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A nomogram prediction of peri-implantitis in treated severe periodontitis patients: A 1–5-year prospective cohort study

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Abstract

Background: No nomogram of peri-implantitis was reported before which is valuable for risk-estimating, clinical decision-making, and better-patients-communicating.

Purpose: To identify the risk indicators and develop a nomogram prediction model of peri-implantitis in treated severe periodontitis patients.

Materials and Methods: A prospective study was conducted on 100 patients with 214 implants. Periodontal and peri-implant parameters were evaluated at implant surgery procedure (T1), and at follow-up (T2). Risk factors were analyzed by logistic regression analyses with generalized estimating equations. Nomogram was developed and the discriminatory ability of the model was analyzed.

Results: The incidence of peri-implantitis at patient-level and implant level were 16% and 11.2% respectively, with no implant lost. The variables associated with peri-implantitis were the $PD_{T1} \geq$ 6 mm (%) > 10%, the implant position, length, and diameter after adjusting for covariates. A nomogram prediction model of peri-implantitis were developed with factors of PD $_{T1} \geq$ 6 mm (%) > 10% and implant placed in posterior. The area under the ROC curves of stepwise model was 0.794.

Conclusions: The residual pockets and implants position were identified as predictors for the peri-implantitis. The nomogram can be used to estimate the risk of peri-implantitis in treated severe periodontitis patients.

KEYWORDS
nomogram, peri-implantitis, periodontitis, posterior, residual pockets

1 | INTRODUCTION

Peri-implantitis is a plaque-associated pathological condition occurring in tissues around dental implants, characterized by inflammation in the peri-implant mucosa and subsequent progressive loss of supporting bone.[1] Other etiologic theories of peri-implantitis, such as provoked foreign body reaction,[2–4] were also reported in recent years. As the global number of individuals that undergo restorative therapy through dental implants increases, peri-implantitis is considered to be a major and growing problem in dentistry.[5,6] According to a meta-analysis with 57 studies, the incidence of peri-implantitis is up to 43.9% within 5 years.[7] As we all know, the inflammatory process that occurs in peri-implantitis lesions is irreversible.[8] Although different treatment approaches, such as mechanical debridement of the implant surface using curettes, ultrasonic devices, air-abrasive devices, or lasers, use of local antibiotics or antiseptics, and so forth, were reported, the efficacy of these therapies for peri-implantitis were limited.[9] Therefore, prevention of peri-implantitis is extremely important. Prediction models in medicine, such as cardiovascular disease[10] and diabetes mellitus,[11] have proliferated in recent years. It is increasingly recommended by health-care providers and policy makers to use prognostic models with clinical practice guidelines to inform decision

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making in the prevention stage of disease. Of all the available models, a nomogram can provide an individualized evidence-based, highly accurate risk estimation. However, there is no prediction model of nomogram to estimate the risk or progression of peri-implantitis, especially for the patients with severe periodontitis.

Developing a prediction model requires a multivariable analysis. To date, various risk factors/indicators have been suggested to directly increase the probability/chance of peri-implant mucositis and peri-implantitis, such as inadequate plaque control, difficult access to mechanical hygiene, smoking habit, residual cementing of prostheses, genetic factors, poorly controlled diabetes, time of implant placement, and occlusal overload.[12–15] Consequently, the identification of risk factors is essential and of importance for the establishment of successful prevention strategies. Previous researches have demonstrated that patients with a history of periodontitis is a risk factor for developing peri-implant lesions.[16–18] Two previous systematic review showed that implants placed in treated periodontitis patients are associated with higher incidence of biological complications and lower success and survival rates than those placed in periodontally healthy patients.[19,20] Nevertheless, it was reported that implants were stable in periodontitis patients in a 5-year prospective study with an individualized maintenance care programme.[21] As of now, the information about peri-implant outcomes in treated severe periodontitis patients in Chinese is not reported yet. Besides, although numerous studies focused on the peri-implantitis were conducted, most of them were designed as cross-sectional study or retrospective cohort study. Since the time-to-event for peri-implantitis is highly variable,[16] it would be best achieved with a prospective study design. However, studies based on prospective cohort design on the risk of peri-implantitis are relatively few. In addition, in light of the fact that most prevalence or incidence studies related to the peri-implantitis in treated periodontitis patients were reported in Europe or United States, the incidence of peri-implantitis in China, where patient demographics, periodontal severity, and health care consciousness may differ from those in Europe or United States, is yet to be fully investigated.

Therefore, the purpose of the present study is to identify the risk indicators associated with peri-implantitis and develop a nomogram prediction of peri-implantitis in treated severe periodontitis patients based on a 1–5-year prospective cohort study in Chinese population.

2 | MATERIAL AND METHODS

2.1 | Patient selection

This was a prospective cohort study consisting of 100 patients with 214 implants at Peking University Hospital of Stomatology from 2008 to 2012 with a follow-up time of 1–5 years. The screening procedure included a clinical and radiographic examination (CBCT), and full-mouth periodontal chartings. Standardized professional periodontal treatments were undertaken before the implants were inserted in patients with periodontitis. Subjects meeting all of the inclusion criteria were informed orally and in writing about the study and signed the informed consent form. The study protocol had been approved by the medical ethics committee of Peking University Medical Center (IRB00001052-09056).

Inclusion criteria:

- Patients who were diagnosed with severe periodontitis.[22]
- Patients who agreed with the related treatment plan and receiving the implant therapy.

Exclusion criteria:

- Contraindications of implant surgery: uncontrolled diabetes, history of head and neck radiotherapy, patients with osteoporosis taking bisphosphate drugs, patients with mental and psychological diseases influencing daily oral maintenance;
- Patients during pregnancy or lactation;
- Patients with loss of single or double jaw dentition;
- Patients with dentulous jaw;
- Prosthetic type of implant supported removable denture;
- Patients who already had other type of implant before implant surgery;
- Patients who cannot keep maintenance therapy for periodontal and peri-implant;
- Patients who refused to participate.

Definition of peri-implantitis[1]:

- Presence of bleeding and and/or suppuration on gentle probing.
- Increased probing depth (PD) compared to previous examinations.
- Presence of bone loss beyond crestal bone level changes resulting from initial bone remodeling.

2.2 | Treatment procedure

2.2.1 | Surgical and prosthetic procedures

Implant surgery was performed following a standard two-stage protocol. Cone-beam CT (Ez3D 2009, E - Woo Technology, South Korea) scan for all patients were obtained before the implant surgery to evaluate the bone level. Dental implants with locking taper (Integra-CP, sandblasted surface, Bicon) were placed for the treated periodontitis patients, under local anesthesia, performed by three equally experienced operators (Meng, H; Zhang, L; Shi, D). All procedures followed the operating manual of implant system. It was incised with horizontal incision, mucoperiosteal flap was elevated, and the drilling protocol followed the surgical instruction. The platforms of the implants were 2-3 mm subcrestal after installation. All the implants were submerged. Guided bone regeneration or maxillary sinus elevation was performed when necessary. The bone graft was autologous bone collected during the preparation of the hole and decalcified freeze-dried bovine bone (bio-oss, Geistlich, Switzerland), and the membranes were resorbable collagen membrane (bio-gide, Geistlich, rishi). X-ray periapical films were taken immediately after surgery. The second stage operations were performed after 4–6 months. The healing abutments were removed and the temporary abutment was connected. About 4 weeks after second stage operation, closed-tray impression was performed by prosthodontists. All the prostheses were made in the denture processing center of Peking University Hospital of Stomatology. The prostheses were bonded to the restoration abutment in vitro. Individualized positioners were made and tapped in the right position. Parallel projection X-ray periapical film was taken immediately after the implant prosthesis was put in. Clinical peri-implant parameters were examined after 1 month.

2.2.2 | Periodontal clinical examination

Periodontal clinical parameters including PD and bleeding index (BI)[23] were recorded at the baseline (T0), at the implant surgery (T1) and at the follow-up (T2). PD was measured throughout the entire mouth except for the third molar using a Williams' periodontal probe at six sites (mesio-buccal, mid-buccal, disto-buccal, mesio-palatal, mid-palatal, and disto-palatal) per tooth. BI was recorded in 30 seconds after probing and the most severe sites were recorded in the buccal (labial) side and lingual (palatal) side. After PD and BI recorded, the mean PD, PD ≥ 6 mm (%), mean BI, BI ≥ 3(%), and full mouth BOP (+) % (FMBS) were calculated, then PD ≥ 6 mm (%) and BI ≥ 3(%) were classified to binary variables with cut-off value of 10% and 30%, respectively.

2.2.3 | Peri-implant conditions

Peri-implant parameters including peri-implantal probing depth (PDi), peri-implantal Bleeding Index (BIi) were recorded at T1 and T2. The mean PDi, max PDi, and mean BIi were calculated. Marginal bone level (MBL) alteration was determined from radiographs and expressed as the change in distance from a reference point on the implant to the most coronal bone-to-implant contact on the mesial and distal aspect of the implant. In cases where the implant reference point was below the margin of the crestal bone, the value was considered as zero. Bone loss was presented as the mean values for distal and mesial changes from baseline for each implant and each time point. The rate of MBL alteration in mesial and distal was calculated as MBL alteration divided by year (mm/year).

2.3 | Statistical analysis

The characteristics for patients and implant, periodontal status at T1 and T2 were compared between groups with and without peri-implantitis. Variables were presented as mean ± SD/*N* (%). Student *t* test (normal distribution) and Mann-Whitney (non-normal distribution) were performed for continuous variables and χ^2 tests were used for categorical variables. Risk factors for peri-implantitis were analyzed by univariate and multivariate logistic regression analysis with generalized estimating equations. The final model selection for the nomogram was performed by a backward step-down selection process using a threshold of $P < .05$, and some factors without significance were excluded from the full model. The receiver operating characteristic (ROC) curve was used to evaluate the discriminatory ability of the model. The statistical analyses were 2-tailed and *P* value <.05 was considered statistically significant. All the statistical analyses were performed with R (http://www.R-project.org) and EmpowerStats software (www.empow erstats.com, X&Y solutions, Inc Boston, Boston, Massachusetts).

TABLE 1 The characteristics of participants between non-peri-implantitis (NPI) group and peri-implantitis (PI) group

Variables	NPI	PI	*P* value
N (%)	81 (81%)	19 (19%)	
Age (year)	44.07 ± 9.44	46.37 ± 9.25	.80
Gender			.44
Male	42 (51.9%)	8 (42.1%)	
Female	39 (48.1%)	11 (57.9%)	
Current smoking			.74
No	61 (75.3%)	15 (78.9%)	
Yes	20 (24.7%)	4 (21.1%)	
Follow-up time (year)	1.73 ± 0.75	2.26 ± 1.01	.21

Data were presented as Mean ± SD/*N* (%).

3 | RESULTS

During the period of study, a total of 100 patients with 214 implants placed between September 2008 and September 2012 with periodontal therapy were analyzed. The mean ± SD age was 44.5 ± 9.4 years. Fifty percent of the participants were male. The participants were divided into NPI group and PI group according to the definition of peri-implantitis. Patient-level incidence of peri-implantitis at the follow-up examination was 19%. There were no significant differences for age, distributions of gender, smoking status, and the follow-up time between NPI and PI group ($P > .05$) (Table 1).

Table 2 presented the characteristics of implant, peri-implant conditions, and periodontal status at T_1 and T_2. The implant-level incidence of peri-implantitis at the follow-up examination was 11.2%. The distributions of implant length (≥8 mm/<8 mm), diameter (≥5 mm/<5 mm), position (anterior/posterior), and percent of PD_{T1} ≥ 6 mm (>10%/≤10%) were significantly different between two groups ($P < .05$). The mean PDi, max-PDi, mean BIi, and △MBL for mesial and distal were significantly higher in PI group than NPI group ($P \le .001$). The mean PD_{T1}, mean PD_{T2}, mean BI_{T2}, and $FMBS_{T2}$ were significantly different between NPI group and PI group. The distributions of PD_{T1} ≥ 6 mm% (>10%/≤10%), PD_{T2} ≥ 6 mm% (>10%/≤10%), and BI_{T2} ≥ 3% (≤30%/>30%) were significantly different between two groups ($P < .05$). No significant difference was found for the other variables.

Table 3 showed the univariate logistic analyses for the risk of peri-implantitis associated with implant-related and periodontal-related factors. The implant length, diameter and position were associated with risk of peri-implantitis (RR = 4.28, 95%CI: 1.82, 10.03; RR = 6.57, 95%CI: 2.54, 17.03; RR = 10.06, 95%CI: 2.33, 43.34; respectively). For the periodontal-related factors, the mean PD_{T1}, (PD_{T1} ≥ 6 mm)% > 10% were positively correlated with the risk of peri-implantitis (RR = 2.69, 95%CI: 1.24, 5.85; RR = 3.91, 95%CI: 1.14, 13.41, respectively).

Table 4 presented the multivariate logistic analyses for the risk of peri-implantitis with implant-related and periodontal-related factors. The implant length, diameter, and position were associated with risk of peri-implantitis with adjustment for age and gender (RR = 5.59, 95%CI: 2.22, 14.05; RR = 6.81, 95%CI: 2.61, 17.77; RR = 10.91, 95% CI: 2.49, 47.73, respectively). For the periodontal-related factors, the PD_{T1} ≥ 6 mm (%) > 10% were still positively associated with the risk

TABLE 2 Implant-related variables and periodontal-related variables in NPI group and PI group

Variables	NPI	PI	P value
	Peri-implant characteristics		
N	190 (88.8%)	24 (11.2%)	
	Implant characteristics		
Length of implant			<.001*
≥8 mm	165 (86.84%)	11 (45.83%)	
<8 mm	25 (13.16%)	13 (54.17%)	
Diameter of implant			<.001*
<5 mm	135 (71.05%)	6 (25.00%)	
≥5 mm	55 (28.95%)	18 (75.00%)	
Jaw			.596
Maxillary	92 (48.42%)	13 (54.17%)	
Mandible	98 (51.58%)	11 (45.83%)	
Position			<.001*
Anterior	108 (56.84%)	2 (8.33%)	
Posterior	82 (43.16%)	22 (91.67%)	
Prosthetic type			.541
Single crowns	161 (84.74%)	22 (91.67%)	
Fixed bridge	29 (15.26%)	2 (8.33%)	
Bone regeneration			.188
No	75 (39.47%)	6 (25.00%)	
Yes	115 (60.53%)	18 (75.00%)	
Sinus lift			.754
No	164 (86.32%)	20 (83.33%)	
Yes	26 (13.68%)	4 (16.67%)	
Bone regeneration (split out the sinus lift)			.241
No	73 (44.51)	6 (30.00%)	
Yes	91 (55.49%)	14 (70.00%)	
	Peri-implant conditions		
Mean PDi (mm)	2.69 ± 0.65	4.65 ± 0.93	<.001*
Max-PDi (mm)	3.44 ± 0.86	6.63 ± 1.35	<.001*
Mean BIi	1.63 ± 1.01	3.10 ± 0.74	<.001*
△MBL-mesial (mm/year)	0.00 ± 0.15	−0.40 ± 0.54	<.001*
△MBL-distal (mm/year)	−0.02 ± 0.14	−0.15 ± 0.39	.001*
	Periodontal status		
	T1		
Mean PD $_{T1}$ (mm)	3.00 ± 0.55	3.24 ± 0.35	.036
PD $_{T1}$ ≥ 6 mm (%)			<.001*
≤10%	93 (48.95%)	3 (12.50%)	
>10%	97 (51.05%)	21 (87.50%)	
Mean BI $_{T1}$ (mm)	2.04 ± 0.59	2.36 ± 0.53	.012*
FMBS $_{T1}$	73.94 ± 20.91	75.60 ± 15.86	.708
BI $_{T1}$ ≥ 3 (%)			.557
≤30%	107 (56.32%)	12 (50.00%)	
>30%	83 (43.68%)	12 (50.00%)	
	T2		
Mean PD $_{T2}$ (mm)	2.93 ± 0.47	3.42 ± 0.47	<.001*
PD $_{T2}$ ≥ 6 mm (%)			<.001*
≤10%	126 (66.32%)	6 (25.00%)	
>10%	64 (33.68%)	18 (75.00%)	
Mean BI $_{T2}$ (mm)	1.81 ± 0.67	2.28 ± 0.46	<.001*
FMBS $_{T2}$	64.48 ± 24.72	81.95 ± 16.02	<.001*
BI $_{T2}$ (≥3%)			.013*
≤30%	128 (67.37%)	10 (41.67%)	
>30%	62 (32.63%)	14 (58.33%)	

PD, probing depth; BI, bleeding index; PDi, peri-implantal PD; BIi, peri-implantal BI; MBL, marginal bone level; FMBS, full mouth BOP (+) %. T1, at implant placement; T2, at follow-up. Data were presented as Mean ± SD/N (%);
*P value < .05.

of peri-implantitis after adjustment of age and gender (RR = 3.62, 95%CI: 1.05, 12.51). No statistical significance was observed for the mean PD_{T1} after adjusting for age and gender.

The multivariate logistic model was used to develop the prediction models of peri-implantitis. There were full and stepwise models at T1 (Figure 1). The scoring full and stepwise models at T_1 were as follows: 0.20492* (length ≥ 8 mm) + 1.64476* (posterior) + 0.88415 *(PD_{T1} ≥ 6 mm% > 10%) + 0.60729* (diameter ≥ 5 mm) and 2.18059* (posterior) + 1.13804*PD_{T1} ≥ 6 mm% > 10%), respectively. The performances of nomograms were measured by time-dependent

TABLE 3 Univariate and cox logistic regression analysis of peri-implantitis risk associated with the implant-related and periodontal-related factors

Exposures	Statistics	HR (95%CI)	P value
	Implant-related factors		
Length of implant			
≥8 mm	176 (82.24%)	Refer.	
<8 mm	38 (17.76%)	7.80 (1.82, 10.03)	.0008*
Diameter of implant			
<5 mm	141 (65.89%)	Refer.	
≥5 mm	73 (34.11%)	6.57 (2.54, 17.03)	.0001*
Position			
Anterior	110 (51.40%)	Refer.	
Posterior	104 (48.60%)	10.06 (2.33, 43.34)	.0001*
Jaw			
Maxillary	105 (49.07%)	Refer.	
Mandible	109 (50.93%)	0.89 (0.38,2.08)	.788
	Periodontal-related factors at T1		
Mean PD $_{T1}$ (mm)	3.03 + 0.54	2.69 (1.24, 5.85)	.0127*
PD $_{T1}$ ≥ 6 mm (%)			
≤10%	96 (44.86%)	Refer.	
>10%	118 (55.14%)	6.71 (1.84, 24.47)	.0039*
Mean BI $_{T1}$ (mm)	2.08 + 0.59	1.29 (0.86, 3.47)	.6332
FMBS $_{T1}$	74.13 + 20.38	1.00 (0.98, 1.03)	.7002
BI $_{T1}$ ≥ 3 (%)			
≤30%	119 (55.61%)	Refer.	
>30%	95 (44.39%)	0.66 (0.26,1.65)	.3733

Data were presented as Mean ± SD/N (%) and HR (95%CI); T1, at implant placement; logistic regression analyses were used with generalized estimating equations (GEE).
*P value < .05.

TABLE 4 Multivariate and Cox logistic regression analysis of peri-implantitis risk associated with the implant-related and periodontal-related factors

Exposure	Adjust HR (95%CI)	*P* value
	Implant-related factors	
Length of implant		
≥8 mm	Refer.	
<8 mm	5.59 (2.22, 14.05)	.0003*
Diameter of implant		
<5 mm	Refer.	
≥5 mm	6.81 (2.61, 17.77)	<.0001*
Position		
Anterior	Refer.	
Posterior	10.91 (2.49, 47.73)	<.0001*
	Periodontal-related factors at T_1	
Mean PD $_{T1}$ (mm)	2.09 (0.93, 4.71)	.0761
PD $_{T1}$ ≥ 6 mm (%)		
≤10%	Refer.	
>10%	3.62 (1.05, 12.51)	.0421*

Data were presented as HR (95%CI); T_1, at implant placement; logistic regression analyses were used with generalized estimating equations (GEE); Adjust for age and gender.
**P* value < .05.

ROC curves and the AUC for full and stepwise models presented in Figure 2 was 0.796 and 0.794, respectively. There was no statistically significant difference in two models. Figure 2 showed the nomogram prediction of peri-implantitis. The nomograms' predictive accuracy was also measured by the bootstrap (500 resample) method and the AUC of the model from Bootstrap remained largely unchanged.

4 | DISCUSSION

In the present study, with implants being placed in the treated severe periodontitis patients, the predictable development of peri-implantitis was observed. The incidence of peri-implantitis at patient-level and implant level were 16% and 11.2%, respectively, for 1 to 5 years' function. The incidence was within the incidence range from 0.4% within 3 years, to 43.9% within 5 years reported by previous systematic reviews.[7] And the incidence was relatively low when compared with that of 28.6% within 10 years and 26% within 3–16 years in previous study among periodontally healthy patients.[24,25] The possible reasons for the relatively stabilized peri-implant conditions in the patients with a history of periodontitis were the effective periodontal therapy which decreased the risk of infection in the surrounding tissue of peri-implant and the short observation time of 1 to 5 years, which might not be long enough long for accumulation of microbial infection to cause peri-implant lesions.

In addition, a simple and easy-to-use prediction nomogram using the multivariate analyses, for the first time, has been developed for predicting the occurrence of peri-implantitis in treated periodontitis patients. In the final prediction model, two risk predictors, namely residual periodontal pockets at implant placement (percent of PD ≥ 6 mm% over 10%) and posterior implants, were included.

Residual periodontal pockets were demonstrated to be the risk indicator for peri-implantitis in patients treated for periodontitis.[26,27] A 7.9-year prospective cohort study of 70 periodontitis patients with 165 implants showed that the non-peri-implantitis group had significantly (*P* = .011) fewer residual pockets (≥5 mm) per patient than the peri-implantitis group (1.9 vs 4.1).[27] Cho-Yan Lee and colleagues also demonstrated the residual periodontal pockets were a risk indicator for peri-implantitis in patients treated for periodontitis.[26] In the present study, implant with residual pockets (percent of PD ≥ 6 mm% over 10%) increased by onefold for the treated periodontitis patients in multivariable analysis independent of age and gender. The patients in this study were with severe periodontitis and extremely poor periodontal conditions. Periodontal pathogens identified in residual periodontal pockets at the time of implant installation were found adjacent to the newly installed implants indicating the spread of pathogens.[28] Therefore, the residual pockets were recommended to be eliminated at the time of implant placement. It is reasonable to treat periodontitis to a level of absence of or minimal inflammation as well as to minimize residual pockets to reduce the possible influence of ecological niches on the integrity of implants and their stability.

The implant position in posterior was identified as the risk indicator, with the RR value of 10.91 for risk of peri-implantitis. Han and colleagues reported a survival rate of 95.8% in posterior region for 3-year follow-up.[29] Douglas reported a high rate of implant failure of 6% with 2 years' function in posterior region with advanced alveolar ridge height resorption[30] in treated periodontitis patients. The high implant failure rate supports our conclusion. The explanations were as follows. On one hand, the posterior regions of the maxilla and the

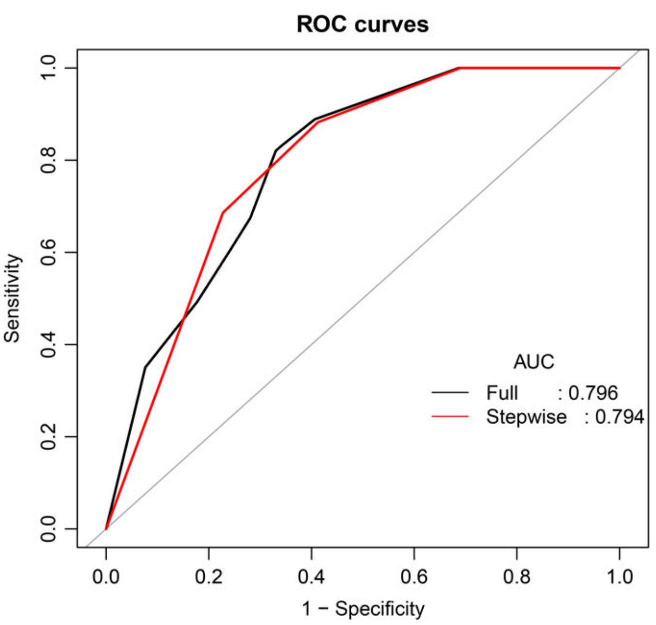

FIGURE 1 Time-dependent ROC curve in predicting the risk of peri-implantitis. Model 1 (black) is the full model including PD $_{T1}$ ≥ 6 mm (%), implant position, length, and diameter. Model 2 (red) is stepwise model included PD $_{T1}$ ≥ 6 mm (%) and implant position, the implant length and diameter were excluded. The AUC_{full} and $AUC_{stepwise}$ are 0.796 and 0.794. There was no statistical significance between two models. AUC, area under the curve; ROC, receiver operating characteristic

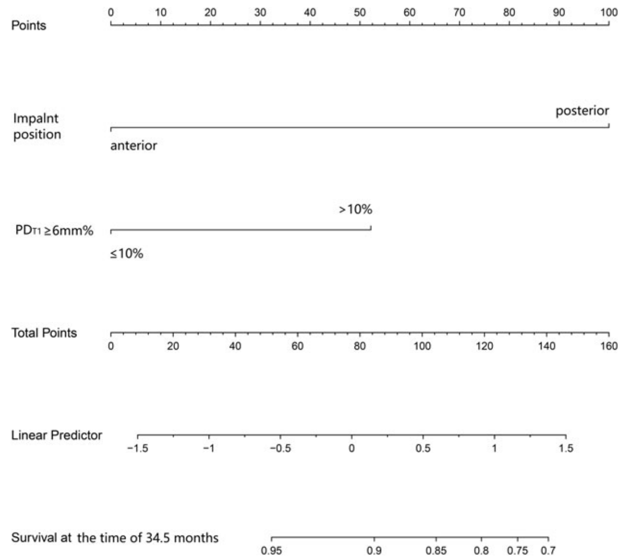

FIGURE 2 Nomogram to estimate the possibility of non-peri-implantitis preoperatively in the severe periodontitis patients. Nomogram was used to estimate the possibility of non-peri-implantitis preoperatively in the treated periodontitis patients. To use the nomogram, find the position of each variable on the corresponding axis, draw a line to the points axis for the number of points, add the points from all of the variables, and draw a line from the total point axis to determine the NPI probabilities at the lower line of the nomogram

mandible tend to lack of sufficient bone volume and keratinized gingival width in the patients with periodontitis, especially in the patients compromised severe periodontitis. On the other hand, it is more difficult to maintain oral hygiene for the posterior region than the anterior region, which leads to a risk of plaque accumulation. Most importantly, posterior region is the main functional area and the occlusal forces in posterior jaws are much higher than in the anterior jaws. As the time passes, the risk of peri-implantitis increases. Therefore, these mentioned possibilities may contribute to the risk of peri-implantitis.

Worth mentioning is that the implant length and diameter were found to be associated with peri-implantitis in the present study. The implant with diameter ≥ 5 mm faced a risk 5 times higher than implant with the diameter<5 mm. It is consistent with the previous research finding that the implant diameter was associated with the peri-implantitis (RR = 1.6).[12] However, what's worth noting is that the implants with diameter ≥ 5 mm in the present study were all placed in the posterior region, which suggested some confounding between position and diameter. Thus, we would like to conclude that it is the posterior implant rather than the implant diameter resulted in the higher risk of peri-implantitis, which indirectly supports our previous results that posterior implant is a risk factor of peri-implantitis. Implant with length ≤ 8 mm was identified to be five times riskier than implant with length>8 mm. Geckili and colleagues found that implant length influenced implant success and shorter implants had lower success rate,[31] which is consistent with the result of our study. However, as we all know, the implant itself could not be the risk factor for peri-implantitis. Periodontal compromised patients tend to have vertical bone resorption, which restricts the available bone volume, necessitating shorter implants. The patients in the present study at baseline were severe periodontitis and accompanied with severe bone resorption. In addition, with the shorter implant placed, it is difficult for the patients to maintain oral hygiene after the restoration. Therefore, we would like to conclude that it may be the poor bone conditions and difficult to maintain oral hygiene that increased the risk of peri-implantitis, rather than the shorter implant itself.

In this study, the bone regeneration procedures did not correlate with onset of peri-implantitis. Few previous studies have focused on association of bone regeneration and onset of peri-implantitis, and no consistent conclusions have been reached. Canullo and colleagues[32] considered that procedures and biomaterials used for bone augmentation could be risk factors for the occurrence and progression of peri-implantitis. However, no evidence was given in the literature. Pimentel and colleagues[33] demonstrated the risk factors of peri-implantitis but did not find the effect of bone graft on prevalence of peri-implantitis at implant-level. We suspected that it might be due to the short implant time in function (1–5 years) and the small sample size of implant. In the present study, therefore, it is necessary to increase observation time and sample size to further analyze the effect of bone regeneration on the risk of peri-implantitis.

Nomogram is a statistical tool that enables users to calculate the overall probability of a specific clinical outcome for an individual patient. It is of great value for risk-estimating, clinical decision-making, and better-patients-communicating. In this study, novel and practical nomograms at T1 were established to predict the risk of peri-implantitis in treated periodontitis patients with good sensitivity and specificity. The nomogram showed good performances for predicting the peri-implantitis ($AUC_{stepwise}$ = 0.794). To our knowledge, we report the first nomogram for predicting postoperative peri-implantitis in treated periodontitis patients. Based on the risk predictors, the nomogram might serve as a tool to provide useful clinical recommendations for the dentist and let patients know what the risk will be after implant surgery. The use of the nomogram in estimating the risk of peri-implantitis to direct clinical treatment is a new concept, which has proliferated in recent years. It is strongly recommended to develop and validate the prediction models for the clinical application.

There are some strengths in the present study. The study, based on a prospective design, identified the residual pocket and posterior implant as risk predictors. Moreover, an easy-to-use nomogram prediction model with the factors was introduced, which no previous study had used in the field of implant before. For clinical recommendation, patients with the high risk scores should be monitored more frequently on the changes that may occur around dental implants in the early post-restorative phase, with focus on bleeding on probing/suppuration and in combination with radiographic evidence of bone loss and early intervention to minimize the occurrence of peri-implantitis. Of course, several limitations should be performed to minimize the occurrence of peri-implantitis. The short observation time, inconsistent definitions of peri-implantitis, inadequate accounting for confounding factors, and the lack of external validation of the prediction model may limit the strength of the evidence for the study.

5 | CONCLUSION

The residual pockets and posterior implants were identified as predictors for the risk of peri-implantitis. A nomogram prediction model for the occurrence of peri-implantitis showed satisfactory predictive accuracy. The nomograms can be used to estimate the risk of peri-implantitis in treated periodontitis patients in Chinese.

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CONFLICT OF INTEREST

All authors declare that they have no conflict of interest.

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