87	.061	−2.360481	0.0544991

Random-effects parameters	Estimate	SE	[95% conf. interval]	
center: Identity				
var(_cons)	0.0606891	0.0770138	0.005046	0.7299227
var(Residual)	1.280742	0.1588866	1.004299	1.633278

Note: LR test versus linear model:  $\text{chibar}^2(01) = 1.87$ . Prob  $\geq \text{chibar}^2 = .0859$ .

**TABLE A7** Multiple model for marginal bone level gain at 12 months (multilevel).



**FIGURE A4** Distribution of residuals for MBL gain at 12 months.

**TABLE A8** Multiple model for composite outcome (probing pocket depth [PPD]  $\leq$  5 mm, absence of bleeding on probing [BOP] and REC  $\leq$  1 mm) at 12 months (multilevel).

Mixed-effects logistic regression Group variable: center				Number of obs = 131 Number of groups = 6 Obs per group min = 4 avg = 21.8 max = 47		
Integration method: mvaghermite				Integration pts. = 7 Wald chi²(9) = 12.25 Prob > chi² = .1996		
Log likelihood = −49.570558						
composite	Odds ratio	SE	z	p >  z	[95% conf. interval]	
group						
Test	1 (base)					
Control	0.9922453	0.5178735	−0.01	.988	0.3567461	2.759808
KM1_cat						
No	0.5740236	0.4325265	−0.74	.461	0.131084	2.513678
Yes	1 (base)					
Plaque6w						
No	1 (base)					
Yes	0.3789253	0.3155946	−1.17	.244	0.0740654	1.938616
PPD1	0.8069098	0.1640247	−1.06	.291	0.5417475	1.201858
retention						
Cemented	1 (base)					
Conometric	1 (empty)					
Screw-retained	0.3186704	0.1712333	−2.13	.033	0.1111629	0.9135315
surface						
Osseospeed	1 (base)					
SLA/SLActive	0.7560751	0.5324718	−0.40	.691	0.1901514	3.006286
TiUnite	0.3202003	0.2703971	−1.35	.177	0.0611806	1.675828
Other	0.0955939	0.1057326	−2.12	.034	0.0109383	0.8354296
smoker						
No	1 (base)					
Yes	0.6500641	0.3833694	−0.73	.465	0.2046293	2.065117
_cons	4.834826	8.446254	0.90	.367	0.1575304	148.3874
center						
var(_cons)	9.86e-34	2.11e-17				

Note: Estimates are transformed only in the first equation to odds ratios. \_cons estimates baseline odds (conditional on zero random effects). LR test versus logistic model:  $\chi^2(0) = 0.00$ . Prob >  $\chi^2 = -$ .



**TABLE A9** Multilevel models using alternative KM classification.

(a) PPD at 12 months						
Mixed-effects ML regression				Number of obs = 136		
Group variable: center				Number of groups = 6		
				Obs per group		
				min = 4		
				avg = 22.7		
				max = 47		
Log likelihood = -253.71083				Wald chi²(5) = 23.66		
				Prob > chi² = .0003		
PPD3	Coefficient	SE	z	p >  z	[95% conf. interval]	
group						
Test	0 (base)					
Control	-0.3211679	0.2668986	-1.20	.229	-0.8442795	0.2019438
PPD1	0.2759549	0.090236	3.06	.002	0.0990956	0.4528142
smoker						
No	0 (base)					
Yes	0.611523	0.2948012	2.07	.038	0.0337233	1.189323
Plaque6w						
No	0 (base)					
Yes	1.052038	0.360342	2.92	.004	0.3457807	1.758295
KM1_cat2						
≤2 mm	0 (base)					
>2 mm	0.0706888	0.2775725	0.25	.799	-0.4733434	0.6147209
_cons	2.148379	0.8439999	2.55	.011	0.4941692	3.802588
Random-effects parameters		Estimate	SE	[95% conf. interval]		
center: Identity						
var(_cons)		0.2029808	0.1939533	0.0311968		
var(Residual)		2.33835	0.2896623	1.834287		
(b) Pocket closure at 12 months						
Mixed-effects logistic regression				Number of obs = 136		
Group variable: center				Number of groups = 6		
				Obs per group		
				min = 4		
				avg = 22.7		
				max = 47		
Integration method: mvaghermite				Integration pts. = 7		
Log likelihood = -70.565211				Wald chi²(5) = 12.38		
				Prob > chi² = .0300		
PPDbelow6	Odds ratio	SE	z	p >  z	[95% conf. interval]	
group						
Test	1 (base)					
Control	1.805272	0.7924812	1.35	.178	0.7636258	4.267804
PPD1	0.7127686	0.0981028	-2.46	.014	0.5442424	0.9334793
Plaque6w						
No	1 (base)					
Yes	0.3636221	0.1903594	-1.93	.053	0.1303283	1.014523
smoker						
No	1 (base)					
Yes	0.4379023	0.2026856	-1.78	.074	0.176764	1.084828

**TABLE A9** (Continued)

(b) Pocket closure at 12 months Mixed-effects logistic regression Group variable: center				Number of obs = 136 Number of groups = 6 Obs per group min = 4 avg = 22.7 max = 47		
Integration method: mvaghermite				Integration pts. = 7 Wald chi²(5) = 12.38 Prob > chi² = .0300		
Log likelihood = −70.565211				p >  z	[95% conf. interval]	
PPDbelow6	Odds ratio	SE	z			
KM1_cat2						
≤2 mm	1 (base)					
>2 mm	0.8821447	0.3933842	−0.28	.779	0.3680903	2.114099
_cons	62.8161	82.35523	3.16	.002	4.809508	820.4295
center						
var(_cons)	0.3763135	0.3749262			0.0533932	2.652244
(c) BOP ≥2 sites at 12 months (multilevel) Mixed-effects logistic regression Group variable: center				Number of obs = 136 Number of groups = 6 Obs per group min = 4 avg = 22.7 max = 47		
Integration method: mvaghermite				Integration pts. = 7 Wald chi²(9) = 18.14 Prob > chi² = .0336		
Log likelihood = −82.419679				p >  z	[95% conf. interval]	
BoP1y	Odds ratio	SE	z			
group						
Test	1 (base)					
Control	0.8652998	0.3306294	−0.38	.705	0.4091891	1.829823
KM1_cat2						
≤2 mm	1 (base)					
>2 mm	0.5492257	0.2153139	−1.53	.126	0.254714	1.184265
Plaque6w						
No	1 (base)					
Yes	3.345704	1.730979	2.33	.020	1.213663	9.223094
Depth_Crest	1.227677	0.129389	1.95	.052	0.9985572	1.509368
retention						
Cemented	1 (base)					
Conometric	0.4849059	0.5757341	−0.61	.542	0.0473169	4.969336
Screw-retained	2.299319	0.9554439	2.00	.045	1.018349	5.191609
surface						
Osseospeed	1 (base)					
SLA/SLActive	1.339588	0.7066912	0.55	.579	0.4763492	3.767188
TiUnite	2.677642	1.522989	1.73	.083	0.8782256	8.163923
Other	2.250684	1.216933	1.50	.134	0.7799634	6.494637
_cons	0.1214407	0.0923087	−2.77	.006	0.027375	0.5387336
center						
var(_cons)	3.55e-34	8.33e-18				

(Continues)

TABLE A9 (Continued)

(d) Recession at 12 months Mixed-effects ML regression Group variable: center				Number of obs = 136 Number of groups = 6 Obs per group min = 4 avg = 22.7 max = 47  Wald chi²(4) = 32.55 Prob > chi² = .0000 p >  z  [95% conf. interval]		
REC_Change3	Coefficient	SE	z			
group						
Test	0 (base)					
Control	0.5827818	0.1870722	3.12	.002	0.2161271	0.9494365
PPD1	0.2455855	0.0637314	3.85	.000	0.1206743	0.3704967
jaw						
Maxilla	0.4577496	0.1999047	2.29	.022	0.0659435	0.8495557
Mandible	0 (base)					
KM1_cat2						
≤2 mm	0 (base)					
>2 mm	0.0793411	0.2031201	0.39	.696	−0.3187669	0.4774492
_cons	−1.732694	0.583457	−2.97	.003	−2.876249	−0.5891394
Random-effects parameters		Estimate	SE	[95% conf. interval]		
center: Identity						
var(_cons)		0.0974337	0.1007866		0.0128297	0.73995
var(Residual)		1.15726	0.1437992		0.9071147	1.476386

Note: (a): LR test versus linear model:  $\text{chibar}^2(01) = 4.74$ . Prob  $\geq \text{chibar}^2 = 0.0147$ . (b): Estimates are transformed only in the first equation to odds ratios. \_cons estimates baseline odds (conditional on zero random effects). LR test versus logistic model:  $\text{chibar}^2(01) = 4.16$ . Prob  $\geq \text{chibar}^2 = 0.0207$ . (c): Estimates are transformed only in the first equation to odds ratios. \_cons estimates baseline odds (conditional on zero random effects). LR test versus logistic model:  $\text{chi}^2(0) = 0.00$ . Prob  $> \text{chi}^2 = .$ . (d): LR test versus linear model:  $\text{chibar}^2(01) = 3.54$ . Prob  $\geq \text{chibar}^2 = 0.0299$ .